UNIVERSIDADE DE LISBOA

FACULDADE DE DIREITO

HUMANITY IS BEING DRIVEN ASHORE: A JURIDICAL AND POLITICAL ESSAY ON MARINE PLASTIC POLLUTION

ESTELA SOFIA CAMPOS GAMEIRO

TESE ORIENTADA PELO PROFESSOR DOUTOR JOÃO MIRANDA, ESPECIALMENTE ELABORADA PARA A OBTENÇÃO DO GRAU DE MESTRE EM DIREITO, ESPECIALIDADE CIÊNCIAS JURÍDICO-AMBIENTAIS

2019

UNIVERSITY OF LISBON

FACULTY OF LAW

HUMANITY IS BEING DRIVEN ASHORE: A JURIDICAL AND POLITICAL ESSAY ON MARINE PLASTIC POLLUTION

ESTELA SOFIA CAMPOS GAMEIRO

THESIS ELABORATED UNDER THE GUIDANCE OF PROFESSOR JOÃO MIRANDA, IN ORDER TO OBTAIN THE DEGREE OF MASTER OF LAW, EXPERTISE IN ENVIRONMENTAL LAW

2019

To Mika, Cindy, Sury, Camila, Freddie, Dalila, Ema and Alice.

To all the animals I will lovingly name, and to the ones I will never see nor protect.

To Nature.

‘Is there anyone who has not gaze upon the ocean with amazement – the immensity of its surface rolling beyond and endless horizon, the thunder of waves upon rocks, the spuming white surf surging upon a beach, and the wind blowing a wet, salt, invigorating air. Ever since man first sheltered himself upon a shore, he has wondered about the oceans, drawn to their content, their power, and their beauty, yet fearful of their rage in storms, their cold, dark depths’.

Gerard Mangone, *Law for the World Ocean* (Stevens & Sons, London, 1981) 1.

‘Seeing a parent albatross gagging up a toothbrush changed my worldview. (...) No matter what coordinates you choose, from waters polar, to solar coral reefs, to the remotest turquoise atoll – no place, no creature remains apart from you and me’.

Carl Safina, *Eye of the Albatross* (New Work: Holt, 2002) 279.

Acknowledgments

The accomplishment that this master thesis represents was only possible thanks to the support of several people. The first one I should mention is Professor João Miranda, the most supportive and patient advisor I could have chosen to orientate my master's dissertation. Professor João Miranda is the main responsible for this achievement, and even though it has been difficult sometimes, I have to thank him for believing in me.

A special thanks to my parents and my grandmothers, for their affectionate support and for offering me all the necessary conditions so I could exclusively dedicate my time to this work.

To my brother Pedro and my cousin João, who played also an important role as my English language *super* advisors, available at all times and giving me strong encouragement, I express my gratitude.

To my friends, I extend my appreciation for their companionship and incentive. As William Shakespeare once wrote, *a friend gently allows you to grow*, and my friends were no exception. Susana stood firmly beside me at all instances, helping me throughout this venture. Diogo, as my colleague, followed up my work very attentively. And Ana Maria, Ângela, Joana, Natacha and Sofia were always present and concerned.

At last, I have to thank to my inspirational gurus, for sharing their genuine and profound love for nature and for showing to the world that hope exists, although it requires commitment and perseverance. MARMEU team is my closest example, and together we will try to make a difference.

Previous Note

The present work, entitled *Humanity is Being Driven Ashore: A Juridical and Political Essay on Marine Plastic Pollution*, is being presented as a master's degree dissertation in Environmental Law at the School of Law of the University of Lisbon, in Portugal, in order to obtain the degree of Master of Law.

The decision of writing this thesis in English language was based on the Article 53(2) of the Masters and Doctoral Programmes' Regulation of the School of Law of the University of Lisbon, approved by diploma *Despacho* no. 6322/2016, of 20 April 2016 and published in the national official journal *Diário da República*, 2nd series, no. 92, of 12 May 2016. This decision was supported by the master thesis supervisor, Professor João Miranda, and it was approved by the Scientific Board of the School of Law, on 2 November 2016.

The reasons invoked, and validated, are widely explained throughout this thesis, but, summing up, they are the following. The environment surrounds human beings. It is a public and collective good, of general interest, whose integrity and stability must be preserved by the whole of humanity. Whatever is the nature of the damages or their extent, environmental protection is a (growing) international concern. To ensure a high level of environment protection, the environment must be protected as a whole, the information must be shared globally, the procedures must be as uniform and universal as possible. Therefore, we consider that analysing, in English language, a theme with such an international relevance, and which presupposes the carrying out of an extended research in English, can be a wider contribute to the achievement of a Good Environmental Status and a healthier Planet Earth for everyone.

Having said that, a last note to say that, in accordance with the international character of this thesis, we used the Oxford University Standard for Citation of Legal Authorities (OSCOLA). All lapses and typos are the sole responsibility of the author.

Table of Contents

Abstract

Since its invention, in the 1950s, plastic can be found in almost every object or structure. It has created numerous opportunities in many fields, boosting markedly mankind's development and even its life span. However, combined with modern consumption patterns, in a world that is more and more urban and technological, plastic amounts have reached proportions never seen before. Consequently, plastic waste quantities are also exceeding all the limits reached so far and it is ending in our oceans for two main reasons: reckless behaviour of consumers and improper waste management. National waste management systems worldwide are facing severe challenges, especially at the moments of collection and disposal. That happens particularly in Asia and the causes are lack of money and structures, and governments and citizens lack of interest.

Marine plastic pollution has been affecting all humanity for several decades but only recently it has been recognised. Each year, at least eight million tonnes of plastics leak into the oceans. Its sources are numerous and can be land-based (80%) – dumps, littering, sewage, industrial activities – or sea-based (20%) – commercial fisheries and offshore oil and gas platforms. Ironically, the characteristics that make plastic so useful – lightness, durability, low cost and malleability – are the same that transform plastic in a long-term problem for the environment. Once in nature, plastics never disappear, they just disintegrate into smaller and smaller particles, while they quickly spread across all the geographic divisions and layers of the ocean. Plastics from all sizes can entangle marine animals and/or can be ingested by them, causing injuries, gut obstructions and death. Plastic waste is even responsible for heavy economic losses. Furthermore, microplastics are entering the human food chain and the consequences are unknown.

Several existing legal instruments, of regional and international scope, are capable of addressing different aspects of marine litter. Some national initiatives are of utility as well. Nevertheless, few countries or regions have an overarching legal framework to tackle the problem. It is clear though that it is impossible to maintain the actual production and consumption patterns, and that is imperative to implement effective plastic waste management.

Keywords: marine pollution; plastic waste; microplastics; International Environmental Law; European Union Law.

I. Introduction

A. *Stranding* News

Between January and February 2016, about thirty cachalots were washed ashore around the North Sea.[1] Although this massive cachalots stranding event could be considered 'the biggest mass stranding in a century',[2] the post-mortem examination did not reveal something new: some of the giant marine animals had large amounts of plastic waste in their stomachs. The garbage included a nearly thirteen-meter-long shrimp fishing net, a plastic car engine cover, the remains of a plastic bucket, and other littles pieces of plastic litter.[3] Very likely, these cachalots, that usually ingest their entire preys via suction, have mistakenly identified those items as food.[4]

In this specific case, it was not the marine litter found in their bodies that caused the stranding and consequent death of these cachalots, but it reflects the plastic pollution extension on the open sea.[5] On these findings, Robert Habeck, Schleswig-Holstein Environment Minister, stated that they were 'the results of our plastic oriented society'.

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[1] These cachalots beached up in Germany, Netherlands, United Kingdom, France and Denmark. Once cachalots are often spotted in groups of fifteen to twenty animals, called pods, scientists assumed as probable that they belong to the same pod(s) and so that all these strandings were related. According to investigators, special conditions in the North Atlantic, that may have influenced warm water and prey distribution, make it '"reasonable to assume" that the pods entered the North Sea together in the hunt for food'. See Aisha Gani, 'Whale Washes Up and Dies on Norfolk Beach in Sixth UK Stranding in Weeks' (*The Guardian*, 4 February 2016) <www.theguardian.com/uk-news/2016/feb/04/sixth-whale-stranded-on-east-anglian-beach> accessed 30 December 2016.

[2] Information advanced in Fiona Harvey, 'Whale CSI: why Sperm Whales Are Washing Up Dead on British Shores' (*The Guardian*, 15 February 2016) <www.theguardian.com/environment/2016/feb/15/whale-csi-why-sperm-whales-are-washing-up-dead-on-british-shores> accessed 30 December 2016.

[3] Wajeeha Malik, 'Sperm Whales Found Full of Car Parts and Plastics' (National Geographic, 31 March 2016) <http://news.nationalgeographic.com/2016/03/160331-car-parts-plastics-dead-whales-germany-animals.html> accessed 30 December 2016.

[4] Jeff Jacobsen, Liam Massey and Frances Gulland, 'Fatal Ingestion of Floating Net Debris by Two Sperm Whales (Physeter macrocephalus)' (2010) 60(1-2) MPB 766.

[5] Cachalots are known as one of the deepest diving species of cetaceans, able to dive as far as one thousand meters in search of squid, their main diet. It happens that the North Sea, with an average deepness of three hundred meters, is to shallow for cachalots, which need at least four hundred meters of water to dive. In such conditions, cachalots cannot make use of their sonar and become disoriented. But most important is that cachalots cannot support their own body weights, which compresses their blood vessels and lungs, causing the collapse of their internal organs. Concluding, these animals died because they accidentally ventured into shallow seas. See 'Why are Sperm Whales Getting Stranded in the UK?' (*ITV News*, 5 February 2016) <www.itv.com/news/2016-02-05/why-are-sperm-whales-becoming-stranded-in-the-uk/> accessed 30 December 2016.

This is not the first news article reflecting the consequences of marine litter on animals that the world has heard of. But, undoubtedly, this uncommon and mysterious chain of strandings of such a huge deep-sea animal,[6] in such unexpected places, was widely covered by the international press and give people the opportunity to learn more about this terrible reality.

Unfortunately, other events of this kind, but of variable proportions, are becoming more and more frequent. So, in order to understand the complexity of this issue, and because there is no point in theorising without knowing the reality and the background of the problematic here considered, we are going to present other similar cases – nonetheless, we recognise that finding reliable sources for some of the following cases was somewhat difficult precisely because media coverage was relatively low.

One of the first fatal incident of this kind dates back to 1989, in the Lavezzi Islands, in France. A stranded cachalot, coming from the Tyrrhenian Sea, 'died of a stomach obstruction following accidental ingestion of plastic bags and 100 square feet of plastic sheeting'.[7]

Around February and March 2008, two male cachalots stranded along the northern California coast. In both cases the debris proved to be fatal and, at that time from the scientists' point of view, this occurrence constituted a previously undocumented cause of anthropogenic mortality in marine mammals.[8] One of the cachalots had a large mass of compacted netting protruding through a rupture in the third compartment of the stomach. Large amounts of coagulated blood were observed in the netting and in the body cavity, due to a gastric rupture following impaction with debris. As for the second male, apart from the visible signs of entanglement on the dorsal surface, it was in poor nutritional condition and moderately decomposed. Its intact stomach contained a large amount of scraps of netting, pieces of line, and plastic bags. These debris completely occluded the pylorus and impacted the third chamber of the stomach causing starvation following gastric impaction. Scientists added that the pieces of netting may have been at sea for at least twenty years. They ranged

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[6] Philip Hoare, 'Whales are Starving - Their Stomachs Full of our Plastic Waste' (*The Guardian*, 30 March 2016) <www.theguardian.com/commentisfree/2016/mar/30/plastic-debris-killing-sperm-whales> accessed 30 December 2016.

[7] Erwin Vermeulen, 'As the Oceans Choke on Plastic so do the Whales' (*Sea Shepherd Conservation Society*, 8 August 2013) <www.seashepherd.org/news-and-commentary/commentary/as-the-oceans-choke-on-plastic-so-do-the-whales/print.html> accessed 3 January 2017. See also Renaud de Stephanis and others, 'As Main Meal for Sperm Whales: Plastics Debris' (2013) 69(1-2) MPB 211.

[8] Jeff Jacobsen, Liam Massey and Frances Gulland, 'Fatal Ingestion of Floating Net Debris..., 765.

in size from ten square centimetres to about sixteen square metres. In total 164 pieces were counted and all of them had at least one cut edge, which suggested that these scraps had been discarded during net repairs.

In 2011, a male calf cachalot was found floating dead very close to the coast of Mykonos Island in the Aegean Sea. While performing the necropsy, marine scientists found it quite odd that 'the stomach was pretty visible and almost came out by itself, just after the first cuts on the whale's body. It was disproportionately big and full for such a young cachalot'.[9] Expecting to witness the first record of a giant squid in the Mediterranean Sea, the biologists saw instead:

> [T]ens of big compacted plastic bags used for garbage or construction materials, all kinds of plastic cover for anything we can buy in a supermarket, plastic ropes, pieces of nets, even a plastic bag with full address and telephone number of a souvlaki restaurant in the town of Thessaloniki (located some 500 km further north).[10]

After considering this situation as 'the most dramatic and extreme case so far',[11] the scientists concluded that 'all our "civilization" was in the stomach of this whale'.[12] Once more, the explanation provided was that cachalots incorrectly identified the plastic bags as their natural prey, the squids. In this case, the marine debris ingested blocked the digestive track of the cachalot, which led to its emaciation and death, after a lot of suffering and pain.

In 2012, a cachalot was found dead on a beach near *Castell de Ferro*, in Granada, Spain. The presumed cause of dead was 'gastric rupture following impaction with debris, which added to a previous problem of starvation'.[13] This time, the residues ingested totalled 59 plastic items – such as flowerpots, a dishwater plastic pot, two stretches of hosepipes, greenhouse agriculture cover materials, plastic burlaps, nine meters of ropes, plastic mulch of greenhouse agriculture, a hanger, a mattress, plastic carafes, a tub of ice-cream, a plastic spray canister, five plastic bags and smalls plastic (with less than four centimetres) – and most

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[9] Giuseppe Notarbartolo di Sciara, Alexandros Frantzis and Luke Rendell, 'Sperm Whales in the Mediterranean: The Difficult Art of Coexisting with Humans in a Crowded Sea' (2012) 41(1) Whalewatcher 36.
[10] ibid.
[11] ibid.
[12] ibid.
[13] Renaud de Stephanis and others, 'As Main Meal..., 207.

of it was used to build greenhouses in southern Spain where tomatoes and other vegetables are produced to be distributed on the European market.[14]

In the mid 2014, a female sei whale, of almost 14 meters, was spotted swimming in Elizabeth River, in Virginia, in the United States of America. Visually thin and disoriented for being far from its natural deep offshore waters, the whale ended up death a few days later.[15] Its necropsy revealed the animal ingested a shard of rigid, black plastic, that was in fact a piece of a DVD case. The rigid plastic edges lacerated the whale's stomach. Unable to feed itself properly, that wound led to the whale's demise.[16]

In August 2015, a team of researchers from Texas A&M University in College Station, Texas, was on the Pacific Ocean off the coast of Costa Rica, gathering data on sea turtle mating. It was then they noticed that a male Olive Ridley sea turtle was having trouble breathing. After assuring that it was not a parasite worm, the researches took eight minutes to remove an entire plastic drinking straw (more than ten-centimetres-long) that was occupying the entire nostril.[17] The team disinfected the sea turtle's nose and after being deemed has fit, healthy and strong, the turtle returned to the ocean. All this process was documented on video by one of the scientists and released on the Internet.[18] Up to now, the original video has more than nine million views[19] and its short version was seen up to four million times.[20]

Once more, in December 2015, Olive Ridley sea turtles from Costa Rica caught the attention of marine scientists. It happened when Nathan Robinson, that already took part in the plastic straw incident, was conducting a research team during a mass nesting sea turtles

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[14] ibid 210 and 212.

[15] Sarah Keartes, 'For an Endangered Sei Whale, Death by DVD Case' (*Earth Touch News*, 13 January 2015) <www.earthtouchnews.com/conservation/human-impact/for-an-endangered-sei-whale-death-by-dvd-case> accessed 6 January 2017.

[16] Isabelle Groc, 'How a DVD Case Killed a Whale' (*National Geographic*, 8 January 2015) <http://news. nationalgeographic.com/news/2015/01/150107-sea-trash-whales-dolphins-marine-mammals/> accessed 5 January 2017.

[17] Jane J Lee, 'How Did Sea Turtle Get a Straw Up Its Nose?' (*National Geographic*, 17 August 2015) <http://news. nationalgeographic.com/2015/08/150817-sea-turtles-olive-ridley-marine-debris-ocean-animals-science/> accessed 3 January 2017.

[18] Nick Kirkpatrick, 'Sea Turtle Trauma: Video shows Rescuers Extracting Plastic Straw from Deep in Nostril' (*The Washington Post*, 17 August 2015) <www.washingtonpost.com/news/morning-mix/wp/2015/08/17/ researchers-save-a-sea-turtle-from-a-plastic-straw-in-this-traumatic-video/?utm_term=.a233d5c28916> accessed 3 January 2017.

[19] COASTS, 'Sea Turtle with Straw up its Nostril - "NO" TO PLASTIC STRAWS' (10 August 2015) <www.youtube.com/watch?v=4wH878t78bw> accessed 3 January 2017.

[20] The Leatherback Trust, 'Removing a plastic straw from a sea turtle's nostril - Short Version' (12 August 2015) <www.youtube.com/watch?v=d2J2qdOrW44> accessed 3 January 2017.

event. Nathan Robinson confessed that he has had terrifying thoughts when someone said that a sea turtle appeared to have something stuck in its nose.[21] In fact, a plastic item was jammed in its nostril and 'it was clear that it was lodged into her nose very deeply'.[22] Fortunately, after a few quick pulls, the object came out and everyone was impressed when they realised the plastic item was actually a plastic fork with almost 13 centimetres.[23] Assuring that the turtle looked healthy and active, she made her way back to the ocean. This incident was also filmed and launched on the Internet and it did not go unnoticed since it counts with more than two million views on YouTube.[24] At last, Nathan Robinson concluded that it was 'painful to think that the single-use plastic objects that we dispose of so freely can cause so much destruction for marine life'.[25]

December 2015 was also a tragic month for a young female orca that washed up dead in Plettenberg Bay, in the Republic of South Africa. It was not clear whether consuming the litter was what caused the orca's death or if the animal became ill and moved inshore and tried to feed on what was available: several large pieces of plastic (yoghurt pots, a shoe sole, food wrappers), seagrass and a lot of tubed organisms.[26] In any case, marine mammal specialists assured the orca had very little real food in her stomach and the stomach lining was disintegrating.[27]

In June 2016, around ten small-spotted catsharks have been found dead floating on the coast of Cornwall, in the United Kingdom. These animals were caught tight in a column of plastic nets and ropes. Trapped and unable to swim, these sharks could not eat or breath and 'effectively drowned as they struggled to break free'.[28]

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[21] Nathan Robinson, 'Plastic Fork Removed from Olive Ridley's Nose' (*The Leatherback Trust*, 10 December 2015) <www.leatherback.org/news-events/2015/plastic-fork-removed-from-olive-ridleys-nose> accessed 4 January 2017.
[22] ibid.
[23] A photo of the plastic fork can be seen in Samantha Guff, 'This Sea Turtle with A Fork Stuck in Its Nose Is Exactly Why We Need to Recycle' (*The Huffington Post*, 17 December 2015) <www.huffingtonpost.com/entry/sea-turtle-fork_us_5672fba5e4b0dfd4bcc0f11e> accessed 4 January 2017.
[24] The Leatherback Trust, 'Plastic Fork Removed from Sea Turtle's Nose' (7 December 2015) <www.youtube.com/watch?v=VRiTABRQOjk> accessed 4 January 2017.
[25] Nathan Robinson, 'Plastic Fork...
[26] Jenna Etheridge, 'Sad Story Emerges of Plett's Stranded Orca' (*News 24*, 17 December 2015) <www.news24.com/SouthAfrica/News/sad-story-emerges-of-pletts-stranded-orca-20151217> accessed 5 January 2017.
[27] Photos of the orca's stomach and its content can be seen in Plett Hope Spot Facebook Page (*Facebook*, 16 December 2015) <www.facebook.com/permalink.php?story_fbid=1618319525087059&id=1421945568057790> accessed 5 January 2017.
[28] Lyn Barton, 'Ghost Nets' Kill Sharks Off Plymouth Coast' (*The Herald*, 13 June 2016) <www.plymouthherald.co.uk/ghost-nets-kill-sharks-plymouth-coast/story-29395096-detail/story.html> accessed 6 January 2017.

All kinds of marine life, including birds, can be caught up by nets and ropes and therefore may suffer from starvation, lacerations, infections, and suffocation. These nets, often nearly invisible in the dim light, 'are made from synthetic fibres that don't decompose, so if they are lost and go unreported they have the potential to go on killing for decades or even longer'.[29]

In August 2016, a new video about an Olive Ridley sea turtle was published on the Internet by the researchers of Texas A&M University. In distress and exhausted, a Costa Rican turtle was dragging a huge bulk of discarded fishing net behind her. All the volume the turtle was carrying was attached to its neck, in a so tight way that it had already started to cut into its flesh. Disinfected the deep wound, the turtle was released into the ocean.[30] In the same month, the same researchers found another sea turtle during the synchronised mass-nesting in Ostional, Costa Rica. Badly entangled the turtle dragged with her a bulk of fishing net up the beach, including a one-kilogram lead weight. The right front flipper was cut into the flesh, but the circulation did not seem cut off and it was able to move her flipper normally.[31]

In the beginning of July 2017, one third of the sea turtles found dead on New Zealand beaches had ingested plastic, being the single-use shopping bags the most common item.[32] Scientists from the Massey University's Coastal-Marine Research Group attested that the turtles' intestinal tract got blocked with soft, white and translucent plastics items similar to jellyfish, their favourite food. Unable to digest food, the turtles died slowly. Eighty stranded turtles that were analysed by these scientists during the past six years had plastic in their stomachs and about half died as a direct result.

At about the same time, nearly 1700 seabirds – albatrosses and giant petrels, especially younger seabirds – were found dead on New Zealand and Australia's beaches.[33] More than one third (37%) of the seabirds had plastic in their stomachs: plastics ranged from one millimetre pieces to plastic spoons, balloons and cigarette lighters. Without certainty, the

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29 ibid.
30 COASTS, 'Sea Turtle Entangled in Ghost Net Rescued' (11 August 2016) <www.youtube.com/watch?v=lVPSTkYihCY> accessed 8 January 2017.
31 Christine Figgener, 'Another Video of an Entangled Turtle' (*PLOTKIN LAB*, 1 September 2016) <http://plotkinlabtamu.wixsite.com/plotkinlab/single-post/2016/08/31/Another-Video-of-an-Entangled-Turtle> accessed 8 January 2017.
32 Ged Cann, 'Third of Turtles Found Dead on New Zealand Beaches had Ingested Plastic' (*Stuff, Fairfax New Zealand Limited*, 2 July 2017) <www.stuff.co.nz/environment/94277174/third-of-turtles-found-dead-on-new-zealand-beaches-had-ingested-plastic> accessed 10 July 2017.
33 Ged Cann, 'Third of Seabirds Found Dead on NZ and Australian Shores had Eaten Plastic' (Stuff, Fairfax New Zealand Limited, 6 July 2017) <www.stuff.co.nz/environment/94448787/third-of-seabirds-found-dead-on-nz-and-australian-shores-had-eaten-plastic> accessed 10 July 2017.

scientists believed that some of the birds died as a direct consequence of the plastic items ingestion. They observed internal rupture and bleeding.

Incidents alike are happening recurrently around the world but only few animals are tracked and helped. In addition, even less situations come to public knowledge. These shocking and startling events exemplify just some of the consequences of plastic debris' leakage in ocean. We know that a whole lot more is happening but the real dimension of this problem is not truly known. Besides raising awareness as news do, or should do, we also expect to share all the recent findings and contributes on the plastic debris issue. Let us then begin this journey!

B. The Purpose

Nowadays, wherever on Earth, consumption patterns are massified. The desire to consume has been slowly invading people's lives since the Industrial Revolution of the nineteenth century, but currently it is taking over people's lives in such a way that material goods become determinant for their affirmation as individuals. Actually, materialism and consumption are valued above all other things and people tend to accumulate an immense number of non-priority items in their lives. These trends only became possible because of the introduction and popularisation of engineered thermoplastics in the 1950s.

Thenceforth, plastic can be found in almost every item that people have around them: the sheets, the alarm clock, the mobile phone, the slippers, the light switch, the toothbrush, the toothpaste, the shower curtain, bath towels… everywhere! It has become one of the world's most important and widespread commodities and definitely it changed for the better the lives of everyone and society itself. Medicine, transportation, industry, food preservation, lifestyle and many other sectors suffered massive changes, boosting quality of life and even life span.

Nevertheless, just the existence of plastic and the fact that humankind became reliant on plastics do not justify why humanity embraced mass consumption. This behaviour was induced by industries, enterprises and even politics, in every way possible, through publicity, fashion shows, political speeches and others. Then, the world started to change and capitalism and private property were set as a new paradigm for humanity. In the meanwhile, the Earth's resources were used abusively, causing pollution, resources depletion and significant environmental imbalances.

This trend continued and in the last fifteen years it was reinforced as a result of technological progresses, the extraordinary spread of the Internet, marketing and sales strategies and the social media buzz. This way, modern materialism and consumption are being define as goals either in high-income, middle-income or low-income countries. However, the commodities distributed around the world are not all similar, situation that is causing a major problem with disposable and single-use plastic items, particularly in low-income countries. In fact, people are seldom encouraged to think about the hidden impact of their daily consumer choices. What is an apparently inconsequent behaviour, gives place to an increasing amount of waste worldwide, especially plastic waste, that will keep rising as living standards around the world rise and urban populations increase.

Nowadays, waste production, regardless of the type, is breaking all records – factor which for itself constitutes a problem and that led to what is the world's newest environmental problem: marine plastic pollution.

This situation has two major causes, the reckless behaviour of consumers and the improper waste management. For most people, waste is not a matter of concern or discussion. *The farther, the better* is the most common and zealous thought regarding waste, even in high income countries, where education and civic duties are more developed. So, once produced and discarded massively, waste needs to be managed and it represents one of the greatest costs to municipal budgets. In addition, managing waste is currently highly complex due to the numerous waste management operations (collection, transportation, sorting, recovery, recycle and disposal), several waste sources (urban, industrial, hospital, agricultural, construction and demolition) and multiple stakeholders involved (local and national authorities, producers, packers, retailers and citizens/consumers).

Globally, few national waste management systems could handle the pressure of waste's continuous growth, which is unsustainable. Some other nations, did not have proper infrastructures due to lack of money, and within these nations, some faced insufficient public understanding of the consequences of inappropriate waste disposal. As a result, only a small percentage of all the waste produced is adequately managed. The rest is not collected, or it is collected but then lost during transportation, or, at last, it is disposed in dumps, some near the sea, or it is directly disposed at sea. Because of the population increase in coastal area, a very significant amount of plastic waste found its way to the seashore and marine environments. The problem is even greater in developing countries, where the main targets are to increase economic growth and production and where issues related to environment protection are not even a priority.

Everything considered, as a result of poor waste management, every year, at least eight million tonnes of plastic waste ends up in our oceans, and if current trends continue, the oceans will contain more plastic than fish by the year 2050. Big or small, literally everything, but especially disposables and single-use plastics, can end up in the ocean, from straws, cutlery, tires, lighters, toothbrushes, bags, vases, slippers, packages and bottles, nets, micro beads, and much more. The great majority, around 80% of marine plastic litter, is derived from land-based sources, which include solid waste disposal and landfills, public littering, industrial activities, storm water discharges and combined sewage overflows. The remaining percentage concerns ocean-based sources, such as commercial fisheries, merchant shipping, maritime-based tourism, offshore oil and gas platforms' activities and aquaculture.

Although plastic marine pollution has only recently been recognised as a real problem, it exists since the first plastic items were created, back in the 1950s. Before that, ocean was not only seen as a source of sustenance, but also as an infinite repository for waste. The difference is that plastic items are not biodegradable. Once in nature, they never disappear, they just disintegrate into smaller and smaller particles, while they quickly spread across all the geographic divisions, and layers, of the ocean. Plastic waste is both a timeless and borderless threat, and it is thus very hard to calculate the existing amount in the ocean. We know it is ubiquitous and can be find in rivers, lakes, oceanic gyres and beaches from all over the world, including in the most remote islands of the Planet Earth, such as Midway Atoll and the Henderson Island. It can also be found in Arctic Sea ice and in the deep sea, even at the bottom of the Pacific Ocean's Mariana Trench.

During its journey through the oceans, plastic particles absorb persistent organic pollutants and other chemicals present in the surrounding waters, increasing the quantity they already carry. This way, the plastic particles became concentrators and transporters of an excessive quantity of hydrophobic toxic chemicals in the marine environment. The worst thing is that they are ingested by marine animals, from zooplankton, to birds, fishes, and mammals, and the chemicals transferred throughout all the trophic levels of the marine food web are actually reaching human food as well. Besides this situation, ingestion of debris can cause physical injuries, obstruction of the gut or accumulation of indigestible material. As dreadful is the phenomenon of entanglement leading to injuries, trapping, or drowning. Tens of thousands of individual animals and at least 558 species suffered from entanglements and ingestion and the great majority starves to death. Plastic waste in our oceans represents a huge threat to marine life.

In our perspective, these events would be sufficient to justify the elaboration of this work and to find solutions for the problem of marine plastic pollution – reason for which we started this introduction with those *stranding news* –, but for those who adopt an anthropocentric conception of the environment, this issue can still be studied because this type of pollution has also been causing some significant impacts on human health and activities. Regarding food chain and health issues, it is possible to attest that plastic particles are present in fish and shellfish caught and sold for human consumption. Even though the studies of the consequences of its ingestion still need to be completed, it is certain that people are ingesting hazardous chemicals. In relation to economic and social impacts, we highlight that commercial fishing, shipping and other marine industries, as well as recreation and tourism can suffer heavy losses because of marine plastic pollution, including compromising millions of jobs. Beach clean-up operations are also really expensive, but it is recommended in order to maintain public health and to protect sunbathers from injuries.

Even though the threats posed by marine plastic pollution were neglected for a long period of time – being only recognised by the international community in the last three years –, the recent and sparse scientific evidences are really worrying and underlined the urgency to take effective action. Everything considered, we can conclude that plastic waste is responsible for some of the serious menaces that wildlife and humans are facing, threatening the fragile balance of marine ecosystems and also human health. It is thus imperative to understand comprehensively and in detail what is causing marine plastic pollution at such high level, which is what we are going to try to explain in Part I of this study.

Following this, the next step – corresponding to Part II – is to identify the numerous policies, measures and approaches that can effectively stop plastic waste from entering the oceans, or reduce its amount and its impacts. Whether short or long-term, they can have a legal, political or voluntary nature and cover a variety of subjects, including packaging waste, waste management, urban wastewater, pollution from ships and ports, beach clean-ups, workshops on plastic alternatives, circular economy and awareness campaigns. Regarding legal instruments, it is important to note that most of them were approved and published many years before this problematic, situation which enhances the challenges ahead. Since plastic waste was then rarely considered by policy makers, there is currently a wide number of legal texts on land and sea activities to study in order to acknowledge which ones can help how to solve more successfully plastic marine pollution problem. This means also that international, regional and national legislation needs to be adequate to the problematic, whether it means updating the existing texts or creating new ones.

Given that humanity is facing a global threat, the first logical response to that menace should be found in International Law, whose cooperative spirit must be particularly encouraged. The United Nations' efforts to do so are noticeable, but their effectiveness can be questioned, for a lot of reasons. In an effort to reach a conclusion, we will therefore analyse their relevant environmental and development policies and the way they influence the actions of countries. European Union Law plays as well an exemplary role in the fight against marine plastic pollution. Even though it reaches less States, it has a much wider scope, including a broader range of pollution combat measures – which we will detail –, and promotes increasingly environmental integration, making sure that environmental concerns are fully considered in the decisions and activities of other sectors. With respect to national and local policy responses, we highlight that more and more countries worldwide are integrating – implementing their own policies or regional/international ones – plastic waste management and marine environmental protection in their common political and societal issues.

With the exception of national laws, to which we will make references throughout Part II whenever suited, we will analyse independently international law instruments, European Union regulations and a set of strategic measures orientated to cease effectively plastic waste from entering the ocean – firstly introducing measures to adopt before plastic turns into waste and before it gets to the sea, and ending with measures to combat plastic waste that is already drifting. These three chapters will be preceded by the presentation of environmental juridical principles with the ability of strengthen all measures' cohesion.

The plastic waste problem is enormous, but it can be solved. Consequently, urgent actions must be taken to prevent further damages. Since marine plastic waste has no geographic or political boundaries, solutions must be held at both global and local level and involve everybody's collaboration, including governments, politicians, industry, scientists, NGOs, consumers and citizens. The entire society is responsible for the elevated levels of plastic consumption and at the same time for its wastefulness and consequences associated. There is no doubt either that the solution for this problem lies in each and every individual.

C. Investigation and Structure

We already made clear that, in our opinion, environmental law must adopt an ecocentric approach. In fact, this is why Part I of our essay – *Unveiling Waves of Plastic* – is quite long. The intention is to craft a profound understanding of a phenomenon with many dimensions in order to convince every and each one of us to stand up against a problem with astonishing dimensions and horrific consequences. To establish new and effective measures, whether legal or not, it is mandatory to know the true reality humanity is facing in a detailed and profound way.

Therefore, in Part I we present the social and economic framework of plastic marine pollution. We start by explaining how personal image and confidence were affected by new consumption patterns and how this relation got tightened after appearance of plastic (whose characteristics we also develop). Following this, we present worldwide data on waste and particularly on plastic waste, and we explain which waste management operations are being used in countries form different regions and with distinct income levels. This analysis led to the conclusion that improper waste management, especially collection mishaps, is actually one of the major causes of marine plastic pollution. All the data shared was gathered from reports of well-known organisations such as World Wildlife Fund, Global Network Footprint, World Economic Forum, World Bank, United Nations, European Environment Agency, Plastic Europe and Eurostat. Here, as in the rest of the work, due to the vast amount of data analysed and shared, we always choose to quote the original values and their units of measure. Therefore, additional effort could be required to adequately compare data.

Once identifying the facts which cause marine plastic pollution, we examine in detail the characteristics, the vastness, the sources and the impacts of this kind of pollution. The information shared was collected from some of the most recent and relevant scientific papers and expert reports. It was somewhat difficult to keep track of developments because new papers and reports are being released almost every week. Within the ones we quoted, we highlight the work of Richard Thompson, Charles Moore, Marcus Eriksen, Erik van Sebille, Jennifer Lavers, Kara Lavender Law and Andrés Cózar. News articles, form reliable sources such as National Geographic, and NGOs' reports were also cited occasionally. References to legislation in Part I will only be developed in Part II.

In Part II, titled *Marine Plastic Pollution under the Rule of Law*, we indicate both juridical and non-juridical measures that can tackle the referred kind of pollution. Even though law is important and can shape governments and people's actions, it is far from being the only solution. During Part II, the work of United Nations, of its programmes and specialised agencies, was given a lot of importance during international law analysis. In turn, European Commission, Institute for European Environmental Policy and BIO Intelligence Service were the main responsible for the data shared regarding European Union Law. National measures and the work of NGOs were based on several UN or NGOs reports.

To conclude, we must clarify that the investigation carried out to prepare this work ended at 31 July 2018. Facts and legislative measures that took place after that date were not considered.

PART I

UNVEILING WAVES OF PLASTIC

II. A Plastic Oriented Society

A. A Consumer Society…

Consumption, defined as 'the action of using up a resource',[34] can be regarded from several different angles. Its interdisciplinary approach, that gathers psychologists, sociologists, economists and marketers, is coherent when putting consumption at one pole and consumers at the other. To keep this consistency, our starting point will be the act of consumption itself, analysed in time and space. Then will come a subjective analysis guided by personal feelings, attitudes and behaviours of consumers, while taking also in consideration individuals' reaction to big businesses' marketing strategies.

Human beings have always consumed natural resources. Over millennia, the act of consumption was carried out solely as a way to satisfy several human basic needs and thus allow humankind's survival. However, as time went by, people began to change their approach regarding consumption.

The Industrial Revolution was the first meaningful event in the promotion of that change and although it had primarily focused on capital goods and industrial infrastructures, such as mining, steel, oil, transports and communications, it came to influence, in a short period of time, people's way of living. Hand production methods were gradually replaced for machines and for new manufacturing processes that promoted an efficient use of water and steam power. So, if it is clear that 'the Industrial Revolution (...) transformed production. It is less obvious, but equally true, that it transformed consumption',[35] and workers – that were also becoming consumers – 'no longer choose to stop work early and enjoy more leisure; rather, they would prefer to work full-time, or even overtime, in order to earn and spend more'.[36]

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[34] 'consumption, n' (*OED Online*, OUP, 2017) <https://en.oxforddictionaries.com/definition/consumption> accessed 10 March 2017.
[35] Neva Goodwin and others, 'Consumption and the Consumer Society' (*Global Development and Environment Institute,* Tufts University, 2008), 5 <www.ase.tufts.edu/gdae/education_materials/modules/Consumption_and_the_Consumer_Society.pdf> accessed 15 January 2017.
[36] ibid 6.

Another significant moment of the referred change was the end of the Second World War. The economy grew strongly and the worldwide living standards began to increase substantially for the first time in human history. Therefore, spending part of the income earned on new services and goods became common for the average household, 'resulting in many people being better fed, owning cars, living in bigger houses (...) and having more clothes and new durable goods'.[37] In parallel, travels, recreation and entertainment activities have also become accessible to the majority of people.

This new society – 'where not a few individuals, nor a thin upper class, but the majority of families enjoys the benefits of increased productivity and constantly expands their range of consumer goods' – represented the dawn of the mass consumption society.[38]

While people were enjoying all these new assets and goods, they were also generating most of the demand for them, thus establishing a two-way causality between productivity improvement and the expansion of markets and a mass consumption society. This two-way causality turned out to be a virtuous circle: as productivity improved, consumer goods' prices went down, becoming affordable to an increasingly large number of households, from high- to low-income; this in turn generated larger markets for these goods, which induced further improvement in productivity. The rhythm became so intense that a series of consumer goods industries took off one after another.

This phenomenon, that varied across countries, regions and time periods, was firstly experienced in the post-war United States of America, but, very soon afterwards, many industrialised countries, such as Canada, Australia, Western Europe countries and Japan, went through similar processes.[39] In these and other advanced economies,[40] as the household's income grew up, some goods changed from a luxury to an amenity, and finally, to a necessity.

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[37] Alan Warde, 'The Sociology of Consumption: Its Recent Development' (2015) 41 ARS 119.
[38] Kimironi Matsuyama, 'The Rise of Mass Consumption Societies' (2002) 110(5) JPE 1035-70. We did not have access to the original version of the article, so it is not possible to refer the specific pages.
[39] ibid.
[40] According to the International Monetary Fund (IMF), in 2016 there were 39 *advanced economies* and 152 *emerging markets and developing economies*. See IMF, *World Economic Outlook: Too Slow for Too Long* (Washington, 2016) 146. This classification is not based on strict criteria, economic or other, and it has evolved over time. The main criteria used by the World Economic Outlook to classify the world into advanced economies and emerging market and developing economies are: (1) per capita income level; (2) export diversification, which means that oil exporters that have high per capita GDP would not make the advanced classification because around 70% of its exports are oil; and (3) degree of integration into the global financial system. See IMF, 'Frequently Asked Questions - World Economic Outlook (WEO)' (*IMF*, 4 October 2016) <www.imf.org/external/pubs/ft/weo/faq.htm#q4b> accessed 6 February 2017

In general, the world underwent massive changes, leading to a paradigm shift in relation to consumption and re-setting people's priorities.[41] The immense desire to consume new products and to acquire new services was somehow satisfied by the creation of new spaces – retail stores full of advertisements, popular magazines and daily newspapers – where these products could be sampled, purchased and enjoyed.[42]

By granting access to new and abundant goods, big businesses' marketers managed to create a new consumer profile, one that would turn into a powerful role model. American-inspired, this model was designed to represent a universal goal of modernisation, democracy and progress.[43]

Other factors strengthened and consolidated this mass consumption growth. Among legal, ideological and commercial factors, the most remarkable were the following: a strong and persuasive marketing, capable of highlight novelty's sensuality and attraction, implemented by big business, especially international firms; the development of markets; the shifting of goods and services (such as housing, transportation, medical care and meals) from collective provision by the work unit to individual provision on the open and often unregulated market; the judgment of independent brokers who analysed and criticised the products; the legislation adopted by each country; and even the level of religion engagement in each state affairs.[44]

This massive consumer society brought several advantages: widespread wealth, better quality of life, higher standards of living, new and better jobs and better working conditions, and even 'qualitative changes in demographics, new trends of social and geographical mobility, and the growing appeal of standardised goods as badges of both democratization and social status'.[45]

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[41] While some goods were taking for granted in advanced economies, they remained luxuries in the so called emerging markets and developing economies.
[42] Sharon Zukin and Jennifer Smith Maguire, 'Consumers and Consumption' (2004) 30 ARS 189 citing Appadurai A, *Modernity at Large: Cultural Dimensions of Globalization* (UMP, 1996) 72.
[43] ibid 176 and 188.
[44] ibid 175 and 179-80. It can also be mentioned that: 'in each country, state (and party) officials decide to modernize the economy by introducing market incentives, allowing individual property ownership, and – as both an incentive to the work force and a means of stimulating aggregate demand – encouraging the production of goods to satisfy consumer desires', ibid 189-90.
[45] ibid 177 citing Schudson M, *Advertising, the Uneasy Persuasion* (New York Basic Books, 1894).

From then on, in spite of the global economy's highs and lows, the needs, tastes and desires of people have evolved, and consumption 'assumed an overwhelming significance in modern life'.[46]

This phenomenon happened particularly in the late 1990s, due to information and communication technologies tremendous growth.[47] Mobile connectivity has been used extensively from both consumers and enterprise segments, with impressive uptakes even in developing economies, and it has proven to be transformational. In the last fifteen years, the world witnessed a digital and information revolution that has completely changed the patterns of consumption, as we will see further on. Apart from mobile global subscriptions, that have reached around seven billion in 2015,[48] sales of technologically sophisticated goods such as smartphones, smartwatches, laptops, tablets, action cameras, 3D printers and music gear, made up a greater portion of household around the world.[49] An example, for a better understanding, are the technological brands that became almost a cult and that gather crowds several days prior to the launch of certain products. It goes so far as people sleeping on streets and people being paid large sums of money by foreigner fans that want to get the products months or days ahead of the release in their own countries.[50] Some people aspire to get these products immediately because they are not willing nor to wait neither to keep the older version of the product. Even more if that one specific acquisition makes them feel a member of an elite product's club, which is as well associated with creativity, success and a bright future.[51]

Why people consume and what motivates such pronounced behaviour is what we are going to see next.

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[46] Sharon Zukin and Jennifer Smith Maguire, 'Consumers and..., 173.
[47] World Bank, *The Little Data Book on Information and Communication Technology 2015* (Washington, DC, 2016) v.
[48] World Bank, *World Development Indicators 2016* (Washington, DC, 2016) 120.
[49] Noting that not all social groups and countries have been affected in the same way, it is worth remember that developing economies experienced a steady decline in absolute poverty, induced by information and communication technologies that improved access to basic services and created employment opportunities, see World Economic Forum, *The Global Information Technology Report 2015 - ICTs for Inclusive Growth* (2015) 4 and 33. Mobile communications had, and still have, a particularly important impact in rural areas: 'for example, farmers in developing countries have benefited from new ICT services such as real-time information about commodity prices and weather, and from the ease of money transfers', ibid 3.
[50] David Gilbert, 'Apple Mania - Why do People Queue up for iPhones?' (*International Business Times*, 20 September 2013) <www.ibtimes.co.uk/apple-mania-why-queue-iphone-5s-5c-507741> accessed 18 January 2017.
[51] 'The Russian Expert Explained the Phenomenon of Queuing for the New iPhone' (*AppleApple.top World News*, 29 September 2016) <http://appleapple.top/the-russian-expert-explained-the-phenomenon-of-queuing-for-the-new-iphone> accessed 18 January 2017.

B. … Hold onto the Extended Self

If there is a particular reason for such consumerist behaviour is an issue that has been studied for some time, by psychologists, psychoanalysts, public relations and advertisers. According to Russell Belk, understanding the meaning that consumers attribute to their possessions is halfway to understand consumers' behaviours and consequently to understand the broader existence of human beings.[52]

'People are what they have and possess' is far from being a brand new idea but it is still full of meaning.[53] Nowadays, people do not buy only a product. They acquire also immediate satisfaction as well as self-esteem and happiness, and this happens because 'people's fragile sense of self needs support',[54] and because 'the objects we possess and consume (...) tell us things about ourselves that we need to hear in order to keep ourselves from falling apart'.[55]

Russell Belk even stated that 'people seek, express, confirm, and ascertain a sense of being through what they have'.[56] And this happens early in life, as early as infants learn to distinguish self from the surrounding environment and, later on, from others, especially the ones that may envy their possessions. Although the emphasis placed on material possessions decreases with age, it remains high throughout life as people seek to express themselves through possessions and use material goods to seek happiness, to remind themselves of experiences, accomplishments and other people in their lives, and even to create a sense of immortality after death. Accumulating stuff and goods provides people a sense of past and reminds them who they are and where they have come from.[57]

People can actually believe that their possessions are part of themselves, and the same happens with external objects and personal possessions, including also body parts, vital organs, a person's mind, other persons (family and friends), places, affiliations and group

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[52] Russell W Belk, 'Possessions and the Extended Self' (1988) 15(2) The Journal of Consumer Research 139.
[53] As early as 1890, William James understood that 'a man's Self is the sum total of all that he CAN call his, not only his body and his psychic powers, but his clothes and his house, his wife and children, his ancestors and friends, his reputation and works, his lands, and yacht and bank-account', see Russell W Belk, 'Possessions and..., 139 citing James W, *The Principles of Psychology* (New York: Holt, 1890).
[54] Russell W Belk, 'Possessions and..., 139 citing Tuan YF, 'The Significance of the Artifact' (1980) 70(4) Geographical Review.
[55] Russell W. Belk, 'Possessions and..., 148 citing Csikszentmihalyi M, 'The Symbolic Function of Possessions: Towards a Psychology of Materialism' (paper presented at the 90th Annual Convention of the American Psychological Association, Washington, DC, 1982).
[56] Russell W Belk, 'Possessions and..., 146.
[57] ibid 160.

possessions. Consequently, the more power and control people have over a certain thing, item or a person, the more they feel that thing, item or person as their own and as themselves.

All this innate and inner process is not immune of external influences. On the contrary, they are limitless and overwhelming. The modern consumer is not anymore an isolated individual doing shopping. Instead, it is a participant of a contemporary phenomenon called *consumerist culture* or *consumerism*,[58-59] that involves the promotion of a social and economic strategy encouraging a non-stop acquisition of goods and services, in ever-increasing amounts.

As everyone knows, consumers' behaviour involves much more than understanding what products consumers buy.[60] This idea was preconised by Edward Bernays[61] in the 1920s, and the documentary *The Century of the Self*,[62] produced by Adam Curtis and aired in 2002 by BBC Two, revealed the circumstances in which this process occurred. Edward Bernays took his uncle Sigmund Freud's ideas about human beings (based on irrational forces hidden inside each person) and showed, for the first time, to American corporations, how they could make people want things that they did not need, by linking mass production goods to their unconscious desires. In the process, Edward Bernays found out that was a lot more going on in human decision making (either between individuals or among groups) and that irrelevant objects could become powerful emotional symbols of how people wanted to be seen by others. Additionally, Edward Bernays wanted to assure that when buying something, people engaged themselves, emotionally or personally, in that product or service, culminating in the idea that if a person did not need a new piece of clothing, buying it would make them feel better anyway. In the same vein, Paul Mazur shared the opinion that people should be trained

[58] Neva Goodwin and others, 'Consumption and..., 4.
[59] *Consumerism* is 'the preoccupation of society with the acquisition of consumer goods'. See 'consumerism, n' (*OED Online*, OUP, 2017) <https://en.oxforddictionaries.com/definition/consumerism> accessed 10 March 2017.
[60] To provide a better insight: 'Loudon and Bitta (1994), defined consumer behaviour as "the decision process and physical activity individuals engage in when evaluating, acquiring, using or disposing of goods and services". It encompasses concepts drawn from psychology, sociology, anthropology, history and economics. This means that, in developing products that consumers would obtain value, marketers require good understanding of how consumers treat their purchase decisions', see Uttera Chaudhary and Ankita Asthana, 'Impact of Celebrity Endorsements on Consumer Brand Loyalty: Does it Really Matter?' (2015) 5(12) International Journal of Scientific and Research Publications 220-1.
[61] Edward Bernays was an Austrian-American pioneer in the field of consumption, public relations and propaganda, who played an extremely powerful and influential role throughout his entire life. Known for being the father of public relations, Edward Bernays used psychological techniques in public relations to achieve crowd manipulation.
[62] David Lessig, 'The Century of the Self (Full Documentary)' (9 July 2015) <www.youtube.com/watch?v =eJ3RzGoQC4s> accessed 16 February 2017.

to desire, to want new things even before the olds were entirely consumed. Concluding, mentalities should be shaped so man's desires could overshadow their needs.

This innovative approach of manipulating the masses was extended not only to business but also to politics. Herbert Hoover, who served as the thirty-first President of the United States of America from 1929 to 1933 during the Great Depression, was the first politician to agree with the idea that consumerism had become the central motor of American life. In a room full of public relations and advertisers he said: 'You have taken over the job of creating desire and have transformed people into constantly moving happiness machines, machines which have become the key to economic progress'.[63]

Whereas politicians began to embrace the idea that advertising was the key to world prosperity, an unprecedented coalition between business and government took place. Recognising that assets and possessions become a way of communication between people was a fact that impelled the governments to succumb to the pressures and skills of big business to gain power. So, both started to use psychological techniques to read, create and fulfil people's inner selfish desires, and to make their products and speeches as pleasing as possible to consumers and voters. It was a win-win situation in the pursuit of creating model citizens and model consumers, promoting thus a stable society and a valuable possibility to make money. Regardless of the point of view, these days, citizens are considered consumers – the *homo sapiens* evolved into the *homo economicus*.[64]

After the Second World War, psychoanalysis was truly and effectively put into big business's practice, and Ernest Dichter's key arguments were fundamental for this accomplishment. He considered that the way people quite often tried to work off their frustrations was by spending on self-sought gratification, and if one identified himself with a product, it could have indeed a therapeutic value. The contemporary man was internally ready to fulfil his self-image by purchasing products that will compliment him, his spiritual and ego satisfaction.[65] Besides, Ernest Dichter considered that products had the power to give people

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[63] ibid.
[64] Carla Amado Gomes, 'Consumo Sustentável: Ter ou Ser, Eis A Questão' in Gomes CA, *Textos Dispersos de Direito do Ambiente - Volume IV* (AAFDL, Lisboa, 2014) 280.
[65] Victor Lebow, an economist and retail analyst consultant, made the following observation in 1955: 'our enormously productive economy demands that we make consumption our way of life, that we convert the buying and use of goods into rituals, that we seek our spiritual satisfaction and our ego satisfaction in consumption. We need things consumed, burned up, worn out, replaced and discarded at an ever-increasing rate', see Victor Lebow, 'Price Competition in 1955' (1955) Journal of Retailing 1-7.

a feeling of common identity with those around them, enhancing their social confidence and success.

The 1950s were also marked by a considerable leap in advertisement, especially because the modern practice of selling advertisement time to multiple sponsors had begun. Advertising impact became increasingly strong and it can be an extremely manipulator activity. Since that time, through advertisement, people are being told what to want and what to buy. Currently markets and brands are still driving consumers' behaviour in order to create someone that would buy their things and that would act as their tools. There is no doubt that people's attitudes and behaviours, not only as consumers, are conditioned.[66] Very few people are truly free from society's conventions, rules, constraints, prejudices and judgements. For this reason, brands, governments, financial institutions and other entities (private, public, legal, corporative, among others) are committed in leading people's lives. Big business influence deeply both individuals and governments, and sometimes the biggest corporations actually overpower them all, which constitutes a major opportunity to make money and to grow bigger. As for individuals, there is no true liberation of the self.[67] People's desires, choices and opinions are socially constructed, new social practices are introduced, cultural models and means of self-expression change all the time and strategic marketing's practices are constantly reviewed.

With regard to marketing, it is important to mention that, over the past ten years, social media mobile applications – such as Facebook, Instagram, Twitter, Snapchat, Pinterest and Tumblr – became part of people's daily routine. The traditional billboards, television and radio commercials are giving place to a new marketing strategy based on these social

[66] Besides *homo economicus*, citizens can also be called *homo ludens*, which is the citizen-consumer dominated by advertising, and commonly superficial and hedonistic. See Carla Amado Gomes, 'Consumo Sustentável..., 280 quoting Gilles Lipovetski, 'A Era do Vazio' (1989).

[67] Temptations for consumers and business tricks are everywhere. For example, shopping malls are carefully designed, so they can create appropriate moods to indirectly encourage buying. That is why anchor stores are strategically positioned. Another manoeuvre of companies is placing advertisements resorting to Internet cookies. Internet cookies are small text files sent automatically to computers' users that store the interaction between the user and the website, thus enabling recognising the device/user in future occasions. The information collected covers, among others, the user name, the ads clicked, the time spent on each webpage. By keeping track of the user over time, cookies – or other online tracking methods such as device fingerprinting and cross-device tracking – are essential to customise people's browsing experience, and to deliver advertisements, images or scripts targeted to each one of them, according their tastes and interests. They are even used across different websites and Internet sessions. Once cookies enable web browsers to keep track of all the websites visited, third parties (advertisers, companies and even governments) can access the information stored, not requiring user's interaction or authorisation to be loaded on the user's browser. Jo Pierson and Rob Heyman, 'Social Media and Cookies: Challenges for Online Privacy' (2011) 13(6) Info 30, 34-7 and 39.

networking services, through which they launch numerous advertisements and overwhelm people.

This is the social media marketing and it represents the most effective way to directly interact with people, and not only with the youngest generations. People born in the 1960s and after that have also joined this phenomenon. Moreover, almost every fan of social networks is registered in more than one networking service. Through these mobile applications people interact with each other and everything around them, including news agencies, celebrities and brands.[68] So, having a strong plan for social media marketing and being present on the web – preferably in several social media channels – is the key to tap into consumers' interest, and if implemented correctly, it can improve the success and the gains of the business.[69] By sharing messages, images and videos, brands conquer consumers. And the more it happens, the more costumers become loyal to the brand, and the more people feel the brand less like a corporation and more like a unified group of people who share the same vision and tastes. A mutual relation is established: both industry leaders and consumers connect and learn with each other, and any practical problems arising can be solved in a short time.[70]

Another reason why social media is crucial for business is because of the highly customisable nature of social media advertisements, allowing to target users by things such as gender, age, tastes, location, education level and their job.[71]

Additionally, social media platforms, potentially reaching a global audience, are great sources for finding what and who is currently trending. Without a doubt, celebrities are always in vogue, which gives way to celebrity endorsement and to celebrity branding.

Celebrity endorsement can be defined as 'an individual who enjoys public recognition and who uses this recognition on behalf of a consumer good by appearing with it in an advertisement'.[72] It dates back to the late eighteenth century but it took off seriously in the

[68] Lily Bradic, 'Celebrity Endorsements on Social Media Are Driving Sales and Winning Over Fan's' (*Social Media Week*, 30 September 2015) <https://socialmediaweek.org/blog/2015/09/brands-using-celebrity-endorsements> accessed 10 January 2017.
[69] 'Social Media Marketing for Businesses' (*WordStream*) <www.wordstream.com/social-media-marketing> accessed 4 March 2017. It is not at issue whether brands pay for it or not, because in general the revenues do compensate the investment.
[70] '16 Reasons Why Your Business Needs Social Media Marketing' (*The Content Factory*) <www.contentfac.com/9-reasons-social-media-marketing-should-top-your-to-do-list/> accessed 4 March 2017.
[71] ibid.
[72] Uttera Chaudhary and Ankita Asthana, 'Impact of..., 220 citing McCracken G, 'Who is the Celebrity Endorser? Cultural Foundations of the Endorsement Process' (1989) 16(3) The Journal of Consumer Research 310-21.

1930s. Already in those days, Edward Bernays was organising fashion shows in department stores and paying celebrities to deliver the message that people should buy things not just for need, but to express their inner sense to others. On the other hand, celebrity branding transforms a very famous person in a brand ambassador.[73]

Celebrities are well recognised personalities that have a strong, attractive and impressive power to influence people. When purchasing the item publicised, the consumer feels an identification with the celebrity in question. Using celebrities' image brings awareness, credibility and confidence to the brand. Above all, it has potential to boost sales drastically, in terms of brand-level sales and firm-level stock returns.[74]

Lately, this practice has been extremely noteworthy and the impact celebrities have on people is unparalleled, thanks to the increasingly sophisticated social media and mobile applications.[75] This type of advertisement is becoming 'an essence in modern competitive marketing environment for high recognition and creation of strong product perception'.[76] As for consumers, their 'potential autonomy is shaped, controlled, and curtailed by the growing concentration and interlocking of corporate media and network operators around the world'.[77] Linking this issue with the subject of the extended self, we should point that people see their mobile phones and other personal gadgets as part of themselves. This and the proximity to famous persons' lives, promoted by social networks, set people's life goals higher and made people more ambitious and competitive, aspiring to everything they could imagine.

At last, everything that has been said until now set us thinking whether or not the increased wealth and consumerism has led to more content and satisfied individuals. If commercials promise liberty and happiness, in truth, they deliver neither. As people become

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[73] ibid 220.
[74] 'Nike alone is thought to have spent around USD 475 million annually on athlete endorsements as part of its USD 1.7 billion advertising budget in 2006 (...), but many companies outside the sports-apparel industry are active participants as well. (...) Signing the kinds of endorsers that featured in our research [athletes' endorsements] on average generates a 4% increase in sales – which corresponds with around USD 10 million in additional sales annually – and nearly a 0.25% increase in stock returns', see Anita Elberse and Jeroen Verleun, 'The Economic Value of Celebrity Endorsements' (2012) 52(2) Journal of Advertising Research 163.
[75] The most effective celebrity endorsements are the ones that demonstrate an authentic connection between the celebrity and the brand. Moreover, brands will tap into the social media channels of these celebrities, creating a unique and personal allure to fans and followers. The fact that social media provides an unprecedented insight into the private lives of celebrities means it also has the power to make these endorsements seem, in general, more genuine and credible. See Lily Bradic, 'Celebrity Endorsements...
[76] Uttera Chaudhary and Ankita Asthana, 'Impact of..., 220.
[77] Jo Pierson and Rob Heyman, 'Social Media..., 31 citing Castell M, *Communication Power* (OUP, 2002).

wealthier, the subjects and the objects of people's comparisons tend to expand contributing to more anxiety and leading to affluenza.[78]

In essence, consumption and consumerism drive most aspects of our lives today and, for better or for worse, they are identified as being at the core of a modern culture and society, contributing to social definition and social recognition. It is important to recognise that consumption is necessary, enjoyable and often a constructive process of appropriation of goods and services and their application to reasonable and commendable personal and sociable ends.[79] However, as a consequence of the wide extension of the nowadays people's self and considering the role of consumption in providing meaning to people's life, consumption rates tend to grow more and more.[80] It is a vicious circle, even though the construction of our extended self can be a positive contribution to our identities.

C. The Ecological Footprint

According to the World Bank, from 1960 to 2015 the number of people rose from 3.035 billion to 7.347 billion.[81] However, for thousands of years, population grew slowly and an evidence is that two hundred years ago the world population was numbered less than one billion.[82] Its peak was in the years of 1962 and 1963, with an annual growth rate of 2.2%,[83] and since then the annual growth has been declining. Although the United Nations projected that this decline will continue for the next decades, they have also announced that global population is projected to increase further to 9.7 billion by 2050 and 11.2 billion by 2100.[84]

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[78] *Affluenza* is a term used by critics of consumerism and it was defined as 'a painful, contagious, socially transmitted condition of overload, debt, anxiety, and waste resulting from the dogged pursuit of more', when presented in 2001. See John de Graaf, David Wann and Thomas H Naylo 'Affluenza: The All-Consuming Epidemic' (San Francisco: Berrett-Koehler Publishers, 2001).

[79] Alan Warde, 'The Sociology..., 120.

[80] We did not forget that people with consumer goals are also interested in goals such as self-realisation, fairness, freedom, participation, social relations and ecological balance, and these may be either served by or be in conflict with their goals as consumers.

[81] World Bank, 'Population, total' (*World Bank*, 2017) <http://data.worldbank.org/indicator/ SP.POP.TOTL?name desc=false> accessed 14 March 2017.

[82] As per estimates from Michael Kremer, 'Population Growth and Technological Change: One Million B.C. to 1990' (1993) QJE 681, 715.

[83] Max Roser and Esteban Ortiz-Ospina, 'World Population Growth' (*Our World in Data*) <https://ourworldindata.org/world-population-growth> accessed 14 March 2017.

[84] Clarifying, ten years ago, the global population was growing by 1.24% per year. In 2015 it was growing by 1.18% per year, or approximately an additional 83 million people annually. See UN, *World Population Prospects: The 2015 Revision, Data Booklet* (UN, Department of Economic and Social Affairs, Population Division, 2015) 3.

This remarkable population growth was particularly reflected, and it still is, in a trend of conspicuous and excessive consumption.[85] In order to satisfy such demand, humanity has been using up, until exhaustion, nature resources.

After many debates and countless scientific studies, that provided a better understanding of the interdependencies of Earth's life support systems and their limits, it became possible to track human pressure's exponential increase and the consequent degradation of natural systems.[86] Humanity's understanding on the subject has never been clearer, though the ecological price of economic growth has never been so heavy.

It is clear now that throughout times nature has had the capacity to absorb the impact of human development, but during these last years, humanity witnessed the limits of natural resilience being strained to the extreme. To make matters worse, almost every event of environment deterioration is felt at a planetary level and the plastic debris lost to the ocean is the finest example.

The increased human pressure – such as conversion of natural habitat to agriculture, overexploitation of fisheries, pollution of freshwater by industries, urbanisation and unsustainable farming and fishing practices – is diminishing natural capital at a faster rate than it can be replenished.[87] As a consequence, nature and ecosystem services are now seriously endangered and the consequences of natural capital depletion are already being felt, each day, by people all over the world.[88]

[85] For a wildlife footprint analysis that links global losses of wild birds to consumer purchases across 57 economic sectors in 129 regions, see Justin Kitzes and others, 'Consumption-Based Conservation Targeting: Linking Biodiversity Loss to Upstream Demand through a Global Wildlife Footprint' (2016) Conservation Letters 531-8.

[86] Results that confirm that human demand for ecosystem services is beyond the biosphere's natural capacity to provide them can be seen in Maria Serena Mancini and others, 'Ecological Footprint: Refining the Carbon Footprint calculation' (2016) 61 Ecological Indicators 390-403. Illustrating the role of the Ecological Footprint as an indicator and potential predictor of habitats' fragmentation and loss, see Elias Lazarus and others, 'Biodiversity Loss and the Ecological Footprint of Trade' (2015) 7 Diversity 170-91. Complementing: 'international trade links consumption in one country to biodiversity loss in another, displacing pressure on biodiversity through the global supply chain', ibid 180. For another perspective, which explains how the Ecological Footprint tool can contribute to the advancement of conservation science, see Alessandro Galli and others, 'Ecological Footprint: Implications for Biodiversity' (2014) 173 BC 121-32.

[87] Natural capital is the most fundamental of the core forms of capital (ie manufactured, human, social and natural) since it provides the basic conditions for human existence. These conditions include fertile soil, multifunctional forests, productive land and seas, good quality freshwater and clean air. They also include services such as pollination, climate regulation and protection from natural disasters. Natural capital sets the ecological limits for our socio-economic systems. It is both limited and vulnerable. See EEA, *The European Environment - State and Outlook 2015: Synthesis Report* (EEA, Copenhagen 2015) 51.

[88] In 2012, the EEA recalled that 'at the current rate of use, the world's natural resource base is in danger of over-exploitation and eventual collapse', see EEA, *Material Resources and Waste - 2012 Update: The European Environment State and Outlook 2010* (EEA, Copenhagen, 2012) 7.

The *Living Planet Report 2016* from World Wide Fund for Nature highlighted the most negative effects: rising atmospheric CO2 concentrations, stratospheric ozone depletion, global warming, ocean acidification, proliferation of invasive species and diseases, loss of biodiversity (of entire biomes),[89] perturbation of biogeochemical flows (nitrogen and phosphorus inputs to the biosphere) – and all at a rate measurable during a single human lifetime.[90] Worse still, is the fact that 'these consequences are expected to grow over time, increasing food and water insecurity, raising prices for many commodities and increasing competition for land and water',[91] competition that will exacerbate conflicts and migration. Climate change and vulnerability to natural disasters, such as flooding and drought, will also promote the general decline in physical and mental health and well-being, which in turn will lead to more conflicts and migration.

On the contrary, what humanity should accomplish is a sustainable development, through improving the quality of human life while living within the carrying capacity of supporting ecosystems.[92] In other words, development shall occur within what the Planet Earth's ecosystems and their services are able to provide season after season, year after year, at no cost to future generations, through guaranteeing an ecological balance and avoiding depletion of natural resources – that is to say sustainably.

Thus, pursuing a sustainable approach to human development requires a better understanding of the choices made by politicians and other decision makers.[93] This explains why sustainability is a topic of fundamental importance, just as it is important to search for the appropriate indicators to assess how overpopulation and human activities jeopardise Planet Earth's ecosystems and ecological assets.

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[89] Marco Lambertini, Director General of WWF International, stated that: 'wildlife populations have already shown a concerning decline, on average by 67 per cent by the end of the decade', see WWF, *Living Planet Report 2016 Summary* (WWF International, Gland, Switzerland, 2016) 4.

[90] WWF, *Living Planet Report 2016 Summary*, 5 and 16. The future of many living organisms is at risk, and data regarding the period between 1970 and 2012 can prove that 'population sizes of vertebrate species have, on average, dropped by more than half [48% to 66%] in little more than 40 years. The data show an average annual decline of 2 per cent and there is no sign yet that this rate will decrease', ibid 6.

[91] ibid 12.

[92] IUCN, UNEP, WWF, *Caring for the Earth: A Strategy for Sustainable Living* (Gland, Switzerland, 1991) 10.

[93] 'Since the 1980s, policy makers and academics as well as the general public have been debating over what sustainable development is, what the best metrics are to measure the level of sustainability a country (or a region), and how to understand and manage the available natural capital', see Simone Bastianoni (ed), *The State of the Art in Ecological Footprint: Theory and Applications* (Global Network Footprint, Academic Conference Footprint Forum, 2010) <www.footprintnetwork.org/content/images/uploads/Academic_Conference_Book_of_Abastracts.pdf> accessed 25 March 2017.

The Ecological Footprint, introduced at the beginning of the 1990s by Mathis Wackernagel and William Rees, was the first comprehensive attempt to measure human carrying capacity. This new non-speculative description of how many planets Earth it would take in any given year to support human demand of resources in the same year is nowadays the most applied indicator of environmental sustainability.[94]

The Ecological Footprint provides an accounting system that 'equates humanity's demand on nature to the amount of biologically productive area required to provide resources and absorb waste (currently just carbon dioxide from fossil fuel, land-use change and cement)'.[95] Simply put, this analysis measures human demand on the planet's resources and compares it to the available Planet Earth's ecological assets.

On the demand side, the Ecological Footprint 'measures the biologically productive land and sea area – the ecological assets – that a population requires to produce the renewable resources and ecological services it uses'.[96] Although it is difficult to track every human-related pressures on the biosphere, it is possible to identify the following six demand categories: 1) cropland footprint, that refers to the demand for land on which will be produced food and fibre for human consumption, feed for livestock, oil crops and rubber; 2) grazing land footprint referring to the demand for rangelands to raise livestock for meat, dairy, leather and wool products; 3) fishing grounds footprint related to the demand for marine and inland water ecosystems necessary to generate the annual primary production (such as phytoplankton), required to support seafood catch as well as aquaculture; 4) forest product footprint referring to the demand for forests to provide fuel wood, pulp and timber products; 5) built-up land footprint that indicates the demand for biologically productive areas needed for infrastructure, including transportation, housing and industrial structures; and 6) carbon footprint that represents the demand for forests as the primary ecosystems available to long-term sequester carbon not otherwise absorbed by the ocean.[97]

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[94] There is another mechanism to assess sustainable development: the Human Development Index (HDI). It was created to 'emphasize that people and their capabilities should be the ultimate criteria for assessing the development of a country, not economic growth alone'. Therefore, it comprehends the following key dimensions of human development: to lead a long and healthy life, measured by life expectancy at birth; the ability to acquire knowledge, measured by years of schooling; and the ability to achieve a decent standard of living, measured by gross national income per capita. See UNDP, 'Human Development Index (HDI)' (*United Nations Development Programme* - Human Development Reports, 2017) <http://hdr.undp.org/en/content/human-development-index-hdi> accessed 24 March 2017. A correlation of Ecological Footprint and the HDI can be found in EEA, 'The European Environment - State and Outlook 2015' (EEA), 184 <www.eea.europa.eu/soer>.

[95] WWF, *Living Planet Report 2016 Summary*, 20.

[96] Alessandro Galli and others, 'Ecological Footprint..., 122.

[97] WWF, *Living Planet Report 2016 Summary*, 21.

On the other hand, on the supply side, 'biocapacity is a measure of the existing biologically productive area capable of regenerating natural resources in the form of food, fibre and timber, and of providing carbon dioxide sequestration'.[98] In other words, biocapacity is 'the ecosystems' capacity to produce biological materials used by people and to absorb waste material generated by humans, under current management schemes and extraction technologies'.[99] The five categories of use that satisfy human demand in the six Ecological Footprint categories are cropland, grazing land, fishing grounds, built-up land and forest land.[100] Biocapacity changes every year due to climate, ecosystem management, changing soil conditions and agricultural inputs.[101]

Ecological Footprint and biocapacity can be, thus, compared at an individual, regional, national or global scale, and both change over time, varying according to the number of people, the rate of consumption, the efficiency of production, among other factors.[102] Hence, since the early 1970s, humanity has been demanding more than our planet can sustainably offer. The most recent data published date back to the year 2012, year which required a biocapacity equivalent of 1.6 Earths to provide the natural resources and services that humanity consumed.[103] As for today, at current population levels, Global Footprint Network estimates that the available biocapacity per person on our planet is 1.7 global hectares (gha).[104]

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[98] WWF, *Living Planet Report 2016: Risk and Resilience in a New* Era (WWF International, Gland, Switzerland, 2016) 77.

[99] David Lin and others, *Working Guidebook to the National Footprint Accounts: 2016 Edition* (Global Footprint Network, Oakland, 2016) 56.

[100] Forest land category satisfies two demand categories: forest products and carbon sequestration. Forests for timber and other forest products, as well as for sequestration of waste (CO2, primarily from fossil fuel burning), thus regulating the climate. See IUCN, UNEP, WWF, *Caring for the Earth...,* 77, and Alessandro Galli and others, 'Ecological Footprint..., 122.

[101] 'Most of the biocapacity increase that the Earth has experienced in the last five decades comes from increasingly intensive agricultural practices', see WWF, *Living Planet Report 2016: Risk...,* 77.

[102] Brad Ewing and others, *Calculation Methodology for the National Footprint Accounts: 2010 Edition* (Global Footprint Network, Oakland, 2010) is a study that describes the methodology for calculating the Ecological Footprint and biocapacity of the National Footprint Accounts and that provides researchers and practitioners with information to deepen their understanding of the calculation methodology. One can also mention the existence of a National Accounts Committee. Their work is to oversee scientific review procedures and standards for Ecological Footprint calculations and to support continual improvement of the scientific basis of the National Footprint Accounts. These accounts provide the conversion factors and calculations necessary to translate quantities of resources used into the bioproductive land or sea area required to generate these resources.

[103] WWF, *Living Planet Report 2016 Summary*, 20.

[104] Global hectares (gha) – concept adopted around the 2000's – are the accounting unit for Ecological Footprint and biocapacity accounts. This concept of productivity-weighted biologically productive hectares is needed because different land types have different productivity (and that is scaled by yield factors and equivalence factors). For example, a global hectare of cropland occupies a smaller physical area than the much less biologically productive

The WWF *Living Planet Report 2016* indicated that 'average per capita Ecological Footprints differ among countries due to varying levels of total consumption'.[105] It is no coincidence that the United States of America is the only country that figures in the three top positions of the categories of countries ranked by ecological footprint per capita and of countries ranked by total ecological footprint.[106] The high-level consumption patterns of the USA have a major worldwide influence, and is for that reason that there is 'a greater awareness today of the costs of consumer culture, of the unsustainable implications of the generalization of the United States model to the rest of the world'.[107] It is thus expected that the economic growth of countries with light ecological footprints will create aspirations and expectations about enhanced standards of living and daily consumption.[108] The expansion of Chinese and Indian economies, and their consequent growing Ecological Footprint, are a blatant example of this situation.[109]

An analysis of the per capita average Ecological Footprint for high, middle, and low-income countries, during the period 1961-2012, revealed that, irrespective of the income level, countries are following – although at a different pace – a similar development pattern, characterised by a shift from agrarian (biomass-based) to industrialised (fossil-fuel-based)

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pasture land, as more pasture would be needed to provide the same biocapacity as one hectare of cropland. See WWF, *Living Planet Report 2016: Risk...,* 77 and 124.

[105] See WWF, *Living Planet Report 2016 Summary*, 22. We can also add that the consumption Ecological Footprint calculates the area needed to produce the materials consumed and the area needed to absorb the carbon dioxide emissions, plus imports minus exports, see Alessandro Galli and others, 'Ecological Footprint..., 122.

[106] In 2012, the USA occupied the third place, with an 8.2 gha Ecological Footprint per capita. Luxembourg came first, registering 15.8 gha and Australia came second with 9.3 gha. As for total Ecological Footprint, the USA occupied the second place with 2,600,000,000 gha, preceded by China, with 4,800,000,000 gha. See Global Footprint Network 'Ecological Wealth of Nations: Countries Ranked by Total Ecological Footprint (In Global Hectares)' (*Global Footprint Network* 2016) <www.footprintnetwork.org/content/documents/ecological_footprint _nations/ecological.html> accessed 24 March 2017, and see Global Footprint Network, 'Ecological Wealth of Nations: Countries Ranked by Total Biocapacity (In Global Hectares)' (*Global Footprint Network* 2016) <www.footprintnetwork.org/content/documents/ecological_footprint_nations/biocapacity .html> accessed 24 March 2017.

[107] Mike Featherstone, *Consumer Culture and Postmodernism* (2nd edn, SAGE Publications, 2007) xxii.

[108] This idea was shared in Alan Warde, 'The Sociology..., 128.

[109] Comparing data from 1999 and 2012 is elucidative of that circumstance, and population rates are a factor of high importance. In 1999 the Ecological Footprint per capita in China was 1.54 gha, in India was 0.77 gha, and in the USA was 9.7 gha. In turn, in 2012, these values were respectively 3.4 gha, 1.2 gha and 8.2 gha. So the reasons why China, USA and India are the top three countries ranked by total Ecological Footprint are the excessive consumption of the USA and the overpopulation of China and India. If in 1999 there were 280,400,00 Americans, 1,272,000,000 Chinese, and 992,700,000 Indians, in 2012 there were 317,505,000 Americans 1,408,042,000 Chinese, and 1,236,687,000 Indians. See WWF, *Living Planet Report 2002* (WWF International, Gland, Switzerland, 2002), and see Global Footprint Network, 'Ecological Wealth of Nations: Countries Ranked by Total Ecological Footprint (In Global Hectares)'...

economies.[110] This analysis even showed the inequality in national demand for renewable resources and ecological services. During the aforementioned period, the average per capita Ecological Footprint increased from 5 gha to 6.2 gha, with a peak of 6.6 gha in 1985, in high-income countries; increased from 1.4 to 2.3 gha per capita in middle-income countries; and remained almost flat (around 1 gha per capita) in low-income countries.[111] It is thus clear that the average per capita Ecological Footprint in high-income countries is almost three times that of middle-income countries, and about six times that of low-income countries.

These figures are the reflex of the major breakthrough of the consumer society, and it makes complete sense that 'as disposable income rises, consumption increases beyond basic needs, and categories such as mobility, goods and services account for a larger share of the population's Ecological Footprint, as is the case for the USA'.[112] After examining the data of *National Footprint Accounts* from 2012, one can see that low-income countries' Ecological Footprint is mainly determined by biomass-based components (demand for cropland and forest products).[113] As expected, carbon is the dominant component of humanity's Ecological Footprint, ranging from 43% in 1961 to 60% in 2012. It is the largest Ecological Footprint component at the global level as well as for 145 countries (especially high and middle-income) of the 233 countries and territories tracked in 2012.[114]

However, as the WWF *Living Planet Report 2016* stated, the 'per capita Ecological Footprints of several countries are as much as six times larger than the available per capita share of global biocapacity (1.7 gha)'.[115] As it can be evidenced by Global Footprint Network – 'and there are presently no better estimates than those delivered by Global Footprint

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[110] The World Bank grouped countries according to relative GDP values of 2016 as: a) high-income (per capita gross national income is equal to USD 10,066 per year or higher); b) middle-income (per capita gross national income is between USD 826 and USD 10,065); and c) low-income (per capita gross national income is below USD 825). See WWF, *Living Planet Report 2016: Risk...,* 80, and World Bank, 'World Bank Country and Lending Group' (*World Bank,* 2017) <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups> accessed 25 March 2017.

[111] WWF, *Living Planet Report 2016: Risk...,* 80. The difference between the values of 1985 and 2012 registered in high-income countries is assigned to the effects of the economic crisis initiated in 2007-2008.

[112] ibid 81.

[113] In 2012, low income group covered 36 countries, with a total of 836,040,000 individuals. The total Ecological Footprint of this income group was 1 gha, distributed as follows: cropland – 0.3 gha; f – 0.1 gha; forest product – 0.3 gha; carbon – 0.2 gha; fish – 0.0 gha; built up – 0.1 gha. See Global Footprint Network, National Footprint Accounts (Microsoft Excel file, 2016) available at <www.footprintnetwork.org/resources/data/>.

[114] World's total Ecological Footprint in 2012 was 2.84 gha and 1.69 gha of that amount stood for carbon Footprint. With respect to upper-middle countries, in 3.4 gha, 2.1 gha correspond to carbon. High income countries totalled 6.2 gha, which 4.1 gha of them was carbon. See Global Footprint Network, National Footprint Accounts (Microsoft Excel file, 2016) available at <www.footprintnetwork.org/resources/data/>.

[115] WWF, *Living Planet Report 2016: Risk...,* 79.

Network's current Footprint accounts'[116] – not all countries contribute equally to the global demand on nature. Likewise, the productive land available to produce resources or absorb carbon dioxide is different between them. On balance, this means that can occur an ecological deficit – when the Ecological Footprint of a population exceeds the biocapacity of the area available to that population – or an ecological reserve – when the biocapacity of a region exceeds its population's Ecological Footprint. Deficit situations means that the nation is importing biocapacity through trade, liquidating national ecological assets or emitting into the atmosphere carbon dioxide waste that their own ecosystems cannot absorb.

In fact, since 1971 humanity has been living in a steadily increased ecological deficit situation. Assuming current population and income trends will remain constant, it can even be anticipated that human demand on the Earth's regenerative capacity will continue to grow steadily and to exceed such capacity by about 75% by 2020.[117] Besides that, one cannot forget that nature's capacity to provide goods and services is unevenly distributed. This means that the most consumerist countries – nearly 105 countries in 2012 – are placing disproportionate pressure on nature as they appropriate more than their national share of the Planet Earth's resources.[118] These countries that exceed their domestic biocapacity, compensate their lack of local materials by depleting stocks elsewhere. In our globalised world, countries meet their demand for resources through trade and actually there are some countries that function as global capacity hubs. Some of these countries are Brazil, China, United States of America, Russian Federation, India and Canada. Together they account for nearly half of the planet's total biocapacity.[119] Other countries are the world's lowest-income countries whose per

[116] This is the opinion of the creators of the Ecological Footprint concept, see William E Rees and Mathis Wackernagel, 'The Shoe Fits, but the Footprint is Larger than Earth' (2013) 11(11) Plos Biology 2.

[117] WWF, *Living Planet Report 2016: Risk...,* 83.

[118] In 2012, Singapore ranked first among the countries with biocapacity deficit. With 0.1 gha per capita biocapacity and 8 gha per capita Ecological Footprint, the percentage that Ecological Footprint exceeded biocapacity in 16,000%. Portugal registered a 1.5 gha per capita biocapacity and 3.9 gha per capita Ecological Footprint, which gives a surplus of 140%. Although the United States of America is one of the richest nations in the world in terms of natural capital, it is running an ecological deficit: its Ecological Footprint per capita was 8.2 gha and biocapacity per capita was 3.8 gha, totalling a surplus of 120%. See Global Footprint Network, National Footprint Accounts (Microsoft Excel file, 2016) available at <www.footprintnetwork.org/resources/data/> and Global Footprint Network, 'Ecological Wealth of Nations: Countries Ranked by Total Ecological Footprint (In Global Hectares)'...

[119] This list of countries can be found in WWF, *Living Planet Report 2016: Risk...,* 82. A brief illustration of this situation is that the domestically unused half of Canada's cropland, commercial forest land and fisheries are committed to export markets, see William E Rees and Mathis Wackernagel, 'The Shoe Fits..., 1. With regard to China, in 2005 one-third of its CO2 emissions resulted directly from the production of exports. Building infrastructure and production capacities are also, but indirectly, attributed to exports' production and thus exports' emissions. And large proportions of these exports go to the developed world, with approximately 27% to the USA, 19% to the European Union, and 14% to countries as Japan, Australia and New Zealand. Nonetheless, this is an issue that raises questions: 'while China's economic development benefits from export growth, so do the consumers

capita Ecological Footprint is less than half the per capita biocapacity available globally, such as Angola, Tajikistan, Pakistan, and Mozambique, where people struggle to meet basic needs. These low-income nations, besides being very poor, are a repository of pollution, which results mostly, or even only, from other countries demand.[120] The migrating of industries, and especially factories, to poor and less regulated countries is a way to avoid the implementation of costly changes imposed by the law or public policies towards environment. All in all, both parts take advantage of this situation: companies produce at a lower cost (in terms of infrastructures and human resources) and maintain wealthier nations cleaner; the new workers, although being exploited and employed without minimum social standards, have to accept any job to survive. Concluding, consumption in high and middle-income countries has a heavy price for poorer countries' people and for the environment.

The economic system, in which we have been living for decades, was developed during a time when resources were abundant and decisions were constantly made without considering the impacts that might arise from exhausting Planet Earth's resources. Yet, the inherent environmental risks are already known and increasingly acknowledged – habitat loss and degradation, species overexploitation, pollution, invasive species and disease, and climate change[121] – and they are not confined to national frontiers, but instead they echo through space and time, becoming international. The same happens with marine plastic pollution. In fact, 'marine litter [strongly] illuminates the sheer dimensions of humanity's ecological footprint, and the difficulty of reducing it'.[122]

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in developed countries, and it can be argued that they should be held at least somewhat responsible for emissions occurring because of their demand for low-priced goods'. It is assumed that if these consumers become partially responsible for China's export emissions, perhaps China would be more willing to reach political agreements on environment. See Christopher L Weber and others, 'The Contribution of Chinese Exports to Climate Change' (2008) 36 Energy Policy 3575-6. The EEA shares a similar view: 'European consumers are responsible not only for material use but also for the generation of waste in other countries', see EEA, *Material Resources and Waste - 2012 Update...,* 9.

[120] The UN emphasised the substantial inequality of global wealth: around 80% of the world population have just 6% of global wealth. Meanwhile the richest 1% held 48% of global wealth in 2014. In truth, just 80 individuals together have as much wealth as the world's poorest 3.5 billion people. Such inequality has become a serious problem for economic efficiency and for social stability. See UNDP, *Human Development Report 2015: Work for Human Development* (UNDP, USA, 2015) 65.

[121] These threats, that are not unique, often interact, which exacerbates the effects on species: for example, habitat destruction and overexploitation might compromise species' ability to respond to changes in climate. The biggest threat is certainly the food demand of an expanding human population which leads the race in the destruction of habitats and overexploitation of wildlife. At present, agriculture occupies about one-third of the Planet Earth's total land area, and accounts for almost 70% of water use. See WWF, *Living Planet Report 2016: Risk...,* 20, 54 and 95. Much more can be learned about these and other facts and other impacts, see ibid 18-87.

[122] Arie Trouwborst, 'Managing Marine Litter: Exploring the Evolving Role of International and European Law in Confronting a Persistent Environmental Problem' (2011) 27(73) Merkourios 9.

If throughout history, different societies have perceived and responded very differently to the limited capacity of nature to absorb the impact of human development,[123] it is time to coordinate joint actions and to harmonise procedures. It is thus clear that responding to risks at the planetary scale will be vastly more challenging than anything humanity have dealt with before. In order to perceive the complex relationships between human actions and the global impacts that affect the natural state of the planet, it was adopted an Earth system perspective. It will help to denote how local changes have consequences that play out at other geographic scales, and to recognise that human impacts that influence one system or boundary might affect other systems and boundaries as well.

The Planetary Boundaries[124] concept was thus created as an attempt to provide this Earth system perspective. Currently, nine human-produced alterations to the functioning of the Earth system form the basis of the Planetary Boundaries framework, which is comprised by: a safe operating space (green zone), based on the understanding of the functioning and resilience of the global ecosystem; a zone of uncertainty (yellow zone), with an increasing risk of disrupting Earth system stability; and a high-risk zone (red zone), whose maintenance will transform Earth in an inhospitable environment for life. These concepts are useful for framing the current understanding of potential tipping points, and at this time four (biosphere integrity, climate change, land-system change and biogeochemical flows) of the nine human-produced alterations have already been pushed beyond the limit of a safe operating space in which human societies can develop and thrive, healthily and sustainably.

Since pollution reaches every corner of the Planet Earth, the response must be given at a global level. And there is no point in questioning the Ecological Footprint method.[125] It

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[123] WWF, *Living Planet Report 2016: Risk...,* 58 citing Costanza R, Graumlich L and Steffen W, *Sustainability or Collapse? An Integrated History and Future of People on Earth* (MIT Press, Cambridge, MA, USA, 2016) and Sörlin S and Warde P, *Nature's End: History and the Environment* (Palgrave MacMillan, London, 2009).

[124] See Johan Rockström and others, 'Planetary Boundaries: Exploring the Safe Operating Space for Humanity' (2009) 14(2):32 Ecology and Society 1-33. The nine Planetary Boundaries subsystems are: 1) biosphere integrity (or destruction of ecosystems and biodiversity); 2) climate change; and 3) its twin problem ocean acidification; 4) land-system change; 5) unsustainable freshwater use; 6) perturbation of biogeochemical flows (nitrogen and phosphorus inputs to the biosphere); 7) alteration of atmospheric aerosols; and 8) pollution by novel entities, including 9) stratospheric ozone depletion. See WWF, *Living Planet Report 2016: Risk...*, 60.

[125] The Ecological Footprint accounting method has been questioned, from time to time, by a few scientists. It is acknowledged that these Ecological Footprint accounts are robust aggregate estimates and that are subject to uncertainty in source data, calculation parameters and methodological decisions. Nevertheless, it is also a fact that this is an evolving tool, that has undergone many improvements in the aftermath of scientific breakthroughs and critical reviews. See William E Rees and Mathis Wackernagel, 'The Shoe Fits..., 1, and David Lin and others 'Ecological Footprint: Informative and Evolving: A Response to van den Bergh and Grazi (2014)' (2015) 58 Ecological Indicators 464-7. For a case-by-case assessment on national Ecological Footprints, see Alessandro Galli,

has been widely used as a management and communication tool by governments, businesses, educational institutions and non-governmental organisations. As the WWF *Living Planet Report 2016* enunciated, in order to achieve global sustainability and a harmonious and respectful coexistence, it will be required that governments and other stakeholders recognise our societies' ecological interdependence and interconnectedness. They should also become more receptive to global and interregional resource management agreements and policies. By promoting an effective management – that will require considerable shifts in technology, infrastructures and behaviours, in order to support less resource-intensive production and lifestyles –, it is expected a more rational and fair economical response to this critical issue.[126]

Disregarding the Ecological Footprint fluctuation due to major economic crises,[127] the present generation is the greatest consumer of resources in the history of life on Earth. It is not by chance that on 1 August 2018, humanity will have used nature's resource budget for the entire year, according to the Global Footprint Network.[128] This particularly date will be the earliest Earth Overshoot Day since the world went into ecological overshoot in the 1970s. This day marks the date humanity exhausts nature's budget (ecological resources and services) for the year. Following this date, humanity operates in ecological deficit, by drawing-down local resource stocks and accumulating carbon dioxide in the atmosphere. In other words, humanity is presently using nature 1.7 times faster than the regeneration of ecosystems. This is akin to using 1.7 Earths.

'On the Rationale and Policy Usefulness of Ecological Footprint Accounting: The case of Morocco' (2015) 48 ESP 210-24.

[126] WWF, *Living Planet Report 2016: Risk...,* 82-3 citing Kissinger and others, 'Interregional Sustainability: Governance and Policy in an Ecologically Interdependent World' (2011) 14 EST 965-76, William Rees, 'Globalization and Extended Eco-footprints: Neo-colonialism and (un)sustainability' (2011) Democracy, Ecological Integrity and International Law 467-89, and David Moore and others 'Projecting Future Human Demand on the Earth's Regenerative Capacity' (2012) 16 Ecological Indicators 3-10.

[127] Indeed, 'the few instances of reductions in the total global Ecological Footprint do not correspond to intentional policies to limit human impact on nature. Rather they were reactions to major economic crises, such as the 1973 oil crisis, the deep economic recession in the USA and many of the OECD countries during 1980-1982 and the 2008-2009 global economic recession. Furthermore, the reductions in total Ecological Footprint were only temporary and were followed by a rapid climb (Galli et al., 2015). Similar patterns are found in several studies on global carbon emissions (Peters et al., 2011, 2012)', see WWF, *Living Planet Report 2016: Risk...,* 75.

[128] The date of Earth Overshoot Day is calculated with data from Global Footprint Network's National Footprint Accounts, including all people's competing demands on nature: the demand for food, timber, and fibres (cotton); the absorption of carbon emissions from burning fossil fuels; and buildings, roads and other infrastructure. Past Earth Overshoot Days since 1970 to 2018 (in 2017, the date was August 3 and in 2016, it was August 5) and Earth Overshoot Days by Country in 2018 can be consulted in the official website of this initiative of Global Footprint Network, which keeps trying to change the way the world measures and manages its natural resources: <www.overshootday.org>.

The outcomes of the current Ecological Footprint are varied and complex, but it is possible to identify environmental pollution, and plastic pollution, amongst them. The circumstances in which it occurs and its impacts are going to be studied ahead, but first we will understand what plastic is, its usages and benefits and how that influences the modern consumption patterns, which are the real main driver of growth and, at the same time, of environmental degradation (and not population per se).[129]

D. How Tidal Waves of Plastic Flooded Society

Whether biopolymers or synthetic polymers, plastics have a range of unique properties that can be combined in numerous ways.[130] They can be extruded, moulded, cast, spun or applied as a coating, and they benefit with the addition of plasticisers (to render the material pliable and flexible), fillers (such as carbon or silica, to reinforce the plastic material), antioxidants, flame retardants (to discourage ignition and burning), and colourings, enabling the creation of hundreds of different varieties of plastic materials with different properties and every desired functionality.[131]

The characteristics of plastics include a high strength-to-weight ratio, a high thermal/electrical insulation and an outstanding durability. They can be stiff and tough, ductile, non-toxic, waterproof, resistant to chemical, physical and biological degradation (bio-inert), of ease sterilisation and transparent.[132] In addition, plastics production requires few energy and it is much cheaper than the alternative materials: metal, wood or glass. Therefore, there are over twenty major types of plastics in use worldwide.[133]

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[129] Gergely Toth and Cecília Szigeti, 'The Historical Ecological Footprint: From Over-population to Over-consumption' (2016) 60 Ecological Indicators 283.

[130] The early plastics were biopolymers, such as natural rubber and egg and blood proteins. Nowadays, plastics are synthetic polymers. In either case, plastics are composed of a network of molecular monomers – carbon, hydrogen, oxygen, nitrogen, chlorine, and sulfur – bond together to form macromolecules. See Emily J North and Rolf U Halden, 'Plastics and Environmental Health: The Road Ahead' (2013) 28(1) REVEH 1.

[131] Anthony L Andrady and Mike A Neal, 'Applications and Societal Benefits of Plastics' (2009) 364 PTRSB 1977.

[132] ibid 1980-1.

[133] Richard Thompson and others 'Our Plastic Age' (2009) 364 PTRSB 1973. The two major plastic categories are thermosets and thermoplastics. Thermoset plastics retain their strength and shape even when heated, making them well-suited for the production of permanent components and large, solid shapes for dental fillings, automobiles and construction purposes. Thermoplastics are defined as polymers that can be softened, melted and recast for different uses, almost indefinitely, through the application of heat, generating products such compact discs, drinking bottles, food storage containers, eyeglass lenses, shampoo bottles and plastic grocery bags. Multiple cycles of heating and cooling can be repeated without severe damage, allowing reprocessing and recycling. For further information,

Regarding plastics applications, they were considered almost inexhaustible already at the dawn of plastic age, back in 1941.[134] In fact, plastic became ubiquitous, and presently, nearly everyone, everywhere, lives constantly surrounded by plastic, found in mobile phones, toothbrushes, toilet seats, adhesives, inks, coatings, floor coverings, carpet fibbers, payment cards, packaged food, bottles of water or soda, milk jugs, carrier bags and many other items.

Of almost infinite use, plastics have been key enablers for continuous innovations and have contributed to the development and progress of society in innumerable ways, bringing technological advances, energy savings and numerous other social benefits.[135] Plastics revolutionised people's daily lives, transforming and simplifying it, and improving their quality of life. Indeed, all the benefits of plastics have been realised in less than a lifetime.

Something that contributed greatly to this innovation and simplification were plastic disposables. The novelty of plastic disposables was introduced in the 1950s. *Life* magazine's edition from August 1955 announced a new trend: the 'throwaway living'.[136] The article was accompanied by a photo of a family happily throwing disposable items up into the air. These items, that meant to be thrown away after use, would allow to reduce greatly housework and that justified the happiness expressed. People felt that disposables had come to set them free and so the world decided to embrace the plastic age.[137]

Medicine and public health benefited the most from disposable plastics. The lightweight and the versatility of these materials, combined with its extremely low cost,

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consult PlasticsEurope, 'Types and Categories of Plastics' (*PlasticsEurope*, 2016) <www.plasticseurope.org/what-is-plastic/types-of-plastics-11148.aspx> accessed 4 April 2017.

[134] Richard Thompson and others 'Our Plastic Age'..., 1973 citing Yarsley VE and Couzens EG, *Plastics* (Middlesex: Penguin Books Limited, 1945). The discovery of vulcanised rubber and polystyrene in 1839 fostered the exploitation of plastics, but it was only in 1907 that the first truly and entirely synthetic polymer (bakelite) was developed. After the First World War there have been significant improvements in chemical technology, leading to an expressive expansion of new forms of plastics. Man-made plastics were significantly developed during the first half of the twentieth century. After that period, plastic mass production took off and it has expanded ever since.

[135] Richard Thompson and others 'Our Plastic Age'..., 1973.

[136] Irene Hofmeijer, 'Are we Moving to a Post-plastic World?' (*World Economic Forum*, 23 December 2015) <www.weforum.org/agenda/2015/12/are-we-moving-to-a-post-plastic-world/> accessed 9 January 2017.

[137] The idea of named ages must not to be confused with geologic subdivisions of time (periods, epochs and age) defined by the International Commission on the Stratigraphy in the International Chronostratigraphic Chart, which is the reference for the International Geologic Time Scale units. We are currently living in the Holocene, an epoch that has lasted near 12,000 years. However, some say that a new time – the Anthropocene – has come because mankind is leaving a stratigraphic signature in sediments and ice, as we will demonstrate further on in relation to plastic. Proposals for marking the start of the Anthropocene include: an early beginning with the spread of agriculture and deforestation; the Columbian Exchange of Old World and New World species; the Industrial Revolution; and the mid-twentieth century Great Acceleration of population growth and industrialisation. See Colin N Waters and others, 'The Anthropocene is Functionally and Stratigraphically Distinct from the Holocene' (2016) 351(6269) Science 137.

enabled the mass production of single-use health care functional and hygienic products.[138] In 2013, single-use objects comprised 85% of medical equipment, such as disposable syringes, latex gloves, dialysis tubes, intravenous bags, sterile packaging for medical instruments, engineered tissues, contact lenses, artificial corneas, absorbable sutures and prosthetics.[139] Future is promising too, as many varieties of polymers are being produced to meet the expanding needs of modern medicine and it is evident that human health's quality will keep improving notoriously.[140]

Plastics provide people a safer and better life not only through medicine. They can also protect people from injuries,[141] and food and drinks from contamination. Moreover, plastics flooring and furniture can also prevent the spread of bacteria and consequently reduce the cost of maintenance. In addition, the use of inexpensive plastics also made sports garment and equipment, information technology and electrical goods far more accessible for people in general. Overall, the applications of plastic have been extended to packaging, building and construction, transportation, electrical and electronic equipment, agriculture, sports, fashion and leisure. Another major advantage of plastic is that they can help to protect the climate, by saving resources and energy and boosting resource efficiency.[142]

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[138] Rolf Halden, 'Plastics and Health Risks' (2010) 31 ARPH 180.
[139] Emily J North and Rolf U Halden, 'Plastics and..., 2-3.
[140] Disposable plastic items are inexpensive, safer for patients and they save time and money because they do not require sterilisation. Their convenience is undeniable and we present some examples: resorting to single-use items have had a marked effect on reducing blood-borne infections, including hepatitis B and HIV; intravenous bags and tubs are used for immediate drug delivery to treat dehydrated patients through fluid replacement, to transfuse blood and to correct electrolyte imbalances as quickly as possible. As a consequence, plastic constitute 20% to 25% of all hospital waste. Polymers have also been utilised in the development of innovative materials and methods of healing patients: absorbable sutures designed to biodegrade over differing time periods, that do not require surgical removal following implantation, reducing the number of procedures a patient must undergo. Orthopaedics is a privileged field: the polymer polymethylmethacrylate is used as bone cement in total hip replacements. See Emily J North and Rolf U Halden, 'Plastics and..., 1-3, and Arizona State University, 'Health and Environment: A Closer Look at Plastics' (*ScienceDaily*, 23 January 2013) <www.sciencedaily.com/releases/2013/01/130123133928.htm> accessed 11 January 2017. We are expecting improvements for the near future: 'soon nanopolymers will carry medicines directly to damaged cells and micro-spirals will be used to combat coronary disease. Artificial, plastic based blood is also being developed to complement natural blood', see PlasticsEurope, 'The Compelling Facts About Plastics 2009: An Analysis of European Plastics Production, Demand and Recovery for 2008' (*PlasticsEurope*, 2009), 4 <www.plasticseurope.org/Documents/Document/20100225141556-Brochure_UK_FactsFigures_2009_22sept _6_Final-20090930-001-EN-v1.pdf> accessed 13 January 2017.
[141] Car airbags and motorcycle helmets are made of plastic, and firefighters and astronauts rely upon flexible plastics clothing to protect them against extreme temperatures.
[142] Plastics allow the reduction of fuel consumption. Nowadays, plastics make up roughly 15% of a car by weight and about 50% of the Boeing Dreamliner (see World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy - Rethinking the Future of Plastics* (2016), 24 <www.ellenmacarthurfoundation.org/publications> accessed 24 November 2016). Regarding cars, around 40% of plastics used contribute to weight reduction, saving over 500L of fuel over 150.000km, thus reducing CO2 emissions. Furthermore, plastics facilitate the manufacture of many eco-efficient products: outer drum of washing machines are conceived to reduce both water and energy consumption, and modern pipes ensure a more efficient,

For all the referred reasons, that reflect a record of continuous innovations, worldwide plastic production grew exponentially. According to PlasticsEurope, global plastics production grew from 1.5 million tonnes in 1950 to 335 million tonnes in 2016.[143] Plastic spread very quickly across the planet and there is far more plastic in the world than people think about. Since the 1950s, growth in the production of plastic has largely outpaced that of any other material.[144]

As for Europe, in 2015, plastic production reached 60 million tonnes.[145] Although European plastics production levels are still below the pre-crisis levels, worldwide plastic production is expected to double in twenty years and almost quadruple by 2050,[146] especially in markets where waste management systems are only just emerging.[147]

Humans' heavy dependence on plastics is well reflected on numbers, numbers which in turn demonstrate that plastic economic value is immense. The first evidence of such value is that the European plastics industry ranks seventh in Europe's industrial value added contribution, side by side with the pharmaceutical industry and very close to the chemical

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safe and leak-free transportation of drinking water and sewage, guaranteeing no waste or contamination; plastics enable the wind turbine' rotors to be longer and more effective and plastic components in solar panels increase their efficiency. Resource saving even promotes quality of life: homes and buildings efficient insulation is only achieved with plastic insulation. Plastic packaging can also save resources: lightweight plastic packaging reduces the weight of transporting goods, the amount of packaged goods that go to waste, and reduces CO2 emissions. The figures speak for themselves: '1.5g of plastics film extends the shelf life of a cucumber from 3 to 14 days. Some 10g of multilayer film in a MAP (modified atmospheric packaging) for meat extends shelf life from a few days to over a week. The amount of CO2 used to produce a single portion of meat is almost 100 times more than that used to produce the multilayer film'. As a matter of fact, 'without plastic packaging, it is estimated that the tonnage of alternative packaging materials would increase by a factor of 4, greenhouse gas emissions by a factor of 2, costs by a factor of 1.9, energy use by a factor of 1.5 and waste by a factor of 1.9 in volume', see PlasticsEurope, 'The Compelling Facts About Plastics 2009..., 4.

143 ibid 6. This analysis contemplated the effects of financial crisis and the consequent severe recession that hit the European plastics industry. Global production fell from 260 million tonnes in 2007 to 245 million tonnes in the following year. Thus, European converters' demand fell back 7.5% to 48.5 million tonnes in 2008. See ibid 2, 6, 9 and 23. For more updated data, see PlasticsEurope, 'Plastics - the Facts 2016: An Analysis of European Plastics Production, Demand and Waste Data' (*PlasticsEurope*, 2016), 12 <www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf> accessed 13 January 2017. The most recent figures can be find in PlasticsEurope, 'Plastics - the Facts 2017: An Analysis of European Plastics Production, Demand and Waste Data' (*PlasticsEurope*, 2018) <www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf> accessed 8 May 2018.

144 Roland Geyer, Jenna R Jambeck and Kara Lavender Law, 'Production, Use, and Fate of All Plastics Ever Made' (2017) 3(7) Science Advances 1.

145 These statistical data comprised the 28 Member States of European Union, Switzerland and Norway, but neither global nor European data considered all types of plastics. It included plastic materials (thermoplastics and polyurethanes) and other plastics (thermosets, adhesives, coatings and sealants), but not the following fibres: PET, PA, PP and polyacryl fibres. See PlasticsEurope, 'Plastics - the Facts 2017..., 16.

146 World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy...,* 24.

147 Ocean Conservancy, 'Stemming the Tide: Land-Based Strategies for a Plastic-Free Ocean' (*Ocean Conservancy,* 2015), 3 <https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf> accessed 7 April 2017.

industry.[148] The European plastics industry, that includes plastics raw materials producers, plastics converters and plastics machinery manufacturers of the 28 Member States, contributed with around 30 billion euros to public finances and welfare in 2016.[149] In the same year, the producing sector provided employment to about 1.5 million people in over 60 thousand companies (mostly small and medium-sized enterprises) and generated a turnover of around 350 billion euros.

Concerning only thermoplastics and polyurethanes, statistics indicated that China was in 2016 the largest producer of these plastic materials, followed by Europe and by the countries of North American Free Trade Agreement.[150] It is therefore hardly surprising that European plastics industry had a trade balance of over 15 billion euros in 2016.[151] In global terms, plastics' largest market is packaging, an application whose growth was accelerated by a global shift from reusable to single-use containers.[152] Global plastic production by industrial sector in 2015 had the following distribution: 36% for packaging; 16% for building and construction; 14% for textiles; 12% for others; 10% for consumer and institutional products; 7% for transportation; 4% for electrical/electronic; and 1% for industrial machinery.[153] In turn, regarding the global production of single-use plastics, the Northeast Asia (China, Hong Kong, Japan, Republic of Korea and Taiwan) is responsible for 26% of the resins manufactured. This region is followed by North America (21%), Middle East (17%) and Europe (16%).[154]

All the above referred plastics attributes explain the commercial and industrial success of plastic packaging and why packaging dominated the plastics converting market in 2016, representing 39.9% of European Union (plus Switzerland and Norway) plastic demand, that is to say 49.9 million tonnes. The remain of the demand by market segments in 2016 was as follows: building and construction - 19.7%; automotive - 10%; electrical and electronic - 6.2%; household, leisure and sports - 4.2%; agriculture - 3.3%. The category 'others' which

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148 See PlasticsEurope, 'Plastics - the Facts 2017..., 13.
149 The European House Ambrosetti calculated that Italian plastics industry was also capable of promote a multiplier effect of 2.4 in gross domestic product and almost 3 in jobs, in 2013. See ibid.
150 In line with PlasticsEurope, the percentages of worldwide plastic materials (only thermoplastics and polyurethanes) production for the year 2016 were distributed as follows: China - 29%; Europe - 19%; NAFTA - 18%; rest of Asia - 17%; Middle East, Africa 7%; Latin America - 4%; Japan - 4%; Commonwealth of Independent States - 2%. See ibid 17.
151 ibid 12. These data include only plastics raw materials producers and plastics converters.
152 Roland Geyer, Jenna R Jambeck and Kara Lavender Law, 'Production, Use,... 1.
153 See Figure S1 in Supplementary Materials, ibid.
154 UNEP, *Single-use Plastics: A Roadmap for Sustainability* (Nairobi, 2018) 2 and 4.

includes appliances, mechanical engineering, furniture, health and safety added up to 16.7%.[155]

Plastic packaging grants safety and hygiene, protecting food (and medicines) against external contamination by building barriers against microbes, moisture and ultraviolet rays and by preventing the spread of germs during manufacture, distribution and display.[156] Plastic packaging ensures also lighter loads and fewer lorries to transport the same number of products, contributing to diminish pollutant emissions, energy costs and financial costs.[157] Although over 50% of all European goods are packaged in plastic, it represented only 19% of the total packaging weight on the European market in 2014.[158]

The alarming fact is that packaging solutions often out-turn for *disposables*, that are articles 'designed to be thrown away after use'.[159] To worsen the situation, there is a proliferation of these low-cost, short-lived – normally discarded within a year of their purchase – and single-use products. More than 40% of plastic is used just once, then tossed.[160]

[155] ibid 22. Although hundreds of plastic materials are commercially available, only a handful of these qualify as commodity thermoplastics in terms of their high volume and relatively low price. The highest-volume plastic families in 2016 were: 19.3% of polypropylene (PP), used in food packaging, sweet and snack wrappers, hinged caps, microwave proof containers, pipes, automotive parts, and bank notes; 17.5% of low-density polyethylene (LDPE), used in reusable bags, trays and containers, agricultural film and food packaging films; 12.3% of high density PE (HDPE) and medium-density polyethylene (MDPE) suitable for toys, milk bottles, shampoo bottles, pipes and houseware; 10% of polyvinylchloride (PVC) used in window frames, profiles, floor and wall covering, pipes, cable insulation, garden hoses, and inflatable pools; 7.5% of polyurethane (PUR), a thermoset plastic proper for building insulation, pillows, mattresses and insulating foams for fridges; 7.4% of polyethylene terephthalate (PET) able to manufacture bottles for water, soft drinks, juices and cleaners; 6.7% of polystyrene (PS) appropriated for eyeglasses frames, plastic cups, egg trays, packaging and building insulation. See ibid 24.

[156] Plastic food packaging is extremely versatile and offers a multitude of applications such as packaging films for fresh meats, bottles for beverages, edible oils and sauces, fruit yoghurt cups or margarine tubs. Additionally, tamper-proof closures also provide protection and security, and transparency allows people to look at food without having to touch it. The taste and quality (nutritional value) of the foodstuff is maintained: perishable food stays fresh for longer with no need to use large number of preservatives. Modern packaging increases Parmesan cheese shelf-life from 20 to about 50 days. See PlasticsEurope, 'The Unknown Life of Plastics'..., 2. The shelf-life of beef can be extended by five to ten days, or even longer, when using the most advanced plastics packaging solution, see PlasticsEurope, 'Plastics Save Food and Resources' (*PlasticsEurope*, 2016) <www.plasticseurope.org/use-of-plastics/packaging/plastics-save-food-and-resources.aspx> accessed 13 January 2017.

[157] For an average packaging weight for 1kg of product, 88g of alternative materials correspond to 22g of plastic. Using plastic packaging for all products would then reduce by around 800kg an average truck load, would save up to 2 litres of diesel per 100km and would decrease 5kg of CO2 per 100km. See PlasticsEurope, 'The Unknown Life of Plastics'..., 2.

[158] See PlasticsEurope, 'The Unknown Life of Plastics' (*PlasticsEurope*, 2016), 2 <www.plasticseurope.org/Document/the-unknown-life-of-plastics---january-2016.aspx> accessed 13 January 2017 and PlasticsEurope, 'Packaging' (*PlasticsEurope*, 2016) <www.plasticseurope.org/use-of-plastics/ packaging.aspx> accessed 13 January 2017. In 2014, shares of packaging waste generated by weight in the EU-28 were: paper and cardboard - 41%; glass - 19%; plastic - 19%; wood - 16%; metal - 6%. See ibid.

[159] 'disposable, n' (*OED Online*, OUP, 2017) <https://en.oxforddictionaries.com/definition/disposable> accessed 24 April 2017.

[160] National Geographic, '10 Shocking Facts About Plastic' (*National Geographic*) <www.nationalgeographic.com/environment/plastic-facts/> accessed 2 July 2018.

Plastic carrier bags are the most representative example and constitute a very worrying situation at an international level. According to UNEP, five trillion single-use plastic bags are used worldwide every year. Plastic drinking bottles are very worrying too: one million are purchased every minute.[161]

To conclude, it is obvious that no one can question the utility and the broad advantages of plastic. However, utilisation of plastic has also negative consequences, and the first is its rapid capacity of becoming waste, especially the single-use plastics that have been (improperly) discarded for decades. Understanding how that happens and how plastic waste is being managed around the globe is the next step.

[161] UN, 'World Oceans Day 2018 to Focus on Cleaning Up Plastic in Oceans' (*United Nations*) <www.un.org/sustainabledevelopment/blog/2018/06/world-oceans-day-2018-to-focus-on-cleaning-up-plastic-in-oceans/> accessed 2 July 2018.

III. World Waste Tour

A. A Global Survey on Municipal Solid Waste

The generation of waste is as ancient and natural as the first human beings. However, after the establishment of an urban and industrial civilisation, waste was no more confused with the metabolism of species perfectly integrated in natural cycles. Anyhow, being perceived as a biological residue[162] or as a material created by humans, it is clear that waste is considered 'unimportant or valueless'[163] and, consequently, something to be refused, to keep away, and if possible, to keep far from sight. Alexandra Aragão is of the opinion that the real difference between waste and the other objects on the market is a psychological aspect. People's attitude towards waste is not even of mere indifference, but of pure disinterest.[164] People do not think where the items they buy might end up.

Whatever people may call it – residues, waste, trash, rubbish, litter, garbage or debris – we will adopt the term *waste*, the broadest term and the most used in scientific, juridical and political texts. Setting aside a more accurate and complete definition of *waste* for later discussion (in Part II), we begin by acknowledging that waste is generated at all stages of the materials life cycle. So during extraction, production, distribution, consumption (either of products and services) and during waste treatment, it is possible to identify mining waste, industrial waste, hazardous waste, packaging waste, municipal solid waste, electric and electronic equipment waste and residues from recycling facilities or incinerator slags.[165]

According to the World Bank report titled *What a Waste: A Global Review of Solid Waste Management*, as the world hurtles towards its urban future, the amount of municipal solid waste (MSW) is growing even faster than the rate of urbanisation – which happens to

[162] A *residue* is defined as 'a small amount of something that remains after the main part has gone or been taken or used', see 'residue, n' (*OED Online*, OUP, 2017) <https://en.oxforddictionaries.com/definition/residue> accessed 10 June 2017. Residues, detritus or surplus are common in nature. All animals produce them, and naturally and gradually they are reintegrated in nature, thus fulfilling Lavoisier's principle of mass conservation.

[163] The meaning of *rubbish* is: '1. Waste material; refuse or litter; 1.1. Material that is considered unimportant or valueless', see 'rubbish, n' (*OED Online*, OUP, 2017) <https://en.oxforddictionaries.com/definition/rubbish> accessed 10 June 2017.

[164] Alexandra Aragão, *O Princípio do Nível Elevado de Protecção e a Renovação Ecológica do Direito do Ambiente e dos Resíduos* (Almedina, 2006) 83.

[165] EEA, *Material Resources and Waste - 2012 Update...,* 7-8.

be increasing quickly: figures revealed that today more than 50% of the world's population, more precisely 3.943 billion people,[166] lives in cities, and that by 2050 there will be so many people living in cities as the world population in 2000, around six billion people.[167] Nowadays, urbanisation is a global phenomenon that reflects not only the population shift from rural to urban areas, but also the transformation of human's social and cultural approach towards life and its purpose. Consequently, the economic development, the degree of industrialisation, the public habits and the even local climate have had a major influence on the generation of municipal solid waste, which became one of the most important products of this new urban lifestyle.[168]

As expected, this urban expansion will add even bigger challenges to waste disposal and management than the ones the world is already facing. Proof of that is the fact that 'rubbish is being generated faster than other environmental pollutants, including greenhouse gases'.[169]

Regarding figures, the generation of municipal solid waste – that encompass residential, industrial, commercial, institutional, municipal, and construction and demolition

[166] Data from the year 2015, see World Bank, 'Urban population' (*World Bank*, 2017) <http://data.worldbank. org/indicator/SP.URB.TOTL> accessed 25 April 2017.
[167] Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste: A Global Review of Solid Waste Management* (*World Bank*, 2012), ix and 3 <https://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/ 336387-1334852610766/ What_a_Waste2012_Final.pdf> accessed 29 April 2017. The highest impact of materials occurs throughout production and use. Less than 5% stems from waste management, which includes emissions from collection trucks, landfills and incinerators. Daniel Hoornweg, Perinaz Bhada-Tata and Chris Kennedy, 'Waste Production Must Peak this Century' (2013) 502 Nature 616.
[168] Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...*, 3 and 8. Despite the absence of an international definition of *urban*, the concept of municipal solid waste is in fact strictly urban because of the following reasons: urban residents produce about twice as much waste as their rural counterparts; only the affluence of urban residents is important in projecting MSW rates; and waste generation rates tend to be much lower in rural areas since, on average, residents are usually poorer, purchase fewer store-bought items (which results in less packaging), and have higher levels of reuse and recycling. See Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...*, 2-3, 8 and 10. An additional note to enlighten that each country has its own definition of *urban*, and collects data accordingly. The criteria to achieve these definitions include population size, population density, type of economic activity, physical characteristics, level of infrastructure, or a combination of these or other criteria. Some countries simply list their urban areas by name. This results in incomparable and sometimes conflicting definitions, that present a problem when trying to compare urbanisation across countries. See Chandan Deuskar, 'What does "urban" mean?' (*World Bank - Sustainable Cities Blog*, 6 February 2015) <http://blogs.worldbank. org/sustainablecities/what-does-urban-mean> accessed 26 April 2017.
[169] Daniel Hoornweg, Perinaz Bhada-Tata and Chris Kennedy, 'Waste Production..., 615.

waste –[170] is approximately 1.3 billion tonnes per year,[171] and it is expected to double to approximately 2.2 billion tonnes per year by 2025. Manifestly, this will represent a significant increase in per capita municipal solid waste generation rates, from 1.2kg to 1.42kg per person per day until 2025.[172] Per day, global solid waste generation is expected to rise from more than 3.5 million tonnes in 2010 to more than 6 million tonnes in 2025.[173] Moreover, using business-as-usual projections, by 2100, solid waste generation rates will exceed 11 million tonnes per day, which is more than three times today's rate.[174]

The current number of MSW is distributed per region as follows: sub-Saharan Africa (AFR) - 62 million tonnes (5%); Middle East and North Africa (MENA) - 63 million tonnes (5%); South Asia (SAR) - 70 million tonnes (5%); Eastern and Central Asia (ECA) - 93 million tonnes (7%); Latin America and the Caribbean (LAC) - 160 million tonnes (12%); East Asia and the Pacific Region (EAPR) - 270 million tonnes (21%); OECD countries - 572 million tonnes (44%).[175-176] The World Bank report noted all the more that it is important to keep in mind that values for waste generation at a regional level can differ markedly due to

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[170] Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...,* 6 and 8. On the methodology that the World Bank's Urban Development and Local Government Unit of the Sustainable Development Network utilised for collecting data, we clarify that municipal solid waste generation data by country were collected from official government publications, reports by international agencies, and articles in peerreviewed journals. Where possible it was used the same source for a group of countries in order to standardise data by methodology and year. For example, municipal solid waste generation data for high-income countries are from OECD publications; countries in Latin America and the Caribbean, from PAHO studies; and some Middle Eastern countries, from METAP data; for several African countries, data were not readily available. As for 2025 projections, which are widely addressed in the report, they were based on expected population and economic growth rates, whose sources were the World Development Indicators, the IEA Annual Energy Outlook from 2005 and the United Nations World Urbanisation Prospects from 2007. See ibid 3 and 11-2. For a compilation of the different definitions for *municipal solid waste* adopted by OECD, PAHO and IPCC, ibid 4. To avoid any confusion, we clarify that the characteristics and amplitude of the concept *municipal solid waste* justified the use of the synonyms *urban waste* and *global waste* throughout the referred report.

[171] The years in reference varied according to the availability of MSW data by country. See Annex C of the World Bank report: Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...*, 40-4.

[172] ibid ix, 2 and 8. Additionally, 'these values are relatively robust, because urban populations and per capita GDP can be well forecast for several decades', Daniel Hoornweg, Perinaz Bhada-Tata and Chris Kennedy, 'Waste Production..., 616.

[173] Daniel Hoornweg, Perinaz Bhada-Tata and Chris Kennedy, 'Waste Production..., 616. In OECD countries, waste will peak by 2050, and in Asia-Pacific countries, by 2075. The urbanisation trajectory of Africa – where waste will continue to rise in the fast-growing cities of sub-Saharan Africa – will be the main determinant of the date and the intensity of the global peak.

[174] ibid.

[175] To consult the table of Country Classification According to Region, see Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...*, xii.

[176] ibid 8-9. It is curious that the upper boundary of the waste generation per capita of the seven referred regions, for the year for 2014, does not correspond, in a proportional way, to the percentages above indicated. OCDE countries produced almost half of the world waste, but its per capita upper boundary was only 3.7kg per day, contrasting with LAC's value, that was 5.5kg per day, and contrasting also with the values of MENA and EAPR, 5.7kg per person and 4.3kg per person, respectively. See ibid 9. Currently, EAPR is the region of the world where waste is growing faster, but this designation might shift to SAR (mainly India) in 2025, and then to AFR around 2050. See Daniel Hoornweg, Perinaz Bhada-Tata and Chris Kennedy, 'Waste Production..., 616.

the influence of a single country.[177] Because of this and the following reasons, it is important to consider also the level of income.

Income level and urbanisation are highly correlated and as living standards increase, production and consumption of goods and services correspondingly increase, as does the amount of waste produced. As expected, the higher the economic development, the greater the amount of municipal solid waste produced.[178] This is particularly accurate in the case of per capita municipal solid waste generated by income level: high income - 2.13kg per day; upper-middle income - 1.16kg per day; lower-middle income - 0.78kg per day; lower income - 0.60kg per day. The total urban waste generation was, respectively: 1,649,547 tons/day; 665,586 tons/day; 1,012,321 tons/day; 204,802 tons/day.[179]

Level of income influences not only waste numbers, but also its composition and management, as we will see ahead. In fact, waste production, composition and management are influenced by many other factors, such as worldwide culture, habits and traditions, and also climate, geographic locations and energy sources.[180] Regarding solid waste composition, global data revealed that organic waste comprised the majority of municipal solid waste (46%), followed by *other* wastes (18%, covering ceramics, textiles, leather, rubber, bones, inerts, ashes, coconut husks, bulky wastes, household goods, multi-laminates, e-waste, appliances, blister packaging and other inert materials), paper (17%), plastic (10%), glass

[177] China is the best example, since it is responsible for producing 70% of the 270 million tonnes of MSW generated per year in EAPR. ibid 8. China is, in fact, the world's largest waste generator since it surpassed the USA in 2004. See ibid 1.

[178] Countries classification was based on four income levels according to World Bank estimates of 2005 gross national income, per capita (high: USD 10,726 or above; upper-middle: USD 3,466-10,725; lower-middle: USD 876-3,465; and lower: USD 875 or less). See ibid 10. To consult the table of Country Classification According to Income see ibid xiii.

[179] ibid 11. Total values are higher in lower-middle income countries because China belongs to this group. As a matter of fact, 'the high, upper-middle, lower-middle, and low income designations are somewhat inaccurate as these classifications are country-wide, and in several countries average national affluence can be very different from average affluence of the urban populations'. For example, China and India have disproportionately high urban waste generation rates per capita relative to overall economic status as they have large relatively poor rural populations that tend to dilute national figures. See ibid 10. Regarding the current top producers of MSW per capita they are predominantly island nations, including Antigua and Barbuda (5.5kg/capita/day), St. Kitts and Nevis (5.45kg), Sri Lanka (5.10kg), Barbados (4.75kg), St. Lucia (4.35kg) and the Solomon Islands (4.30kg). Guyana (5.33kg) and Kuwait (5.72kg) also score highly. The top five producers in the developed world are New Zealand (3.68kg), Ireland (3.58kg), Norway (2.80kg), Switzerland (2.61kg) and the USA (2.58kg). The countries producing the least urban waste are Ghana (0.09kg) and Uruguay (0.11kg). See ibid 80-4.

[180] In 2012, Japan and the USA registered roughly the same GDP per capita, but due to Japan's higher-density living, higher prices for a larger share of imports and cultural norms, Japan ended up producing about one-third less rubbish per person than the USA, where the average person throws away their body weight in rubbish every month. See Daniel Hoornweg, Perinaz Bhada-Tata and Chris Kennedy, 'Waste Production..., 615-6.

(5%), and metal (4%).[181] Data on waste composition by income revealed that plastic waste varied between 8% and 12%, not showing dependence on the income level as other types of waste. In low-income and lower middle-income countries, plastic ensured the second position higher after organic waste.[182] On the contrary, in upper middle-income and in high-income countries, plastic came third, after organic waste and paper.[183] The same trend was observed with respect to waste composition by region: only in Africa, EAPR and SAR plastic waste amounts exceeded the paper waste; the remaining regions (ECA, MENA, LAC and OECD) produced more paper waste than plastic waste.[184] Global 2025 estimates by income revealed that plastic waste – and all the other waste categories – will be ranked exactly in the same positions, although the values will change slightly.[185]

Nearly 50% of the plastic waste generated globally in 2015 was plastic packaging. Half of that appears to come from Asia, being China the largest worldwide generator of plastic packaging waste. On the contrary, the USA is the largest generator of plastic packaging waste on a per capita basis, followed by Japan and the EU.[186] Moreover, it was estimated that between one to five trillion plastic bags are consumed worldwide each year. Five trillion is almost ten million plastic bags a minute. If tied together, they would go around the world seven times every hour and cover an area twice the size of France.[187]

At last, we note that all data shared should be considered with a degree of caution due to global inconsistencies in definitions, data collection methodologies and completeness.[188]

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[181] It should be noted that these are only approximate values, given that data sets came from 105 countries and were obtained from various sources and concerned various years. See ibid 17-8, 20 and 32. Construction and demolition waste (building rubble, concrete and masonry) was not included in the World Bank report. It must be analysed case-by-case because it varies considerably from city to city. Industrial, commercial and institutional waste also needs further local refinement since many industrial processes give origin to specific wastes and by-products that are not included in waste composition analyses. See Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...*, 16-7.
[182] Waste composition in low-income countries is: other 17%; metal 3%; glass 3%; plastic 8%; paper 5%; organic 64%. In lower middle-income countries is: other 15%; metal 2%; glass 3%; plastic 12%; paper 9%; organic 59%. See ibid 19.
[183] Waste composition in upper middle-income countries is: other 13%; metal 3%; glass 5%; plastic 11%; paper 14%; organic 54%. In high-income countries is: other 17%; metal 6%; glass 7%; plastic 11%; paper 31%; organic 28%. See ibid.
[184] ibid 21 and 90-2 for MSW composition by country, including plastic.
[185] See ibid 19 for the exact estimates amounts.
[186] UNEP, *Single-use Plastics:...*, 2 and 5.
[187] ibid 12.
[188] The World Bank, the Eurostat and the EEA noticed in numerous publications that this is a difficulty verified in every region and country, however with a lower incidence in OECD. Undefined words or phrases, incomplete or inconsistent data, omitted units, no indication of dates, estimates made without basis and information collected at a non-representative moment are some of the factors that can influence the reliability of the information. Additionally, low and middle-income countries data can also be compromised by large seasonal variations (such as seasonal rains, un-containerised waste and horticultural variations), incomplete waste collection and disposal (a significant level of waste is disposed directly through local burning or thrown in waterways and low lying areas), and a lack of weight

B. European Union's Waste Statistics

The EU is an important regional organisation and has been playing a leading role in environmental matters, as we will see in Part II. This is the main reason why we will analyse it separately, even though most EU countries are also OECD members, whose data we have already shared. The other reason is because EU data concerning waste and its management are more updated and faultless than the global data previous presented, mainly due to the implementation of obligations of documentation and reporting.[189]

The most recent data on the total waste generated by all economic activities and households across the 28 Member States of the EU refers to the year 2014. It amounted to 2503 million tonnes – the highest amount recorded in the EU since data are collected –, and was distributed as follows: construction and demolition - 869 million tonnes (34.7%); mining and quarrying - 706 million tonnes (28.2%); manufacturing - 255 million tonnes (10.2%); waste and water services - 228 million tonnes (9.1%); households - 208 million tonnes (8.3%); energy - 93 million tonnes (3.7%); wholesale of waste and scrap - 25 million tonnes (1.0%); agriculture, forestry and fishing - 20 million tonnes (0.8%); and other services - 99 million tonnes (3.9%).[190] Eurostat estimated that per inhabitant, the average amount of waste generated in 2014 across the same 28 countries almost reached five tonnes, more accurately 4,931kg.[191]

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scales at landfill sites to record waste quantities. Low and middle-income countries would be more inclined to use volume since it does not require sophisticated measuring equipment and can be estimated. High-income countries usually use mass as a basis since they have greater funding resources and support to complete a more accurate waste characterisation. Another major inconsistency is the use of imperial units versus metric units, causing the true value to be unknown. Likewise, it is essential to know whether the percentages are given on a dry or wet basis, because component percentages will differ markedly depending on moisture content. When in doubt, which is frequent, it is assumed that the composition was determined on a wet basis. See ibid 32-3 and EEA, *EEA Signals 2014: Well-being and the environment: Building a resource-efficient and circular economy in Europe* (EEA, Copenhagen, 2014) 27.

[189] See the Regulation 2150/2002/EC of the European Parliament and of the Council of 25 November 2002 on waste statistics [2002] OJ L332/1 (Waste Statistics Regulation) and the Commission Regulation (EC) No 1445/2005 of 5 September 2005 [2005] OJ L229/6.

[190] Eurostat, 'Waste Statistics: Statistics Explained' (*Eurostat*, May 2017) <http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics> accessed 8 May 2018. Evidently, there are big differences between EU Member States total waste generation, and these differences result from population and economic size of a country and also from its mineral waste generation. Normally, the smallest Member States report the lowest levels of waste generation and the larger ones, the highest. Nevertheless, in 2014 relatively high quantities of waste were generated in Romania and Bulgaria and a relatively low quantity in Italy. See Table 1 for more details.

[191] See ibid. The EU's demographics shows a highly populated union of 28 Member States. On 1 January 2014, the population of the EU was around 506,973,8685, and on 1 January 2015 this number rose to 508,504,320. See Eurostat, 'Population Change - Demographic Balance and Crude Rates at National Level' (*Eurostat*, 7 April 2017) <http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_gind&lang=em> accessed 5 May 2017.

In 2014, the waste generated excluding major mineral waste[192] by the EU-28 was 891 million tonnes, and on average 1.8 tonnes per inhabitant.[193] Fortunately, the overall level of waste excluding major mineral waste fell 5.3% between 2004 and 2014, and the quantity per inhabitant fell by 8.0%, although the EU's population grew during this period.[194] This means that economic production in the UE is becoming less waste intensive.[195] Coherently, more recently, the EU's total resource use has declined.[196] In turn, consumption has contributed intensively to the production of municipal waste, and wealthier countries generated more waste.[197]

Municipal waste definitions vary from country to country, reflecting their diverse waste management practices.[198] There is, however, a standardised notion of *municipal waste*

[192] A lot of the waste from mining and quarrying and from construction and demolition is classified as major mineral wastes. In general, the Member States that have higher shares of mineral waste are those that have relatively sizeable mining and quarrying activities, such as Bulgaria, Sweden, Finland and Romania, and/or construction and demolition activities, which is the case of Luxembourg. In these Member States, major mineral waste accounted 85% or more of all waste generated, as was also the case in Liechtenstein and Serbia. See Eurostat, 'Waste Statistics...

[193] According to Eurostat, waste generated excluding major mineral waste is composed of the following economic sectors: agriculture forestry and fishing; mining and quarrying; manufacturing; energy; waste/water; construction; other sectors; and households. It does not cover mineral waste and soil, of which 90% originate from the mining and construction sectors. See ibid, Table 2.

[194] ibid. In 2014, the highest levels of the waste generated excluding major mineral waste were recorded for water and waste services, for households and for manufacturing activities (208, 204 and 184 million tonnes, respectively). Their development followed different patterns over time (2004-2014): waste generation by water and waste services increased by 87.7%; waste generated from construction grew at a rapid pace (57.3%); and waste generated by households remained quite stable. Waste generated by manufacturing activities fell by 32.2%. Likewise, the quantity of waste generated by mining and quarrying and by agriculture, forestry and fishing diminished considerably, by 24.1% and 68.7%, respectively, as did the quantity of waste generated by the remaining sectors. See ibid, Table 2.

[195] EEA, 'Waste Generation' (*EEA*, 9 December 2016) <www.eea.europa.eu/data-and-maps/indicators/waste-generation-1/assessment> accessed 5 May 2017. As a consequence, European greenhouse gas emissions have decreased by 19% since 1990, despite a 45% increase in economic output. Fossil fuel use declined too, as have the emissions of some pollutants from transport and industry, see EEA, *The European Environment - State and Outlook 2015: Synthesis Report*..., 12.

[196] The EU-28 domestic material consumption declined by 10% between 2000 and 2012, despite a 16% increase in economic output. Per capita numbers increased in 13 countries and decreased in 19 (a time series is available for 32 countries: EU-28 and Norway, Turkey, Serbia and Switzerland). Significant increases were primarily due to large-scale infrastructure investments. On the other hand, declines were related to the economic crisis and a subsequent collapse in construction activities. See EEA, 'The European Environment - State and Outlook 2015'..., 35, 169 and 215-6.

[197] In 2014, municipal waste generation per person was highest in Denmark and Switzerland and lowest in Romania, Poland and Serbia. Tourism contributed to high generation rates in Cyprus and Malta, see EEA, 'Municipal Waste Management Across European Countries' (*EEA*, 23 May 2017) <www.eea.europa.eu/themes /waste/municipal-waste/municipal-waste-management-across-european-countries> accessed 25 May 2017.

[198] EEA, *Managing Municipal Solid Waste: A Review of Achievements in 32 European Countries* (EEA, Copenhagen, 2013) 7. In fact, 'the more complex municipal waste management systems in use today with sorting steps, pre-treatment, imports and exports, seem to have led to uncertainties and differences in municipal waste reporting. These differences generally reduce the comparability of municipal waste data and also affect the interpretation of recycling rates', ibid 8.

for European Union purposes, which covers household waste and waste similar in nature and composition to household waste.[199]

The most recent data are from 2016, when the municipal waste represented about 10% of total EU-28 waste generated.[200] Between 2004 and 2012, total municipal waste generated in the European Economic Area (which includes EU countries and also Iceland, Liechtenstein and Norway) declined by 2%, despite a 7% increase in real household expenditure.[201] In the same period, per capita generation declined by 5%, falling from 503 to

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[199] This notion results from the combination of various provisions: of the Landfill Directive Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste [1999] OJ L182/1 (Landfill Directive); of the Waste Statistics Regulation; and of the OECD/Eurostat Joint Questionnaire on Waste, to be interpreted taking into consideration the European List of Waste (LoW) (Commission Decision 2014/955/EU of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and of the Council [2014] OJ L370/44). Taken altogether, it is possible to conclude that the definition of *municipal waste* comprises waste coming from households and even from commerce and trade, small businesses, office buildings and institutions (schools, hospitals, government buildings), and selected municipal services, just as waste from parks and gardens maintenance and waste from street cleaning services. This municipal waste can be collected in one of the following ways: a) by or on behalf of municipalities; b) directly by the private sector (business or private non-profit institutions) covering mainly separate collection for recovery purpose; and c) door-to-door through traditional collection (mixed household waste); or d) separately for recovery operations (through door-to-door collection and/or through voluntary deposits). Waste from rural areas that are not served by a regular waste service are comprehended in this definition too. In turn, waste from municipal sewage networks and municipal construction and demolition waste are excluded from this definition. Some examples of municipal waste are: paper and cardboard; textiles (clothes and carpets); plastics and plastic packaging; glass (clear or stained; flat glass, lamps or dishes); metals (ferrous and non-ferrous); organic materials from household (kitchen waste, food leftovers, garden waste, grass clippings, leaves; home composting is not considered); hazardous household waste (spent solvents, acids, alkalines, photochemicals, pesticides, used oils, paints, inks, adhesives and resins, WEEE, batteries and accumulators, detergents, hazardous medicines); edible oil and fat, rubber waste, ceramics; bulky waste (as white goods, old furniture, mattresses); residual waste (mixed waste from households and similar institutions with the exception of separately collected fractions); waste from municipal services (organic materials from municipality services; garden and park waste from municipalities, waste from maintenance of roadsides, if managed as waste; kitchen and canteen waste; waste from public bins and street sweepings; market cleansing waste; cemetery waste). Eurostat, 'Guidance on Municipal Waste Data Collection' (*Eurostat, Unit E2 - Environmental statistics and accounts; sustainable developmen*t, September 2016), 3, 10 and 12 <http://ec.europa.eu/eurostat/documents/342366/351811/Guidance+on+municipal+waste+reporting/0710f1a4-6b68-4d48-ac4c-75901bc0644b> accessed 7 May 2017.

[200] Eurostat, 'Municipal Waste Statistics: Statistics Explained' (*Eurostat*, July 2018) <http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics> accessed 2 July 2018.

[201] EEA, 'Waste Generation'... Expenditure on household consumption was distributed in the following way: housing, water, electricity, gas and other fuels - 24.4%; transport - 13.0%; food and non-alcoholic beverages - 12.3%; miscellaneous goods and services - 11.5%; recreation and culture - 8.5%; restaurants and hotels - 8.5%; furnishings, household equipment and routine household maintenance - 5.4%; clothing and footwear - 5.0%; alcoholic beverages, tobacco and narcotics - 4.0%; health - 3.9%; communications - 2.5%; and education - 1.1%. See Eurostat, 'Household Consumption by Purpose: Statistics Explained' (*Eurostat*, November 2016) <http://ec.europa.eu/eurostat/statistics-explained/index.php/Household_consumption_by_purpose> accessed 5 May 2017.

478 kg/capita.[202] Updated data on total municipal waste for the period between 2004 and 2014, shows a decline of 3% and a per capita decline of 7%.[203-204]

Regarding plastic, the available data concerns the total generation of post-consumer plastic waste in EU-27 (plus Norway and Switzerland) in 2008. It amounted to 24.9 million tonnes and its contributors were: packaging (63%); automotive (5%); electrical and electronic equipment (5%); building and construction (6%); agriculture (5%); house wares, leisure and sports (3%); and others (13%), including furniture and medical waste.

Due to its representativeness, we will start by analysing plastic packaging waste. In 2015, it represented just 19% of all the packaging waste generated[205] in EU-27 in 2015: 84.5 million tonnes – the highest volume registered since data began to be collected (in 2005).[206] From 2005 to 2015, albeit various fluctuations during the periods 2008-2009 and 2011-2012, plastic packaging waste increased 7.4%.[207]

With reference to plastic carrier bags, in 2010, 98.6 billion were placed on the EU market, weighting in total 1.61 metric tonnes – with an average weight per bag of 8.5g (single-use non-biodegradable), 8.9g (biodegradable) and 78.9g (multiple-use). Likewise, every EU

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[202] EEA, 'Waste: SOER 2015 Briefing' (*EEA*, 18 February 2015) <www.eea.europa.eu/soer-2015/europe/waste> accessed 5 May 2017. In 21 of these 31 countries, the amount of municipal waste generated per capita increased between 1995 and 2016. During this period, the highest average annual growth rates recorded belonged to Greece (2.4%), Malta (2.3%), Latvia (2.1%), and Denmark (1.9%). In 2016, the municipal waste generated in Denmark was 777kg per capita, the highest value of the year, while the minimum value was 261kg per capita in Romania. As Eurostat explains, these variations reflect differences in consumption patterns and economic wealth, but also depend on how municipal waste is collected and managed. There are even differences between countries regarding the degree to which waste from commerce, trade and administration is collected and managed together with waste from households. See Eurostat, 'Municipal Waste Statistics...

[203] These figures took into account 35 countries: EU-28, Iceland, Norway, Switzerland, Turkey, Republic of Macedonia, Bosnia and Herzegovina and Serbia, according to EEA, 'Municipal Waste Management...

[204] Detailed data on the composition of all individual municipal waste streams for each country of the EU-28 and the associated countries are rare. At least we know that non-metallic recyclables, such as paper, cardboard, wood, textile, shoes, glass and plastics, as well as animal and vegetal waste constitute the lion's share of municipal solid waste. See FhG-IBP, *Waste 2 Go: D 2.2 Waste Profiling* (*Waste 2 Go,* 2014), 3 and 23 <www.waste2go.eu/download/1/D2.2_ Waste%20profiling.pdf> accessed 5 May 2017.

[205] Eurostat explained that in contrast to other waste statistics, the term packaging waste generate' means not the amount of packaging collected, but all packaging placed on the market. See Eurostat, 'Packaging Waste Statistics: Statistics Explained' (*Eurostat*, April 2018) <http://ec.europa. eu/eurostat/statistics-explained/index.php/Packaging_waste_statistics> accessed 8 May 2018. According to Article 3(1) of the European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste [1994] OJ L365/10 (Packaging and Packaging Waste Directive), *packaging* consists only of sales or primary packaging, grouped or secondary packaging and transport or tertiary packaging.

[206] In 2015, paper and cardboard represented the largest part of packaging waste (41%), followed by plastic (19%), glass (19%), wood (16%) and metal (5%). Per inhabitant, in 2015, packaging waste totalled 167.3kg, a number significantly higher than the 160.8kg registered in 2005, and even than the 162.6kg marked in 2014. In 2015, this quantity varied between 51.2kg per inhabitant in Croatia and 222.2kg per inhabitant in Germany. See Eurostat, 'Packaging Waste Statistics...,

[207] Paper and cardboard increased 4.9% and 11.1%, respectively, and wood increased 3.5%. Glass and metal declined.

citizen used around 198 plastic carrier bags in 2010, and the vast majority of these bags (89%) were single-use.[208] Of these numbers, eight billion plastic carrier bags were littered and in 2020 it will rise to 8.6 billions.[209]

Other relevant but minor sources of plastic waste are building and construction sector, motor vehicles, and electrical and electronic equipment. Although the construction sector is the second largest consumer of plastics in Europe, it only accounts for 6% of plastic waste generated per year. The main reason for this is that plastics used in construction often have a significantly longer design life than plastics used for other purposes. They can last between 30 and 40 years before being disposed of.[210] In turn, the average service life of vehicles is around fourteen years, so the generation of automotive plastic waste increases at a slow rate. This is in fact good because the wide variety of polymer types used is one of the reasons why the proportion of recycled ELVs plastics is extremely low.[211] At last, electrical and electronic devices have on average a service life of three to twelve years, with larger objects having a longer service life. Usually, they are not collected in higher quantities, which, in addition to the brominated flame retardants from older appliances, hinders recycling.[212]

In conclusion, and considering everything that has already been said, we must stress the existence of social, economic and other external influences in the production of waste, especially municipal solid waste and packaging waste. Some facts and variables were ascertained by the Fraunhofer Institute for Building Physics, from Germany, and are the following. People older than 65 years tend to produce a lower total amount of MSW and less packaging waste, whereas people younger than sixteen years generate high amounts of nappies and plastic bottles. The health and social work sector generates large amounts of nappies and incontinence pads. Local conditions can influence MSW generation as observed

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[208] European Commission, 'Commission Staff Working Document - Impact Assessment for a Proposal for a Directive of the European Parliament and of the Council Amending Directive 94/62/EC on Packaging and Packaging Waste to Reduce the Consumption of Lightweight Plastic Carrier Bags' SWD/2013/0444 final, 11. It was estimated that there were about 250-300 producers of plastic carrier bags in the EU, with 15,000 to 20,000 employees, but we remember that 'a non-negligible part of these plastic carrier bags is imported from outside the EU. Around 30% of all plastic carrier bags and 70% of single-use plastic carrier bags on the EU market are imported, mainly from Asia; for the lightest single-use bags the share of imports would be even higher. In general, imports from outside the EU tend to be thinner single-use HDPE bags, while EU producers tend to specialise in higher-value, thicker LDPE bags due to specific machinery required. On the other hand, woven PP plastic bags (very thick) may be more competitively produced in Asia due to the low costs of the labour involved', see ibid 13.

[209] ibid 21.

[210] BIO Intelligence Service, *Plastic Waste in The Environment - Revised Final Report* (Paris, 2011) 69 <http://ec.europa.eu/environment/waste/studies/pdf/plastics.pdf> accessed 18 April 2017.

[211] ibid 70.

[212] ibid 69-70.

in areas with large tourist industries, where a significant amount of packaging and food waste is produced. In spring and summer months, a higher percentage of plastic bottles is observed as a result of increased liquid consumption owing to elevated temperatures and in winter months a lower percentage of nappies are disposed.[213] Last but not least, demographic changes, such as an increase in the number of one-person households, also affect the amount of waste generated, particularly packaging goods in smaller units.[214]

Municipal waste is definitely the 'product of social metabolism'[215] and there is no end in sight to how much waste society is going to produce and how much plastic is going to be consumed, which amplifies the concern about the uncertainties of the future.

C. Waste Management Syncretism

Waste is undesirable, inconvenient and troublesome. The further away the better. But where does it go? When people get rid of it, they are not aware of the system complexities, of the waste materials' intricate nature, nor of its resulting pollution. The following examples try to describe this complexity. Landfills require land availability, but siting them is often opposed by potential neighbouring residents, resulting in the NIMBY phenomenon.[216] Some of the larger waste fractions, such as organics and paper are relatively easy to manage. However, multi-laminates waste, hazardous waste (as syringes, batteries and radioactive waste) and e-waste pose excessively large problems. Waste incineration is expensive and poses challenges of air pollution and ash disposal.[217] In any case, deciding waste destination is always difficult.

Solid waste management – that comprehends collection, transport, recovery and disposal of waste, including also the supervision of such operations and the after-care of disposal sites – is almost always the responsibility of local governments and it is one of the most important services a city shall provide. It is often their single largest budget item,

[213] FhG-IBP, *Waste 2 Go...,* 26.
[214] EEA, *EEA Signals 2014: Well-being...,* 27.
[215] This expression, that is an adaption of household metabolism used by Klass Noorman, results from the application of the biological paradigm to the social process of production, consumption and elimination of residues. See Alexandra Aragão*, O Princípio do Nível...*, 85.
[216] NIMBY is the acronym for 'not in my back yard'. It describes the opposition that residents express to the siting of something perceived as unpleasant or hazardous in their own neighbourhood and that will necessarily provoke the neighbourhoods' social and economic devaluation.
[217] Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...,* 4.

particularly in low-income countries as well as in many middle-income countries, being also the largest source of employment in these cities.[218]

The amount of waste is crucial to reduce environmental impacts, but waste management also plays a key role. Managing municipal solid waste is an intensive service,[219] and it must comply with economic, social and environmental criteria. In truth, solid waste is one of the most pernicious local pollutants, that if not collected contributes to local flooding and to water and air pollution: methane from the organic waste stream contributes to greenhouse gas emissions. Poorly managed waste can also impact public health, because they provide breeding areas and food to bacteria, insects and rodents that are potentially vectors of disease.[220]

Ensuring waste management is a prerequisite for ensuring any other municipal service, and to do it efficiently, a strong social contract between the municipality and the community is required, as well as people's comprehension and cooperation. Nonetheless, each country and city has their own site-specific situations, and distinctive institutional, financial, social and environmental problems. These problems begin right at the initial stage of waste management – the collection.

In low-income countries,[221] collection is sporadic and inefficient. Service is limited to high visibility and wealthy areas, and to businesses willing to pay. A high fraction of inerts and compostables affect collection, which justifies the overall collection rate is below 50%. By contrast, in these countries, collection services make up the bulk of the municipality's solid waste management budget, reaching 80% to 90%. Consecutively, only a small proportion of the budget is allocated towards disposal, and waste – including medical waste

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[218] However, solid waste management, whether it is formal or informal, represents only 1% to 5% of all urban employment. See ibid 1.

[219] Municipalities need to develop capacities to conduct procurements, to manage contracts and professional and often unionised labour, and they need ongoing expertise in capital and operating budgeting and finance. As formalities increase so do issues of labour organisation, health and safety, ageing demographics (solid waste workers tend to be younger), the friction between sanctioned and unsanctioned recycling, and the apportion of costs and responsibilities. Local waste management officials also need to deal with the integrated and international aspects and legal measures imposed on solid waste. See ibid.

[220] Deaths from infectious diseases (diarrhoea and malaria), often related to poor water, sanitation and waste management, have declined as a result of a broader access to safe water and sanitation, alongside better access to immunisation, insecticide-treated mosquito nets and essential medicines. See WHO, 'An estimated 12.6 million deaths each year are attributable to unhealthy environments' (*WHO*, News Release, 15 March 2016) <www.who.int/mediacentre/news/releases/2016/deaths-attributable-to-unhealthy-environments/en/> accessed 17 July 2017.

[221] For the purpose of this section, and according to the World Bank estimates of 2008, low-income countries are those that have per capita gross national income of USD 975 or lower. See Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...,* 38-9.

– ends up being disposed in low budget and low technology sites, usually in open dumps. This causes high polluting of nearby aquifers, water bodies and communities. Naturally, local residents and workers might suffer significant health impacts.

In turn, recycling markets are unregulated and most of the times recycling takes place through the informal sector and waste picking (by 'middlemen'). This gives rise to large price fluctuations, which is as unsatisfactory as the fact that the fee collection system – regulated by local governments – is ineffective.[222] Nonetheless, recycling rates tend to be high both for local markets and for international markets and imports of materials for recycling, including hazardous goods such as e-waste and ship-breaking. Very often waste is burned, and not incinerated because of high technical and operation costs, high moisture content in the waste, and high percentage of inerts.

As for middle-income countries,[223] there is an improved and increasing collection service, especially in residential areas, that is promoted by a larger vehicle fleet and more mechanisation. Accordingly, transfer stations are being slowly incorporated into the solid waste management system. There are some controlled and sanitary landfills with some environmental controls, but open dumping is still common. Concerning recycling, markets are somewhat more regulated and there are some high technology sorting and processing facilities. For this reason, even though the informal sector still exists and material prices fluctuate considerably, the recycling rates are relatively high. Furthermore, incinerators are also used, but they face several operational difficulties since air pollution control equipment is not advanced or is often outdated and replacement costs are prohibitive.

The survey on costs revealed that waste collection represents 50% to 80% of the municipal solid waste management budget. Waste fees are regulated by some local and national governments and can be included in electricity or water bills. These profits support the expenditures on more mechanised collection fleets and disposal, that are higher than in low-income countries.[224]

[222] ibid 5 and 14.
[223] For the purpose of this section, and according to the World Bank estimates of 2008, lower-middle income countries are those that have per capita gross national income between USD 976 and USD 3,855, and the upper-middle countries are those that have per capita gross national income between USD 3,856 and USD 11,905. See ibid 38-9.
[224] ibid 5.

High-income countries,[225] where waste volume is a key consideration, have compactor trucks, highly mechanised vehicles and some transfer stations. Collection methods tend to be mechanised, efficient and frequent. There are sanitary landfills with a combination of liners, leak detection, leachate collection systems and gas collection. Open new landfills is often problematic due to concerns of neighbouring residents, but there are increasing options available to waste planners, so we will focus on recycling and incineration. Recyclable material collection services and high technology sorting and processing facilities are common and regulated. Although informal recycling (mostly dedicated to aluminium can collection) still exists, overall recycling rates are higher than in low and middle income countries. Incineration – which is more prevalent in areas with high land costs or low availability of land, such as islands – is subject to some form of environmental controls (as emissions monitoring) and is associated with energy recovery systems.

Collection costs can represent less than 10% of the budget, while large budget allocations serve to intermediate waste treatment facilities.[226]

Evidently, the degree and sophistication of waste picking influences the overall collection. The degree of separation at source impacts the total amount of material recycled and the quality of secondary materials that can be supplied. Alike, recyclables mixed with organic waste get contaminated, what reduces their recovery possibilities. However, source separation and separate collection, especially of household waste, add comprehensively costs to the waste collection process. It happens it is more expensive to collect per tonne as waste is more dispersed. Often, especially in developing economies, municipal solid waste is not separated or sorted before it is taken for disposal, but recyclables are removed by waste pickers prior to collection, during the collection process or at disposal sites.[227]

Bearing all this in mind, the amount of municipal solid waste collected varies widely by region and by income level, and even collection within cities can differ greatly. Collection rates – that are directly related to income levels – range from 41% in low-income countries

[225] For the purpose of this section, and according to the World Bank estimates of 2008, high-income countries are those that have per capita gross national income of USD 11,906 or higher. See ibid 38-9.
[226] ibid 5.
[227] The World Bank report added that: 'in cities like Buenos Aires, waste pickers tend to remove recyclables after the waste is placed curbside. The resulting scattered waste is costlier to collect: in some cases the value of recyclables are less than the extra costs associated with collecting the disturbed waste. In some cities informal waste pickers have strong links to the waste program and municipally sanctioned crews can be prevented from accessing the waste as informal waste pickers process the waste', see ibid 14-5.

to 98% in high-income countries.[228] In line with this trend, it is not surprising that regions with low-income countries tend to have low collection rates. South Asia and Africa have the lowest rates, with 65% and 46%, respectively, and OECD countries have the highest, estimated at 98%.[229]

Annex G of the World Bank report shows MSW collection data for cities that in 2001 had an urban population over 100,000. Only 10.6% of these cities had values equal or below 65% of MSW collection coverage[230] It is frankly a good result, but ensuring collection is not sufficient to prevent waste leakage into the ocean, as we will demonstrate afterwards.

Waste disposal data are the most difficult to gather. For start, many countries do not gather waste disposal data at a national level, which makes it hard to compare data across income levels and regions. Furthermore, even if data are available, disposal estimates and definitions used for each of the categories are often either not known or not consistent. Sometimes compostable and potentially recyclable material is removed before the waste reaches the disposal site, not being included in statistics.

For these motives, and also because data are from varied years and sources, worldwide figures on municipal solid waste disposal comprise only 87 countries and do not express accurate values. Fortunately, the data gathered made it possible to conclude the following: the amount of waste disposed on landfill is 340 million tonnes per year; the amount that is recycled is 135 million tonnes per year; the waste that generates energy (WTE) totals 120 million tonnes per year; dumped waste reaches 75 million tonnes per year;[231] waste composting sums up to 70 million tonnes per year; finally, any other disposal – not detailed in the report – represents 46 million tons per year.[232]

More interesting and revealing is analysing data per income level. Hence, in low-income countries waste destiny unfolded as follows: landfills - 59%; other - 26%; dumps -

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[228] ibid 13 and 15. The remaining data demonstrated a proportional link between income level and average waste collection rates: upper-middle income countries collect 85% of their waste and lower-middle income countries collect about 70%. See ibid 15.

[229] ibid. MENA (85%) comes in second place, followed by LAC (78%), ECA (78%) and EAPR (73%).

[230] ibid 63-70. Data concerning total urban population and waste collection are not all from the year 2001. Some cities shared information only a few years later. In Africa Region merely 3 of the 14 most populous cities have a collection waste rate over 65%. In fact, it is in Africa that most low-income countries are located. See Annex B of the World Bank report, ibid 38-9.

[231] Very briefly, a dump is an excavated piece of land used as storage for waste materials while a landfill is also an excavated piece of land for waste storage but it is subject to specific regulations. Dumps do not have leachate collection and treatment systems while landfills do. In addition, landfills are covered daily with soil to deter pests and prevent bad smells from being released into the air while dumps may be covered or not.

[232] See Fig. 11 in Daniel Hoornweg and Perinaz Bhada-Tata, *What a Waste...*, 22. Annex L presents MSW disposal methods data by country, see ibid 87ff.

13%; compost - 1%; incineration - 1%; and recycling - 0%. As for lower-middle income it was: dumps - 48.81% (this value is relatively high due to the inclusion of China); other - 32.54%; (poorly operated) landfills - 11.03%; recycling - 5.24%; compost - 2.17%; and incineration - 0.22%. Waste destiny in upper middle-income countries was: landfills - 59%; dumps - 33%; other - 6%; compost - 1%; recycling - 1%; and incineration - 0%.[233] Lastly, high-income countries registered the following values: landfills - 42.51%; recycling - 21.94%; incineration - 20.75%; compost - 11.22%; other - 3.57%; and dumps - 0.01%.[234] Concluding, whatever is the income level, landfills are the most constant option. In turn, open dumps are an option that is less and less used as income rises.

Per region analysis shows that two contrasting regions – OECD and Africa Region – whose populations are roughly equal in number, register a major difference on waste disposal. OECD produces about 100 times the waste of Africa Region, but Africa's collected waste is almost exclusively dumped or sent to landfills, while more than 60% of OECD's waste is diverted from landfill. In statistical terms, OECD registers no dumps, and: landfills - 42.22%; recycling - 21.82%; incineration - 20.94%; compost - 11.52%; and other - 3.49%. With regard to Africa Region the destiny of the waste is as follows: dumps - 43.81%; landfills - 49.52%; compost - 0.95%; recycling - 2.67%; incineration - 0.95%; and other - 2.10%.[235]

Meanwhile, regarding plastic, it was estimated that 8,300 million metric tons of virgin plastics have been produced between 1950 and 2015.[236] Of all these mass-produced plastics ever manufactured, 2,500 million metric tons – which represent 30% – are currently in use. The remaining 5,800 million metric tons of plastic became waste and were distributed as follows: 4,600 million metric tons were discarded; 500 million metric tons were recycled; and 700 million metric tons were incinerated. However, to determine more accurate and realistic numbers, one has to consider the cumulative waste generation of primary and of secondary (recycled) plastic waste, which totalled 6,300 million metric tons of plastic waste, distributed in the following way: 4,900 million metric tons discarded, accumulating in landfills or in the natural environment; 600 million metric tons recycled; and 800 million metric tons incinerated. So, 79% of the plastic waste ever accumulated was discarded, 9% was recycled (only 10% of which have been recycled more than once), and 12% was

[233] ibid 24.
[234] ibid 23.
[235] ibid 24. MSW disposal methods for cities over 100,000 can be seen in Annex H, ibid 71-7. For MSW disposal methods by country see Annex J, ibid 87-9.
[236] Roland Geyer, Jenna R Jambeck and Kara Lavender Law, 'Production, Use,... 1-5.

incinerated. Especially alarming is the fact that if current production and waste management trends continue, roughly 12,000 million metric tons of plastic waste will be in landfills or in the natural environment by 2050.

Before 1980, plastic recycling and incineration were negligible. Since then, only non-fibre plastics (HDPE, LDPE, linear low-density PE, PP, PS, PVC, PET and Polyurethane) have been subject to significant recycling efforts. Global recycling and incineration rates have slowly increased to account for 18% and 24%, respectively, of non-fibre plastic waste generated in 2014.[237] Moreover, and on the basis of limited information, the highest recycling rates in 2014 were in Europe (30%) and China (25%), whereas in the USA, plastic recycling has remained steady at 9% since 2012.[238] As for incineration, in Europe and China, rates have increased over time, reaching 40% and 30%, respectively, in 2014. However, in the USA, non-fibre plastics incineration peaked at 21% in 1995 before decreasing to 16% in 2014, while recycling rates increased, with discard rates remaining constant at 75% during that time period. To date, fibre products do not experience significant recycling rates and are thus incinerated or discarded together with other solid waste.

Plastic packaging waste was also studied regarding the year 2013. Of the 78 million tonnes produced, 40% were landfilled, 32% leaked, 14% incinerated, and 14% recycled (2% were effectively recycled; 8% were recycled into lower-value applications; and 4% were lost in process).[239]

Once again, we will focus specifically on European Union, that since the 1990s has been introducing multiple waste policies and targets. Instead of focusing disposal methods, they are now giving much importance to prevention, recycling and circular economy, as we will see more in-depth in Part II. Even though national waste definitions and data processing methodologies remain poorly standardised, collection is always guaranteed and landfill diverting registers a substantial progress – both in absolute terms and as a proportion of total

[237] See Figures S5 and S6 in Supplementary Materials for Roland Geyer, Jenna R Jambeck and Kara Lavender Law, 'Production, Use,...

[238] Scientists collected these data from National Bureau of Statics of China, 'Annual Data, China Statistical Yearbook, 1996-2016', available at <www.stats.gov.cn/ENGLISH/Statisticaldata/AnnualData/>, from EPA, 'Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Tables and Figures for 2012' (EPA, 2014) available at <www.epa.gov/sites/production/files/2015-09/documents/2012_msw_dat_tbls.pdf> and from Daniel Hoornweg, Perinaz Bhada-Tata and Chris Kennedy, 'Waste production,...

[239] World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy...,* 12-3.

waste generated –, as a result of reduced generation of some wastes and increased recycling and energy recovery (waste incineration).[240]

In 2014, the year of the most recent EU data available, about 2,320 million tonnes of waste[241] were treated in the EU-28 as follows: 48.9% were disposed – 47.4% were landfilled and 1.5% were incinerated without energy recovery; and 51.1% were recovered – 36.2% were sent to recycling, 10.2% were backfilled (which means the use of waste in excavated areas for the purpose of slope reclamation or safety or for engineering purposes in landscaping), and the remaining 4.7% were sent for incineration with energy recovery.[242] These results represent an evolution in relation to 2004 figures: 54.6% were disposed; and 45.4% were recovered. The quantity of waste subject to disposal in 2014 was 1.7% lower than it had been in 2004, and the recovered one grew by 23.4% from 960 million tonnes in 2004 to 1,185 million tonnes in 2014.[243]

These good results are due to the application of many measures over the years. As was to be expected, the same positive trends were observed regarding EU municipal waste. Between 1995 and 2016, the total municipal waste landfilled in the EU-28 fell by 85 million tonnes, or 59%, from 145 million tonnes (302kg per capita) in 1995 to 60 million tonnes (118kg per capita) in 2016, which corresponds to an average annual decline of 4.1% – this decline has been accentuated during the shorter period 2005-2016, by as much as 5.4% per year on average. As a result, the landfilling rate compared with municipal waste generation, in the EU-28 dropped from 64% in 1995 to 24% in 2016.[244]

A more comprehensive study demonstrated that the rates of landfilling have decreased in 27 out of 31 countries during the period 2004-2012. The largest decreases occurred in Poland (35 percentage points), the United Kingdom (33 percentage points), and Estonia (28 percentage points).[245] Whereas Lithuania, Cyprus, Romania, Greece, Malta,

[240] EEA, 'Waste: SOER 2015 Briefing'...
[241] Eurostat, 'Waste Statistics... We note that this number includes the treatment of waste imported into the EU, and therefore the reported amounts are not directly comparable with those on waste generation.
[242] Significant differences can be observed among the EU Member States concerning the use they make of these various treatment methods. Italy is the country that recycled more waste in 2014 – 76.9% of the 129.2 million tonnes of waste –, followed by Belgium – 73.9% of 42.8 million tonnes. Belgium registered the smaller percentage of waste landfilled – just 8.2% – followed by Slovenia – 9.2% of 5.4 million tonnes. That same year, Portugal treated 9.9 million tonnes of waste: 55% were recycled; 31.8% were sent to landfill; 10% were incinerated; and 3.1% were recovered for energy production. In turn, Bulgaria, Romania, Greece, Sweden and Finland favoured landfill. See ibid.
[243] ibid.
[244] Eurostat, 'Municipal Waste Statistics...
[245] EEA, 'Waste - Municipal Solid Waste Generation and Management' (*EEA*, 8 February 2015) <www.eea.europa.eu/soer-2015/countries-comparison/waste> accessed 25 May 2017.

Croatia, Turkey and Latvia landfilled more than three quarters of their municipal waste.[246] In general, countries with landfill restrictions of recyclable and recoverable waste, achieve on average higher recycling rates of plastic post-consumer waste. In 2016, these countries were Switzerland, Austria, Germany, Netherlands, Sweden, Denmark, Luxembourg, Belgium, Norway and Finland.[247]

In EU-28, the amount of waste recycled rose from 25 million tonnes (52kg per capita) in 1995 to 72 million tonnes (141kg per capita) in 2016, at an average annual rate of 5.2%. The share of municipal waste recycled overall rose from 11% to 29%.[248]

Taking into consideration EEA countries, they achieved a recycling rate of 37% in 2012, compared to 28% in 2004,[249] but there were large differences in performances amongst the countries: Germany, Austria, Belgium and Switzerland recycled more than half of their municipal waste in 2012; albeit the highest increase in recycling rates between 2004 and 2012 occurred in Iceland, UK, Italy, Slovenia, Lithuania, Cyprus and the Czech Republic (18 to 25 percentage points). In six countries the share of recycled municipal waste barely changed (Austria, Finland, Serbia, the Former Yugoslav Republic of Macedonia, Montenegro and Switzerland), and to worsen the situation, recycling rates decreased in three countries: Malta, Turkey and Spain. Overall, in fourteen out of thirty-five countries, the increase in recycling rates exceeded ten percentage points over this period.[250]

Recycling and composting (which grew with an average annual rate of 5.1% from 1995 to 2016) together accounted for 45% in 2016 relative to waste generation. Waste incineration has also grown steadily during the same period, even though not as much as recycling and composting: since 1995, the amount of municipal waste incinerated in the EU-28 has risen by 34 million tonnes and accounted for 68 million tonnes in 2016.[251]

Specifically regarding plastic waste, in 2016, 27.1 million tonnes of plastic post-consumer waste were collected through official schemes in the EU-28 (plus Switzerland and Norway) in order to be treated. Of that quantity, 31.1% were recycled (63% inside the EU and 37% outside the EU), 41.6% were recovered for energy production and 27.3% were sent

[246] ibid.
[247] PlasticsEurope, 'Plastics - the Facts 2017..., 33.
[248] Eurostat, 'Municipal Waste Statistics...
[249] EEA, 'Waste: SOER 2015 Briefing'...
[250] EEA, 'Waste - Municipal Solid...
[251] Eurostat, 'Municipal Waste Statistics...

to landfills.[252] For the first time, more plastic waste was recycled than landfilled. Over time, focusing the period 2006-2016, plastic waste treatment evolved in the following way: recycling rose from 4.7 to 8.4 million tonnes (which means 79%); energy recovery rose from 7 to 11.3 million tonnes (that is to say 61%); and landfill decreased from 12.9 to 7.4 million tonnes (meaning -43%).[253]

Due to its relevance, plastic packaging waste statistics must be analysed as well. From 2006 to 2016, total plastic packaging waste collected increased 12% (from 14.9 to 16.7 million tonnes), recycling increased by 74% (from 3.9 to 6.8 million tonnes), energy recovery increased 71% (from 3.8 to 6.5 million tonnes) and landfill decreased by 53% (from 7.2 to 3.4 million tonnes). In particular, figures from 2016 were: 16.7 million tonnes collected; 40.9% of which were recycled; 38.8% were recovered for energy production; and 20.3% were sent to landfill.[254]

Considering all the evidence presented above, there is no doubt that waste management is slightly improving worldwide, especially in the EU, but it is clearly not sufficient to keep plastic waste away from our oceans. Moreover, the syncretism of cultures, politics and economies highly influence the progress and the harmonisation of waste management, which causes the countries to move at different speeds in the search for solutions.

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[252] PlasticsEurope, 'Plastics - the Facts 2017..., 30.
[253] ibid 31.
[254] ibid 34-5. A graphic of plastic packaging recycling rates by country can be consulted ibid 37: in 2016, Czech Republic, Germany, Netherlands, Sweden, Ireland and Spain recycled more than 45% of all their plastic packaging waste, and Portugal recycled approximately 42%.
Data on the major types of packaging waste can be found in Eurostat, 'Packaging Waste Statistics..., but we highlight here the most relevant of EU-27. In 2015, the recycling rate of packaging waste (by kg/inhabitant) went up from 56.9% in 2006 to 65.8%, and the recovery rate (including incineration at waste incineration plants with energy recovery) rose from 68.9% in 2006 to 79.0%. In the same year, Belgium was at the top, recycling almost 82% of all its packaging waste. It was followed by Czech Republic and Denmark (around 75% each). In turn, Portugal recycled nearly 57% of all its packaging waste. Per inhabitant, the volume of all packaging waste generated showed fluctuations and only a slightly increase, but both recycling and recovery volumes in 2015 were significantly higher than in 2006. In 2015, almost half of the Member States showed amounts of packaging waste generated per inhabitant of more than 150kg. Bulgaria and Croatia exhibited EU's lowest amounts of generated and recycled packaging waste, showing generation per inhabitant of 54.7kg and 51.2kg, respectively. Germany (222.2kg/inhabitant), Luxembourg (211.9kg/inhabitant) and Ireland (209.1kg/inhabitant) report the highest amounts of packaging waste generated. Germany, Ireland and Italy reported the highest amounts of packaging material recycled (154.1kg/inhabitant; 141.2kg/inhabitant; 135.4kg/inhabitant respectively).

D. Waste Collection Mishaps

Waste management is a long and complex process and its efficiency and sufficiency depends on organised procedures, solid infrastructures and appropriate budgets. However, many low-income and middle-income countries, with emphasis on East and South Asia, cannot provide these conditions. A study published in *Science* magazine in February 2015 proved this, and furthermore, it presented for the first time the quantity of plastic entering the oceans from waste generate on land.[255]

By linking worldwide data on solid waste, population density and economic status, a group of scientists and engineers designed a framework to calculate the amount of mismanaged plastic waste generated in 2010.[256] In total, 192 coastal countries with at least 100 permanent residents that border the Atlantic, Pacific, and Indian oceans and the Mediterranean and Black seas were analysed. They estimated that 6.4 billion people living in these areas (correspondent to 93% of the global population) generated 2.5 billion metric tonnes of municipal solid waste in 2010. In the same year, roughly 11% of the total amount of waste, 275 million metric tonnes, was plastic. Scaling by the population living within 50km of the coast, the investigators estimated that 99.5 million metric tonnes of plastic waste were generated in coastal regions in 2010. Of this, 31.9 million metric tonnes were classified as mismanaged and an estimated 4.8 to 12.7 million metric tonnes (on average, eight million metric tonnes) entered the ocean, being equivalent to 1.7% to 4.6% of the total plastic waste generated in those countries.[257]

In addition, the framework developed allowed the identification of the largest sources of mismanaged plastic waste. Figures revealed that the amount of mismanaged plastic waste generated by the coastal population of a single country could actually range from 1.1 metric

[255] Jenna R Jambeck and others, 'Plastic Waste Inputs from Land into the Ocean' (2015) 347(6223) Science 768. We note that the estimates presented in this study 'result from the relatively few measurements of waste generation, characterization, collection, and disposal, especially outside of urban centres. Even where data were available, methodologies were not always consistent, and some activities were not accounted for, such as illegal dumping (even in high-income countries) and ad hoc recycling or other informal waste collection (especially in low-income countries)'. In addition, the authors did not address international import and export of waste once it would affect national estimates (but not global totals). See ibid 770.

[256] The referred framework, that focused on waste generated on land, considered: the mass of waste generated per capita annually; the percentage of waste that was plastic; and the percentage of plastic waste that was mismanaged and, therefore, had the potential to enter the ocean as marine debris. For the purpose of this report, *mismanaged waste* was defined as 'material that is either littered or inadequately disposed', being *inadequately disposed* the waste that is not formally managed, including disposal in dumps or open, uncontrolled landfills, where it is not fully contained. See ibid 768-9.

[257] ibid 770.

tonnes to 8.8 million metric tonnes per year, with the top twenty countries' mismanaged plastic waste representing 83% of the total mismanaged plastic waste in 2010. In decreasing order, the top twenty countries ranked by mass of mismanaged plastic waste (in units of millions of metric tons per year) were: China, Indonesia, Philippines, Vietnam, Sri Lanka, Thailand, Egypt, Malaysia, Nigeria, Bangladesh, South Africa, India, Algeria, Turkey, Pakistan, Brazil, Burma, Morocco, North Korea and USA.[258-259] Sixteen of these twenty producers are middle-income countries, countries with an accentuated economic growth but lacking of waste management infrastructures.[260] On top of that, a few of these countries have some of the largest coastal population. As a result, in all these countries, in 2010 the average mismanaged waste fraction was 68%, and only two of them – Brazil and the USA – registered mismanaged fractions lower than 15%.[261]

The most important conclusion of this study was that in 2010, over half of land-based plastic waste leakage came effectively from just five countries: China, Indonesia, the Philippines, Vietnam and Sri Lanka. These five focus countries have all succeeded at achieving significant economic growth in recent years, and as a consequence, consumers' demands are growing much faster than local waste management infrastructures. Furthermore, we have to mention that their disposable products are not like the ones that exist in Europe or in the USA. The working class Asians can now afford cheap goods such as cigarettes, sodas, instant noodles, razors, soap, shampoos and many other stuff. The problem is that corporations produce these items it tiny and cheap quantities so that everyone, even the most destitute labourers, can afford them. For example, in isolated Philippine villages, people do not buy a bottle of shampoo. Instead, they buy mini plastic pouches of shampoo for five cents, and that is much more likely to end up in the ocean than a bottle and much more disinteresting

[258] Even though the USA has a highly developed garbage collection system, it made the top twenty for two reasons: it has a large and dense coastal population and, as a wealthy nation, there is a large consumption of products.
[259] The eighteenth place could be occupied by the coastal European Union countries, 23 in total, if all these countries were considered collectively. See ibid 769.
[260] These countries classification was based on income levels according to World Bank estimates of 2010 gross national income per capita. Besides the middle income countries, there were Bangladesh, Burma and North Korea, low-income countries and USA, high-income. See ibid.
[261] Anyhow, in these two countries, even a relatively low mismanaged rate can result in a large mass of mismanaged plastic waste because of large coastal populations (74.7 millions and 112.9 millions, respectively) and because of high per capita waste generation, especially in the USA (1.03kg and 2.58kg, respectively). See ibid 769.

to collect or recover in a dump. Companies are in fact churning out a lot more plastic packaging in poor Asian nations with no means or facilities to manage it properly.[262]

Shortly after this study, the Ocean Conservancy published a report highlighting viable improvement opportunities to significantly reduce and ultimately stop plastic-waste leakage. Naturally, this report focused on the five countries that together accounted for 55% to 60% of the total plastic waste leakage.[263] There is, though, a difference in the list of the five focus countries. The report considered China, Indonesia, the Philippines, Thailand, and Vietnam, because the methodology they adopted suggested that Sri Lanka contributed with a lower quantity of ocean plastic than that originally reported.[264]

Based on the five focus countries, it was acknowledged that the two main drivers of plastic leakage were the waste that remained uncollected and the low residual value of some plastic waste.[265] Effectively uncollected plastic waste represented 75%, while the remaining 25% leaked from within the waste management system itself.[266] This means that even when waste collection is assured, it does not mean that waste will not end at our oceans and seas. As a matter of fact, during the last century, people mistakenly assumed that the ocean had an unlimited capacity for waste dispersal and that it could serve as the planet's ultimate sink. Naturally, uncollected waste gives origin to open dumps, illegal dumping and ocean leakage of any type of waste. Large amounts of waste are abandoned in public places, where they await decomposition, burning or use as animal feed. Unsurprisingly, a lot of waste, including plastic, is deposited on purpose into and around rivers and other water bodies, that present direct pathways into the marine ecosystem, expecting to be swept up by the wind and cast into the ocean. On average, roughly a tenth of waste deposited in or near waterways is plastic.[267] In turn, post-collection leakage can happen during the waste transport, or caused by improper dumping, as well as formal and informal dump sites that are inadequately located or lack proper controls. In addition, as collection systems aggregate large quantities of waste,

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[262] Patrick Winn, '5 Countries Dump More Plastic (more 60%) into the Oceans Than the Rest of the World combined' (*GlobalPost*, 13 January 2016) <www.pri.org/stories/2016-01-13/5-countries-dump-more-plastic-oceans-rest-world-combined> accessed 2 May 2017.
[263] Ocean Conservancy, 'Stemming the Tide..., 6.
[264] ibid 44-5.
[265] ibid 7.
[266] ibid.
[267] ibid 14.

even a few points of post-collection leakage end up representing substantial amounts of plastic waste escaping into the ocean and other waterways.[268]

In all five focus countries, collected and uncollected plastic waste can enter the ocean from the following four physical locations: low-waste-density rural areas; medium-waste-density urban areas; high-waste-density urban areas; and dump sites on waterways.

In the five focus countries, low-waste-density rural areas do not have collection services, which is mostly accurate in rural areas of China and the Philippines, where collection rates are frequently lower than 10% in individual districts. In turn, collection rates are close to zero in Indonesia.[269] Uncollected waste from these sources contributes between 1.7 million and 2.1 million metric tons of plastic to the ocean per year.[270]

In medium-waste-density urban areas lacks proper waste management infrastructures. When rapid urbanisation in emerging markets is not accompanied by development of sufficient waste management infrastructure, it creates a huge gap in coverage. Uncollected waste from medium density urban areas in the five focus countries adds between 1.9 million and 2.4 million tonnes of plastic to the ocean per year.[271]

With regard to high-waste-density urban areas, it is worth note that their services are overstretched and that waste management costs discourage citizens to use them, increasing thus illegal dumping. Megacities and highly urbanised provinces have high levels of population density as well as high levels of waste density, which definitely overburden the existing and sometimes precarious waste management systems. Accordingly, many of these systems offer infrequent pickup and limited routes. Analysis suggests that uncollected waste from these specific urban areas adds between 1.6 million and 1.9 million metric tons of plastic to the ocean per year.[272]

Finally, dump sites on waterways allow manifestly the entry of plastic in the ocean, being the better example a large open dump site in Dagupan, Philippines, located very close to the coast. Collection systems in the focus countries still make heavy use of informal or open dump sites – receiving large piles of waste – that have little or no infrastructure in place to control ocean leakage or any other adverse effects that come from the presence of waste. Some dumps are intentionally located near waterways because land adjacent to rivers tends

[268] ibid.
[269] ibid 19.
[270] ibid 16.
[271] ibid.
[272] ibid 17.

to be cheaper than in other parts of the country.[273] Waste deposited at such sites in the five focus countries adds between 1.1 million and 1.3 million metric tons of plastic to the ocean per year.[274]

Plastic waste can even enter the ocean if trash haulers practice illegal dumping. It occurs when waste transport systems are poorly regulated and there is little or none incentive to follow the laws. To save time, reduce fuel expenses and avoid paying tipping fees at landfills, some trash haulers willingly resort to illegal dumping. Local rivers and tributaries are frequently used as sites for illegal dumping, and in the five focus countries, it adds between 700,000 to 900,000 metric tons of plastic to the ocean per year.[275]

With regard to plastic waste value,[276] it is worth noting that it not only prejudices collection, but it also influences leakage itself. Only 40% of plastic waste is collected in the five focus countries. The rest is not collected and therefore never aggregated. The problem is that in these five focus countries, more than 85% of plastic waste extraction for recycling takes place at points of aggregation, rather than within individual households. Since the average material value of plastic waste is often not high enough it is not possible to support the collection and transportation costs associated with either a mechanical or a manual process of aggregating just the plastic waste. Places that do not have publicly funded waste collection are even less likely to have plastic waste collected.

Regardless of where the waste lays, waste pickers, which are often part of vulnerable communities,[277] tend to focus their efforts on high-value plastic. As a consequence, plastic waste of low (films and composites) and medium-value (PS - disposable plates and cutlery, CD/Video cases and styrofoam products; and LDPE - frozen food bags, six pack rings, dry cleanings bags and molded laboratory equipment) are more likely to leak than high-value plastics (PET - water boltless, jelly jars and prepared food trays ; and HDPE - juice bottles, yogurt and butter tubs and shampoo/detergent bottles).[278] To worsen the situation, 80% of

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[273] ibid 27.
[274] ibid 17.
[275] ibid.
[276] For the purpose of this report, value stands for ‘a quantitative function of price at secondary dealers and time taken to collect, combined with a qualitative function of homogeneity and likelihood of rejection by secondary dealers’. See ibid 7.
[277] In truth, this secondary dealers, that collect materials from waste and sell them to recyclers, face many health risks since they operate in extremely hazardous conditions. They work surrounded by waste that can spontaneously combusts in case of extreme heat, and they are highly exposed to the toxicity of ferrous leachate and to disease agents, being even under a constant threat of junk slides at dump sites. See ibid 20.
[278] Waste pickers’ earnings were presented in the report. Interviews with waste pickers and junk-shop managers were combined with direct estimates of the amount of time taken to extract individual items of waste from a standard

plastic waste has low residual value.[279] Waste pickers are relatively efficient at extracting high-residual-value plastic materials and in some cases (for example, in the Philippines), extraction rates for PET bottles reach 90%. In contrast, the low-residual-value plastics, that represent 61% of the plastic waste leakage, is neglected, and so collection rates are close to zero.[280]

In order to discover the sources and pathways of leakage – as well as the benefits (in economic and leakage-reduction terms) of different solutions and the foundations for an implementation plan to address the challenge of controlling leakage – some work field was done in China and the Philippines.[281]

China tops the list when it comes to mismanaged plastic waste, being exclusively responsible for 28% of global plastic waste leakage. According to the report, this is one of the reasons why China was chosen for this study, and the other one is that China has the potential to be a major driver of global solutions in a near future. In fact, China is the most populated country in the world, it has experienced rapid economic and social development over the last twenty years and it is home to the world's largest plastic recycling industry.[282]

In turn, Philippines was chosen because it had not only one of the highest collection rates in the region (excluding Hong Kong, Singapore, Taiwan or South Korea), but also the most innovative approach to waste management and treatment in that region. These two factors combined were taken in consideration as a hypothesised linchpin around which could be built a solution set.[283] Nevertheless, ocean leakage is very high, as will elucidate below.

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waste pool. Therefore, the time needed to collect 1kg of waste was the following: plastic bags - 61 minutes; PP - 37 minutes; PET - 37 minutes; and HDPE - 21 minutes. The price paid per kilogram was, respectively: USD 0.05; USD 0.12; USD 0.23; and USD 0.16. Considering the average amount of time taken to extract the items from the waste piles, the study concluded that over a ten-hour collection day, focused exclusively on plastic bags, a waste picker might earn as little as USD 0.50. If the waste picker focus on PET bottles, the earnings can be seven times higher, reaching USD 3.70. HDPE products registered collection rates lower than expected, mainly because they are less homogeneous, more difficult to recognise, or less likely to be high-purity polymers (which means free of material contamination). See ibid 15-6.

[279] ibid 14.

[280] ibid 7 and 14-5. In turn, medium-residual-value plastic materials represent 21% and the high-residual-value plastic materials represent 18%.

[281] In addition to field visits in China and Philippines, the work group consulted more than 100 experts from more than 50 organisations. They concluded that in many cases, public data were either unavailable or of insufficient quality. Therefore, they had to make assumptions, using case studies and experts' inputs. For this reason, the key outputs should be considered as indicative rather than precise metrics. Despite everything, the team expected that the report can offer a number of new-to-the-world insights that can underpin future debate around and understanding of plastic waste leakage, besides mobilising a diverse set of stakeholders to start down an accelerated path to a substantive reduction in plastic waste leakage. See ibid 12.

[282] ibid 18.

[283] ibid 12, 18 and 46.

The first conclusion that can be drawn from this study is that the scale and density of waste generation – that differ by an order of magnitude in China and in the Philippines – play a major role in the economics of collection. China produces 48.1 million metric tons of plastic waste per year (five million tonnes leak into the ocean), and the Philippines produces 2.7 million metric tons per year (and half a million-ton leak). While waste is spread over a much greater geographic area in China, resulting in a much lower density of waste – 200 metric tons/km^2 per year in Shanghai, and less than 30 metric tons/km^2 in the province of Guangdong and other rural regions –, in Metro Manila in the Philippines, where roughly 560,000 metric tons of plastic waste are generated each year within an area of 620km^2, the plastic waste density is 900 metric tons/km^2. Logically, lower plastic waste densities mean higher costs of collection, which implies as well less frequent waste collection.[284]

Following the same reasoning, it was concluded that collection rates differ, not just between countries but also between urban and rural areas. As said before, the Philippines registers remarkably high collection rates. At the national level, the average is about 85%, reaching close the 90% in some dense urban areas, such as Metro Manila. Rates are 80% or lower in less dense areas. In consonance, even some very rural areas have collection rates above 40%. These elevated rates of collection are probably due to the extensive involvement of local communities in waste collection services, validated by the Ecological Solid Waste Management Act of 2000 (Republic Act 9003) formally delegating many waste management services to these groups. On the contrary, China's overall collection rates are much lower. Urban areas can collect about 65% of waste, but rural collection rates are generally under 5%, which explains and enhances rural deeply ingrained practices of burning and river dumping. The nationwide average is thus significantly pulled down, resulting in just under 40% of the approximately 440 million metric tons of waste generated each year.[285]

The amount of waste that enters each country is also important for collection purposes. Imported end-of-life plastic contributed, during many years, to the waste stream in China but it was not a significant contributor in the Philippines. As a matter a fact, until 2018, China used to take 45% of the world's plastic waste imports, corresponding to nine million metric tons a year.[286] In China, the bulk of the imported plastic ended up in just six of China's

[284] ibid 12 and 18.
[285] ibid 19.
[286] ibid 12 and 20-1. Citing local environmental concerns, China stopped receiving imported plastic waste, since January 2018. Historically, the bulk of China's plastic waste imports came from the USA and Europe, but lately China become also an attractive market for plastic waste exports from countries in its own region, including the

31 provinces: Zhejiang, Guangdong, Jiangsu, Shandong, Fujian, and Hebei. Although the figures presented in the report do not include residual waste from imported plastic – which amounted to one million to 1.5 million metric tons per year –, estimates of recycling yields suggested that as much as 20% of imported plastic could enter the waste stream, accounting for roughly 4% of total plastic waste in China.[287]

Naturally, each country has different leakage points. Open dump sites proximity to waterways has evident implications on the leakage rate of waste that exits the system through illegal dumping. Although little over half of open dump sites are located within about a kilometre of a waterway, ocean leakage depends a lot on the geomorphological characteristics of the country. For instance, the Philippines is surrounded by water and has an extensive network of rivers and tributaries, which means that there is a high likelihood that mismanaged waste will enter the waterways. That is why 74% of plastic leakage comes from waste that was in fact collected.[288] Unsurprisingly, China's rate is much lower, just 16%.[289] It all makes sense because just less than 60% of China's population lives near a significant waterway and because only about 20% of dump sites are located near waterways.

The research allowed to conclude that albeit waste management systems are not yet an airtight way to prevent plastic waste leakage, simply collecting waste into a management system significantly reduces its chances of leaking into the ocean. Making assumptions about waste leakage rates based on geographic proximity between provinces, rivers and the coast, it is estimated that in the five focus countries, for every tonne of uncollected waste near waterways, almost 18kg of plastic enter the ocean, which is equivalent to the weight of more than 1,500 PET bottles. Otherwise, making assumptions about waste leakage rates based on

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Philippines. Before the 2018 ban, the importation of plastic waste into China has already declined as a result of the Green Fence, a government policy intended to curb the import of low-residual-value plastic waste that was rejected by recyclers and that burdened the local waste stream.

[287] ibid 20-1.

[288] The most updated statistics in the Philippines, made available by the National Solid Waste Management Commission of the Philippines, revealed the following facts: plastic waste totals 2.7 million tons; the amount collected is 2.27 million tons (84%), while the amount not collected is 432,000 tons (16%); from the collected waste, 17% (386,000 tons) leaks into the ocean; from the uncollected waste, 31% (135,000 tons) leaks into the ocean; therefore, from the total amount of leaked waste, 521,000 tons, 74% correspond to collected waste and the remaining 26% correspond to the uncollected waste. See ibid 21.

[289] The most updated statistics in China, made available by China Statistical Yearbook from 2014, revealed the following facts: plastic waste totals 48.1 million tons; the amount collected is 18.8 million tons (40%), while the amount not collected is 29.3 million tons (60%); from the collected waste, only 4% (0.8 million tons) leaks into the ocean; from the uncollected waste, 14% (4.2 million tons) leaks into the ocean; therefore, from the total amount of leaked waste, 5 million tons, 16% correspond to collected waste and the remaining 84% correspond to the uncollected waste. See ibid 22.

the geographic proximity of disposal sites to waterways, as well as comparing the quantities of waste received at those disposal sites with the quantities estimated to have entered the collection system, it was calculated that in the focus countries, for every metric tonne of plastic waste that is collected, 7kg of plastic waste is leaked to the ocean between collection and disposal, which is less than half the amount leaked from uncollected waste.[290]

Taking into account all the information gathered so far, there are no doubts that ill-designed and ill-operated waste-management systems contribute substantially to marine plastic waste, particularly in the developing world. An effective system of collection needs thus to be developed and/or maintained and at the same time used by all citizens.

Since population is growing and so are the plastic waste generation rates, the challenge ahead will only get bigger. In addition, the consequences of plastic pollution will grow worse each day, which creates the need to get to know and understand them. But before we will present the marine plastic pollution problem.

[290] ibid 14.

IV. Marine Plastic Pollution

A. A Timeless Threat

Oceans and seas cover about 71% of the Earth's surface. They play a crucial role in controlling Earth's climate, and they also provide humanity with a wealth of benefits comprising food, livelihoods and cultural and commercial uses. Therefore, maintaining marine environment's health and balance, including its biodiversity, is vital to mankind's survival.

However, for several decades, oceans and seas have been threatened by overfishing, unsustainable fishing methods, discharges of sewage, garbage, animal waste and fertilisers, tourism, recreation practices, and urban settlements in coastal areas. Predictably, these human interventions lead to the following impacts: habitat loss and degradation, species overexploitation, pollution, invasive species and disease and climate change.[291] These impacts affect naturally marine environmental systems, but also all the other ones, because they all interact with each other. Since the sea is in fact a unique and global interconnected mass of water that covers and encircles most of the Planet Earth,[292] it can be a mean of transportation of harmful agents.

Of the threats mentioned, the newest, the most pervasive and the fastest growing menace to the future of the oceans is plastic pollution and its leakage into the ocean. These days, the marine environment is being threatened by an unprecedented type of pollution.[293]

We note that not all residues constitute a form of pollution, but plastic waste surely does.[294] As Marcus Eriksen noted, 'once plastic is lost to the environment, it becomes

[291] The way these impacts affect marine fauna (specific species) and flora are described in more detail in WWF, *Living Planet Report 2016: Risk...,* 39. For further references see also José G B Derraik, 'The Pollution of the Marine Environment by Plastic Debris: A Review' (2002) 44 MPB 842.
[292] This mass is geographically divided into distinct named regions: the Atlantic Ocean, the Pacific Ocean, the Indian Ocean, the Arctic Ocean and the Antarctic Ocean.
[293] Surfrider Foundation Europe, 'Monitoring Marine Litter Across Europe 2015' (*Surfrider Foundation Europe*, 2015), 7 <www.surfrider.eu/wp-content/uploads/2016/04/rapport_ospar_2015-hd.pdf> accessed 24 November 2016.
[294] Alexandra Aragão*, O Princípio do Nível...*, 85.

pollution, not the politically loaded terms "debris" or "litter"'.[295] And by *pollution* we must understand, at least: 'the presence in or introduction into the environment of a substance which has harmful or poisonous effects'.[296]

Even though plastic represents just 10% of the municipal solid waste produced worldwide, plastic constitutes 60% to 80% of all marine debris, being the dominant type of anthropogenic material found in the sea.[297] A study published in 2015 disclosed for the first time that, each year, eight million tonnes of plastic waste enters the oceans from land.[298] The same study predicted that by 2025, if no waste management infrastructure is improved, the cumulative quantity of plastic waste available to enter the ocean from land will increase by an order of magnitude.[299] In practical terms, it means that by 2025 the ocean could contain one tonne of plastic for every three tonnes of finfish.[300] To make these figures comprehensible, Jenna Jambeck, the environmental engineer from the University of Georgia that led the study, likened it to lining up five – or ten, by 2025 – grocery bags of trash on every foot of coastline around the globe.[301]

The scale of this phenomenon is in fact astounding. Plastic debris is the most common feature on the surface of the ocean, occupying about a fourth of the planet's surface.[302] It should be noted though, as we will see later, that 'historical time series of surface plastic concentration in fixed ocean regions show no significant increasing trend since the 1980s,

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[295] Marcus Eriksen, 'The Plastisphere - The Making of a Plasticized World' (2014) 27(2) Tulane Environmental Law Journal 154.
[296] 'pollution, n' (*OED Online*, OUP, 2018) <https://en.oxforddictionaries.com/definition/pollution> accessed 30 July 2018.
[297] David K A Barnes and others, 'Accumulation and Fragmentation of Plastic Debris in Global Environments' (2009) 364 PTRSB 1987. Recently this number has been more specified: three-quarters of all marine debris is plastic. See Secretariat of the Convention on Biological Diversity, *Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity* (Technical Series No. 83, Montreal, 2016) 11.
[298] Jenna R Jambeck and others, 'Plastic Waste Inputs..., 770.
[299] To project the increase in mass to 2025, the scientists applied a range of conversion rates from mismanaged waste to marine debris. By estimating the mass of plastic waste entering the ocean from each country in 2010 and using population growth data, they predicted the percentage growth of plastic waste. See ibid 769.
[300] Ocean Conservancy, 'Stemming the Tide..., 3.
[301] Laura Parker, 'Eight Million Tons of Plastic Dumped in Ocean Every Year' (*National Geographic*, 13 February 2015)<http://news.nationalgeographic.com/news/2015/02/150212-ocean-debris-plastic-garbage-patches-science/> accessed 11 July 2017.
[302] Charles Moore, 'Trashed' (*Natural History Magazine*, November 2003) <www.naturalhistorymag.com/html site/master.html?http://www.naturalhistorymag.com/htmlsite/1103/1103_feature.html> accessed 29 July 2017.

despite an increase in production and disposal'.[303] In turn, the quantities of debris have increased in the shorelines.[304]

Marine plastic debris definition matches partially the *marine litter* definition, which consists of 'any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment'.[305] Plastic items might be 'deliberately discarded or unintentionally lost into the sea and on beaches including such materials transported into the marine environment from land by rivers, draining or sewage systems or winds'.[306] Based on an International Coastal Cleanup held in 2012, the top pollutants found worldwide were cigarettes and cigarette filters, food wrappers and containers, plastic bottles, plastic bags (easily wind-blown),[307] lids and caps, plastic tableware, straws and stirrers, glass bottles, beverage cans, and paper bags.[308] There were also a large amount of discarded fishing equipment, lighters, cotton buds, toothbrushes, polystyrene and resin pellets.

Plastics debris can be categorised according to their size (macro, meso or micro)[309] and according to their state of decay (primary or secondary microplastics). Although there is no international nomenclature nor general consensus upon sizes, which differ in almost every study and report,[310] it was suggested by the National Oceanic and Atmospheric

[303] Andrés Cózar and others, 'Plastic Debris in the Open Ocean' (2014) 111(28) Proceedings of the National Academy of Sciences 10239. See also Richard C Thompson and others, 'Lost at Sea: Where is All the Plastic?' (2004) 304(5672) Science 838, and Kara Lavender Law and others, 'Distribution of Surface Plastic Debris in the Eastern Pacific Ocean from an 11-year Data Set' (2014) 48(9) EST 4732-8.
[304] David K A Barnes and others, 'Accumulation and Fragmentation..., 1995.
[305] Francois Galgani and others, *Marine Strategy Framework Directive - Task Group 10 Report - Marine Litter* (Joint Research Centre of the European Commission, French Research Institute for Exploitation of the Sea and International Council for the Exploration of the Sea, April 2010) 1.
[306] ibid.
[307] While the precise proportion of marine litter attributed to plastic bags is uncertain, it is interesting to observe the results of some research and clean-up projects in different EU regions. For example, 'plastic carrier bags accounted for 73% of the plastic waste collected by trawlers along the Tuscany coast. Similarly, they represented more than 70% of total debris in most stations sampled in the Gulf of Lions and around the cities of Nice and Marseille (France). Plastic bags were also found on UK beaches, reaching average densities of one bag every 23 metres', see European Commission, 'Commission Staff Working Document - Impact Assessment for a Proposal for a Directive of the European Parliament and of the Council Amending Directive 94/62/EC..., 16.
[308] In 2012, the Ocean Conservancy's International Coastal Cleanup harnessed the efforts of over 561,000 volunteers in 97 countries to pick up over ten million pounds of pollution along 17,700 miles of shoreline. See more in Ocean Conservancy, *Working for Clean Beaches and Clean Water: 2013 Report* (2013).
[309] Even knowing that there is no minimum limit, some scientists introduced the term *nanoplastics* referring to plastic particles in the <100nm size range. Just as the other size classes, nanoplastics may be emitted to or formed in the aquatic environment. See Albert A Koelmans, Ellen Besseling and Won J Shim, 'Nanoplastics in the Aquatic Environment. Critical Review' in Bergmann M, Gutow L and M Klages (eds), *Marine Anthropogenic Litter* (Springer International Publishing, 2015) 325-40. For more information on nanoplastics see João Pinto da Costa and others, '(Nano)plastics in the Environment - Sources, Fates and Effects' (2016) 566-567 Science of the Total Environment 15-26.
[310] Reviews on plastic particles size ranges can be found in: Valeria Hidalgo-Ruz and others, 'Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification' (2012) 46(6) EST 3065-

Administration (NOAA) that *microplastics* should be defined as plastic particles smaller than five millimetres in diameter.[311]

A 2014 study, that combined the available worldwide data with a modelling approach, estimated that the weight of the global plastic pollution comprised 75.4% macroplastic (>200mm), 11.4% mesoplastic (4.76-200mm), 10.6% large microplastics (1.01-4.75mm) and 2.6% small microplastics (0.33-1.00mm).[312] This means that of the 5.25 trillion plastic pieces floating in the sea – excluding debris on the seafloor and on the beaches –, and weighing 268,940 tons, 233,400 tons correspond to larger plastic items and 35,540 tons to microplastics.[313] Although large plastic particles are heavier, they are less numerically abundant. In turn, the two size classes of microplastics account for 92.4% of the global particle count, and when compared to each other, the smallest microplastic category have roughly 40% fewer particles than the larger microplastics.[314]

In 2015, by comparing three scaled model solutions and compiling all available plastic data collected with surface-trawling plankton nets (totalling 11,000 observations), it was estimated that the accumulated number of microplastic particles in 2014 ranged from 15 to 51 trillion particles, weighing between 93 and 236 thousand metric tons. These numbers correspond solely to 1% of the global plastic waste estimated to have entered the ocean in the year 2010,[315] and less than 0.1% of the world annual production (322 million tonnes in 2015 and 335 million tonnes in 2016). These estimates varied widely compared to the previous global estimates, and the motives are: the scarcity of data in most of the ocean, differences in model formulations, and fundamental knowledge gaps in relation to sources, transformations and fates of microplastics in the ocean.

7; and Marcus Eriksen and others, 'Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea' (2014) 9(12) Plus One 2 and 4-5.

311 See Courtney Arthur, Joel Baker and Holly Bamford (eds), *Proceedings of the International Research Workshop on the Occurrence, Effects and Fate of Microplastic Marine Debris* (NOAA Technical Memorandum, 2009).

312 Between 2007 and 2013, 24 expeditions allowed the collection of data at 1571 field locations in the following regions: North Pacific, North Atlantic, South Pacific, South Atlantic, Indian Ocean, Mediterranean Sea and circumnavigating Australia. In this study, the microplastic limit boundary (0.33mm) was based on typical neuston net mesh size. Macroplastic had no established lower boundary, though it was set at 200mm (which represented a typical plastic water bottle, ubiquitous in the ocean). Its upper boundary is unlimited. See Marcus Eriksen and others, 'Plastic Pollution in the World's Oceans...

313 ibid 1-2 and 9.

314 The authors of this study pointed out that these estimates were highly conservative, and that they should be considered minimum estimates. See ibid 11.

315 Erik van Sebille and others, 'A Global Inventory of Small Floating Plastic Debris' (2015) 10(12) Environmental Research Letters 1.

These plastics float in all ocean regions and change their size over time. Plastics that are produced (and released to the environment) in a micro-size range are categorised as primary microplastics. These particles are used: as scrubs in personal care products; in drilling fluids for oil and gas exploration; as industrial abrasives; and for the manufacturing of plastic products (pre-production plastics), namely plastic resin pellets and plastic powder used in moulding. These particles can be as well dust and fibres from textiles, ropes, paints and residues from waste treatment.[316] In turn, secondary microplastics are the result of larger pieces of plastic breaking down into smaller pieces, through a process that can happen both at sea and on land and that we will now explain.

Plastic does not biodegrade and it cannot be digested, so while in nature it never really goes away. Once in the marine environment, plastic debris is exposed to chemical (ultraviolet rays), physical (abrasion by waves action and wind) and even biological degradation, causing them to break into tiny and tinier fragments during centuries.[317] The exact lifetime of discarded plastics will depend on the type, density and chemical nature of the material, on the characteristics of the environment in which it is placed (the presence of relevant microorganisms and the water temperature) and also on how *degradation* is defined or measured.[318] Since mass-production of conventional plastics started only 70 years ago, it is too early to say exactly how long these materials will persist. Nevertheless, the longevity of plastic is estimated to be hundreds to thousands of years, and it is likely to be far longer in deep sea and in non-surface polar environments.[319]

Ironically, the characteristics that make plastic so useful – lightness, durability, low cost and malleability – are the same that make its disposal problematic and that transform plastic in a long-term problem for the environment.[320] Marine plastic pollution is expected to last for centuries, even if stopped immediately.

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[316] Karen Duis and Anja Coors, 'Microplastics in the Aquatic and Terrestrial Environment: Sources (with a Specific Focus on Personal Care Products), Fate and Effects' (2016) 28(1) Environmental Sciences Europe 4.
[317] Lisbeth van Cauwenberghe and others, 'Microplastics are Taken up by Mussels (Mytilus edulis) and Lugworms (Arenicola marina) Living in Natural Habitats' (2015) 199 Environmental Pollution 10.
[318] Anthony L Andrady and Mike A Neal, 'Applications and..., 1981.
[319] David K A Barnes and others, 'Accumulation and Fragmentation..., 1985. The persistence of this debris was recently illustrated by accounts that plastic swallowed by an albatross had originated from a plane shot down 60 years previously some 9600km away. See ibid citing Weiss KR, 'Plague of Plastic Chokes the Seas' (*Los Angeles Times*, 2 August 2006).
[320] See EEA, *Material Resources and Waste - 2012 Update...,* 22 and see European Commission, 'Green Paper on a European Strategy on Plastic Waste in the Environment' COM(2013) 123 final, 5.

B. A Borderless Threat

Unsurprisingly, plastic pollution is ubiquitous. It is a form of pollution that does not know any boundaries, especially in aquatic environments, allowing trash to end anywhere on the sea. Normally buoyant, plastic actually moves throughout the entire sea, being dispersed over long distances, due to the influence of hydrodynamics and geomorphology.[321] In effect, a considerable number of publications validate the fact that marine plastic debris can accumulate in the open sea, shorelines, estuaries, lakes, rivers, watersheds, closed gulfs, bays and in the deep sea.[322] Even the shorelines of the most remote islands are becoming increasingly affected by plastic debris, in a way similar to the beaches of the industrialised western world.[323] The Midway Atoll and the Henderson Island represent the most alarming examples and for that reason they will be addressed here.

The Midway Atoll National Wildlife Refuge is located in the North Pacific Ocean halfway between North America and Asia and it is thirteen hundred miles from the nearest town. It incorporates the Papahānaumokuākea Marine National Monument, which is the largest contiguous fully protected conservation area under the USA flag, and also one of the largest marine conservation areas in the world.[324] Its biodiversity is incredibly rich – Midway Atoll's three small islands provide a virtually predator-free safe haven for nearly 3.5 million individual birds, including the world's largest albatross colony. The atoll is encircled by half a million acres ring of coral reef that hosts an amazing variety of unique wildlife, including

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[321] Timeless and borderless characteristics of plastic waste in the marine environment are very well exemplified by an episode occurred with the Ever Laurel ship. Travelling from Hong Kong to the USA in the year 1992, this ship lost some of its cargo in the North Pacific during a storm, including one container that held 28,800 toys. Since then, red beavers, green frogs, blue turtles and yellow ducks have washed ashore in the USA, in Nova Scotia, in Greenland, in Alaska, in the UK, in France and in Australia. See EEA, 'Litter in Our Seas' (*EEA*, 2014) <www.eea.europa.eu/signals/signals-2014/close-up/litter-in-our-seas> accessed 25 May 2017, and Surfers Against Sewage, *Marine Litter Report* (Cornwall, October 2014), 16 <www.sas.org.uk/wp-content/uploads/SAS-Marine-Litter-Report-Med.pdf > accessed 27 November 2017.

[322] Marcus Eriksen, 'The Plastisphere..., 153 and Marcus Eriksen and others, 'Plastic Pollution in the World's Oceans..., 2.

[323] José G B Derraik, 'The Pollution of the..., 844 citing Walker TR and others, 'Marine Debris Surveys at Bird Island, South Georgia 1990-1995' (1997) 34(1) MPB 61-5 and Benton TG, 'From Castaways to Throwaways: Marine Litter in the Pitcairn Islands' (1995) 56(1-2) Biological Journal of the Linnean Society 415-22.

[324] CNN, 'Midway, a Plastic Island' (30 November 2016) <http://edition.cnn.com/videos/us/2016/11/30/midway-plastic-island-nick-paton-walsh-orig-jql.cnn> accessed 6 April 2017. See also 'About Papahānaumokuākea' <www.papahanaumokuakea.gov/new-about/> accessed 6 April 2017. This National Monument is managed by the USA Fish and Wildlife Service, NOAA, Hawai'i Department of Land and Natural Resources and the Office of Hawaiian Affairs.

green sea turtles, spinner dolphins, endangered Hawaiian monk seals and an unprecedented rate of endemic fish.[325]

Unfortunately, neither the law protection nor the distance from the civilisation grant safety to these species. Debris of all sizes wash ashore every day. A line of trash, especially plastic, can be observed all along the beach, including fishing nets, ropes, bottles, bottle tops, cigarette lighters, styrofoam packaging, a motorcycle helmet, a mannequin's head, an umbrella handle, a flip-flop and a myriad of tiny brightly coloured different particles. The continuous cleaning actions taken by the competent entities made possible the removal of 125 tonnes of debris since 1999,[326] but it is very far from preventing the death of thousands of albatrosses, especially cubs.

Albatrosses collect their food on the water surface, but instead of picking squids, fishes and its eggs, they accidentally swallow pieces of plastic, which will feed them and their cubs. However, until five months old, albatrosses do not have the ability to regurgitate what they cannot digest, what will cause them to starve to death with the stomach full of plastic. In fact, it is estimated that of the 1.5 million Laysan Albatrosses that inhabit Midway, nearly all have plastic in their digestive system, and approximately one-third of the chicks die.[327] As a result, hundreds of albatrosses' decaying skeletons lay on the ground of this atoll. They bluntly reveal the ingestion of endless tiny shards of plastic.[328] These birds are literally choking to death in our waste, and yet the plastic ingested will remain there forever in the sand, waiting to be eaten repeatedly, and by mistake, by other birds. In such a scenario, a strong sense of powerlessness was the feeling reported by the unique two groups that were allowed to visit the islands.

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325 See 'About Papahānaumokuākea'... and 'Midway Atoll National Wildlife Refuge and Battle of Midway National Memorial - Wildlife & Habitat' (US Fish & Wildlife Service) <www.fws.gov/refuge/Midway_Atoll/wildlife_and_habitat/> accessed 7 April 2017.

326 CNN, 'Midway... According to John Klavitter, deputy refuge manager of the Midway Atoll National Wildlife Refuge, the US Fish and Wildlife Service is able to clean up about eight of the twenty tons of debris that reaches Midway yearly, see May-Ying Lam, 'Filming the Triumphs and Tragedies of Midway Island's Albatrosses' (*The Washington Post*, 5 September 2012) <www.washingtonpost.com/national/health-science/filming-the-triumphs-and-tragedies-of-midway-islands-albatrosses/2012/08/23/8cacb376-eb91-11e1-9ddc-340d5efb1e9c_story.html> accessed 7 April 2017.

327 'Q&A: Your Midway Questions Answered' (*BBC News*, 8 March 2008) <http://news.bbc.co.uk/2/hi/talking_point/7318837.stm> accessed 7 April 2017.

328 Chris Jordan took blunt awarded photos of these birds: 'the albatrosses' bodies melt away, leaving a spattering of bones, bills and feathers. As the feathers decay, they wilt into burnt siennas accented by snow white vertebrae, grating against the uncomfortable pastels of the plastics. Softness is still present in many frames, whether in the form of blooming tufts of down or delicate bones. In the most advanced stage of decomposition, the rot leaves a dark shadow around a plastic crater in the earth', see May-Ying Lam, 'Filming the Triumphs and Tragedies of Midway Island's Albatrosses'... In our opinion, CNN video footage is also really impressive.

Regarding Henderson Island, a UNESCO World Heritage Site since 1988, that belongs to the Pitcairn Islands Group in the Eastern Pacific Ocean, we must note that it registered in 2015 the highest density of debris ever reported anywhere in the world. This island is remote, uninhabited, rarely visited by humans and with no major terrestrially based industrial facilities or human habitations within five thousand kilometres. It is described by the UNESCO as a gem and one of the world's best remaining examples of an elevated coral atoll ecosystem practically untouched by humans.[329] Yet, it was estimated that there are 671.6 items/m^2 of plastic debris on the surface of these beaches and approximately 68% of the debris is buried <10cm in the sediment. In total, an estimated 37.7 million debris items, weighing a total of 17.6 tonnes, existed in Henderson by 2015, with up to 26.8 new items/m accumulating daily.[330]

Troubling is also the fact that only 8% of the debris found is fishing-related. The rest were catalogued as daily single-used items – water bottles, plastic helmets, garden containers, plastic bags, drinking straws, plastic razors, cigarette lighters, toothbrushes, plastic cutlery – coming from China, Japan, Chile, Germany, Canada and New Zealand.[331] Even though they are potentially dangerous, these items have not caused (yet) massive impacts on biodiversity. The most severe situations reported comprised hundreds of purple hermit crabs making their homes in plastic containers, and the fact that waste at the beach was creating a barrier for sea turtles attempting to enter the beach. This phenomenon can lead to a reduction in sea turtle-laying numbers, and can affect also native seabird species. In fact, being one of the world's biggest marine reserves and hosting four endemic species of land birds and large breeding seabird colonies, there is a high likelihood that animals can suffer severe complications and death due to plastic.

As the marine eco-toxicologist Jennifer Lavers observed, remote islands serve as sentinels for the health of the wider marine ecosystem, acting like a sieve or a trap and filtering

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329 'World Heritage List - Henderson Island' (*UNESCO*) <http://whc.unesco.org/pg.cfm?cid=31&id_site=487> accessed 7 April 2017.

330 However, that is not all: 'these values underestimate the true amount of debris, because items buried >10cm below the surface and particles <2 mm (<5 mm in the beach-back area) and debris along cliff areas and rocky coastlines could not be sampled', see Jennifer L Lavers and Alexander L Bond, 'Exceptional and Rapid Accumulation of Anthropogenic Debris on one of the World's Most Remote and Pristine Islands' (2017) 114(23) Proceedings of the National Academy of Sciences 6052-3.

331 Jennifer L Lavers and Alexander L Bond, 'Exceptional and Rapid Accumulation..., 6054 and Helen Hunt, '38 Million Pieces of Plastic Waste found on Uninhabited South Pacific Island' (*The Guardian*, 15 May 2017) <www.theguardian.com/environment/2017/may/15/38-million-pieces-of-plastic-waste-found-on-uninhabited-south-pacific-island> accessed 20 May 2017.

out the ocean. These islands, as well as turtles and seabirds, especially fulmars,[332] are reliable proxies for the state of the world's oceans.

The scientist alerted that this scenario must be regarded as a wake-up call to the world, because plastic pollution is as grave a threat to humanity as climate change. Jennifer Lavers' findings have proved to her, and to the world, that nowhere is safe from plastic pollution.[333] Regardless of where we travel, it is now demonstrated that our impacts precede us. All corners of the globe are already being impacted. This is a global and international issue, that is not even restricted to marine ecosystems.

C. Gyres and Garbage Patches

Charles Moore[334] was used to sail to open sea and still he often struggled to find words that could describe the vastness of the Pacific Ocean to people who have never been to sea. The same happened in 1997, when returning from an ocean race between Los Angeles and Hawaii. Charles Moore and his crew decided to navigate one of the most remote regions of the ocean. One that fishermen shun because its waters lack the nutrients to support abundant catches. One that sailors dodge because it lacks the wind to propel their sailboats. It was the eastern part of the North Pacific Subtropical Gyre. However, instead of a pristine ocean, he was confronted with the sigh of plastic, as far as the eye could see, stretching from horizon to horizon. There was plastic debris – bottles, bottle caps, wrappers, fragments – floating everywhere.[335] During a week, no clear spot was found, and that was because they were

[332] Changes in the frequency of wildlife ingestion of or entanglement in debris are often used as an indicator of pollution in the marine environment, as we will see later, especially in relation to fulmars. Fulmars are widely distributed and used as litter indicators in the North Atlantic and Pacific.
[333] Helen Hunt, '38 Million Pieces... and Dani Cooper, 'Remote South Pacific Island has Highest Levels of Plastic Rubbish in the World' (*ABC*, 15 May 2017) <www.abc.net.au/news/science/2017-05-16/plastic-pollution-on-henderson-island-in-south-pacific/8527370> accessed 20 May 2017.
[334] Charles Moore is an American chemist that became a world-renowned investigator and a tireless advocate for our oceans. In 1994, he founded Algalita Marine Research Foundation, a non-profit group dedicated to solving the issue of marine plastic pollution. Sensing its potential threat to the marine environment, he decided to dedicate his resources and time to understand and raise awareness about ocean plastic pollution. His accomplishments were not only being the first to ever conduct an expedition to study plastic marine pollution, but also authoring scientific papers on plastic particulate pollution, including the book *Plastic Ocean.* Through his continuous sea expeditions, that combine already more than 150,000 miles, and through his lectures across the globe, he can effectively raise awareness to this problematic. More information is available at <www.captain-charles-moore.org/about/> and <www.algalita.org/about-algalita/captain-moore/>.
[335] Charles Moore, 'Trashed'...

sailing through the Eastern Pacific Trash Vortex, which forms part of the Great Pacific Garbage Patch, one of the biggest garbage patch there is.[336]

After the awareness raised by Charles Moore, increasing attention was paid to plastic waste by policymakers, scientists, businesses and the media.[337] Nonetheless, it was not the first allusion to plastic debris issue. *Plastics on the Sargasso Sea Surface*, from 1972, published by Edward Carpenter and KL Smith Jr, two scientists from the Woods Hole Oceanographic Institution in Massachusetts, was the first report observing unexpected plastic debris concentration in western Atlantic Ocean. Plastic particles, in concentrations averaging 3500 pieces and 290g/km^2 were widespread in the Sargasso Sea, in the Atlantic Ocean.[338]

We have already seen that plastic pollution has reached some of the most remote places on Earth, but in effect, the significant quantities of plastic in the sea, although widespread, are concentrated in defined areas, the ocean gyres. They are large systems of circular ocean currents formed by the Earth's wind patterns and the forces created by the rotation of the planet.[339] Any of the three major types of ocean gyres – tropical, subtropical and subpolar – are very important because their movement helps to drive the ocean conveyor belt, that circulates water around the entire planet, granting the regulation of sea temperature, salinity and nutrient flow.

There are five major oceanic gyres: the North Pacific Gyre, the South Pacific Gyre, the Indian Ocean Gyre, the North Atlantic Gyre and the South Atlantic Gyre. They are all subtropical gyres, which means they circle areas beneath regions of high atmospheric pressure. Their centre is a high pressure zone (anticyclone), calm and relatively stable, which means that the ocean water generally stays in one place while the currents of the gyre circulate

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336 National Geographic, 'Great Pacific Garbage Patch' (*National Geographic*) <www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/> accessed 30 July 2017.

337 European Commission, 'Plastic Waste: Ecological and Human Health Impacts' (Science for Environment Policy, November 2011), 3 <http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR1_en.pdf> accessed 30 October 2017.

338 Edward Carpenter and Kenneth L Smith Jr, 'Plastics on the Sargasso Sea Surface' (1972) 175(4027) Science 1240-1.

339 Three forces concertedly cause the circulation of a gyre: global wind patterns, Planet Earth's rotation and its landmasses. Wind drags on the ocean surface, causing water to move in the direction the wind is blowing. The Earth's rotation deflects, or changes the direction of, these wind-driven currents. This deflection is a part of the Coriolis effect, that shifts surface currents by angles of about 45 degrees. In the Northern Hemisphere, ocean currents are deflected to the right, in a clockwise motion, while in the Southern Hemisphere, ocean currents are pushed to the left, in a counter clockwise motion. Beneath surface currents of the gyre, the Coriolis effect results in what is called an Ekman spiral. While surface currents are deflected by about 45 degrees, each deeper layer in the water column is deflected slightly less. This results in a spiral pattern descending about 100m. See National Geographic, 'Ocean Gyre' (*National Geographic*) <www.nationalgeographic.org/encyclopedia/ocean-gyre/> accessed 30 July 2017.

around placid ocean areas thousands of kilometres in diameter. The circular motion of the gyre draws in debris – like a vacuum cleaner –,[340] that make their way to the centre of the gyre, where they become trapped[341] and break down even more into a kind of *plastic soup*. In other words, the surface currents converge in a kind of *oceanographic dead-end*. Due to the region's lack of movement, the debris can accumulate for years and that is why these regions are frequently called garbage patches.

We will start with the North Pacific Subtropical Gyre,[342] which in truth gives place to the Great Pacific Garbage Patch – the first of its kind to be found, as seen above. This patch spans waters from the West Coast of North America to Japan, comprising actually the Western Garbage Patch, located near Japan, and the Eastern Garbage Patch, located between the North American states of Hawaii and California.[343] These areas are linked together by the North Pacific Subtropical Convergence Zone, located a few hundred kilometres north of Hawaii and close to where Midway Atoll is situated. This convergence zone is where warm water from the South Pacific meets up with cooler water from the Arctic, and this zone acts like a highway that moves debris from one patch to another. This patch, that is the most famous and the biggest one, contains all types of plastic debris, microplastics and even 'logs, telephone poles, and other wood debris from the 2011 Japanese earthquake and tsunami'.[344] The distribution, abundance, and characteristics of neuston plastic in the North Pacific, Bering Sea, and Japan Sea were studied for the first time during the four-year period of 1985-

[340] Expression used by Erik van Sebille to characterise the garbage patches: vacuum cleaners of the sea. See UNSWTV, 'Charting the Garbage Patches of the Sea' (8 January 2013) <www.youtube.com/watch?v=M4UK9Yt6A-s> accessed 30 July 2017.

[341] Let us follow the trail, for example, of a plastic water bottle discarded off the coast of California. It takes the California Current south toward Mexico. There, it may catch the North Equatorial Current, which crosses the vast Pacific. Near the coast of Japan, the bottle may travel north on the powerful Kuroshiro Current. Finally, the bottle travels westward on the North Pacific Current. The gently rolling vortexes of the Eastern and Western Garbage Patches gradually draw in the bottle. See National Geographic, 'Great Pacific Garbage Patch'...

[342] The North Pacific Subtropical Gyre is created by the interaction of the North Pacific Current to the north, the California Current to the east, the North Equatorial Current to the south and the Kuroshio Current to the west. These four currents move in a clockwise direction around an area of 20 million/km^2. Covering, thus, most of the northern Pacific Ocean, this is one of the five major oceanic gyres. See National Geographic, 'Great Pacific Garbage Patch'... For more detailed information on the ocean, currents and climate, see Matthias Tomczak and Stuart Godfrey, *Regional Oceanography: An Introduction* (2nd edn, 2003).

[343] National Geographic, 'Great Pacific Garbage Patch'...

[344] Laura Parker, 'Plane Search Shows World's Oceans are Full of Trash' (*National Geographic*, 4 April 2014) <http://news.nationalgeographic.com/news/2014/04/140404-garbage-patch-indian-ocean-debris-malaysian-plane/> accessed 11 July 2017.

88.[345] Since then, several scientific expeditions were organised, and their results are exposed throughout this chapter.

The South Pacific Garbage Patch[346] existence was recently demonstrated. In April 2017, Charles Moore was the responsible for the finding of a massive amount of plastic floating in the South Pacific off the coast of Chile and Peru.[347] In this remote area, plastic was only explored once before, in 2011, by Marcus Eriksen (a marine plastic expert and research director at the Five Gyres Institute), so further investigations were needed.[348]

Although Charles Moore's team is still processing the data and weighing the plastic collected in their six-month expedition, estimates indicate that this zone of plastic pollution can be as big as a million square kilometres in size, that is to say 1.5 times the size of Texas, being primarily composed of tiny plastic pieces, smaller than grains of rice. Occasionally, buoys and some fishing gear were found because the fishing industry is particularly active in the Southern Hemisphere. Anyhow, figures reveal that things have changed drastically since 2011.[349]

This update on the South Pacific Patch is extremely valuable to the community in general, and particularly to scientists, such as Erik van Sebille, PhD in physical

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345 Robert H Day, David G Shaw and Steven E Ignell, 'The Quantitative Distribution and Characteristics of Marine Debris in the North Pacific Ocean, 1984-88' in R S Shomura and M L Godfrey (eds), *Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii* (NOAA Technical Memorandum, 1990).

346 The Southern Pacific Gyre, circulating counter clockwise, is bounded by the Equator to the north, Australia to the west, the Antarctic Circumpolar Current to the south and South America to the east. The centre of this gyre is the site that is as far from continents as it is possible to go on Planet Earth's surface. The South Pacific Gyre is the largest gyre, encompassing an area twice the size of North America, and its centre can be described as the deadest spot in the ocean, because it is in fact the most oligotrophic oceanic region on Earth, where least amount of organic matter is produced in the overlying water column. See University of Rhode Island, 'Subseafloor Sediment in South Pacific Gyre one of Least Inhabited Places on Earth' (*ScienceDaily*, 1 July 2009) <www.sciencedaily.com/releases/2009/06/090622171408.htm> accessed 25 July 2017. The already referred Henderson Island is part of this patch, being located on the western boundary of the South Pacific Gyre, a known plastic-accumulation zone.

347 Charles Moore's research projects can be followed in his Research Gate profile. He announced the existence of the South Pacific Garbage Patch at <www.researchgate.net/project/2016-17-South-Pacific-Expedition-en-route-to-the-Galapagos. An expedition recap can be found at <www.algalita.org/sp-expedition/>.

348 The article published by Marcus Eriksen and others, 'Plastic Pollution in the South Pacific Subtropical Gyre' (2013) 68(1-2) MPB 71-6, clarified that marine plastic pollution in the open sea of the southern hemisphere was largely undocumented. The expedition carried out in March and April 2011 covered 4489km of the South Pacific Subtropical Gyre and allowed to conclude for the existence of plastic pollution in the southern hemisphere. The results shown an increase in surface abundance of plastic pollution near the centre and shown a decrease as moving away, enabling to verify the presence of a garbage patch. The average abundance and mass was 26,898 particles km^{-2} and 70.96 g km^{-2}, respectively.

349 Katherine Lindemann, 'Scientists Confirm the Existence of Another Ocean Garbage Patch' (*Research Gate*, 19 July 2017) <www.researchgate.net/blog/post/scientists-confirm-the-existence-of-another-ocean-garbage-patch> accessed 26 July 2017.

oceanography, working in the Institute for Marine and Atmospheric Research of the Utrecht University. He is responsible for the project *Tracking of Plastic in Our Seas*, that is sponsored by the European Research Council Horizon 2020 Starting Grant (2017-2022). The goal is to construct a three-dimensional distribution of marine plastic pollution, and thus create a novel comprehensive modelling framework able to track plastic movement through the sea.[350]

It was in 2010 that Marcus Eriksen found out that the Indian Ocean Gyre[351] *hosts* the Indian Ocean Garbage Patch. There are no specific studies about this patch, only a description of the Five Gyres Institute's team that sailed the Indian Ocean from Perth, Australia to Mauritius. Marcus Eriksen said it comprises a massive area, of at least five million square kilometres, but with no clear boundaries, because it is very fluid and changes with the seasons.[352]

With respect to North Atlantic, the first references to plastic pollution date back to 1972, focusing the Sargasso Sea. Therefore, studies on the plastic accumulation in the North Atlantic Subtropical Gyre[353] began early. For 22 years, since 1986 to 2008, nearly seven thousand undergraduate students and faculty scientists, who joined the Sea Education Association, examined the abundance, spatial distribution and temporal variability of plastic debris. More than 6100 surface plankton net tows were conducted on board the SEA's sailing

[350] TOPIOS project can be followed on its author's Research Gate profile, available at <www.researchgate.net /project/Tracking-Of-Plastic-In-Our-Seas-TOPIOS>.

[351] The Indian Ocean Gyre is actually two distinct tropical gyres – the northern and southern Indian Ocean Gyres – separated by the Equator, because the Coriolis effect is not present at the Equator and winds are the primary creators of currents. For this reason, as a tropical gyre, it tends to flow in a more east-west (instead of circular) pattern, as proven by its geographical representation. Its extent is determined largely by landmasses. The Equator forms its southern boundary, and it is bounded elsewhere by the Horn of Africa, Sri Lanka and India, and the Indonesian archipelago. This northern part of the system is sometimes called the Indian monsoon current, named by the wind that drives it. It is one of the very few currents – plus the South Equatorial Current and the West Australian Current – of this ocean gyre that is a complex system extending from the eastern coast of Africa to the western coast of Australia and that changes direction. In the summer, the current flows clockwise, as the monsoon blows in from the southwestern Indian Ocean. In the winter, the current flows counter clockwise, as the wind blows in from the Tibetan plateau in the northeast. The South Indian Gyre is located between Madagascar and Australia. See National Geographic, 'Ocean Gyre'...

[352] Laura Parker, 'Plane Search Shows World's Oceans are Full of Trash...

[353] The North Atlantic Gyre is a circular system of ocean currents that stretches across the Atlantic Ocean from near the equator almost to Iceland, and from the east coast of the USA to the west coasts of Europe and Africa. The currents that compose this gyre and that flow in a circular pattern include: the Gulf Stream in the west, along the East Cost of the USA; the North Atlantic Current in the north, crossing the North Atlantic to Europe; the Canary Current in the east, flowing south as far as the north-western coast of Africa; and the Atlantic North Equatorial Current in the south, that crosses the Atlantic Ocean to the Caribbean Sea. The North Atlantic Ocean Gyre is stable and predictable, always flowing in a steady, clockwise path around the North Atlantic Ocean. Its temperature depends on the currents: Gulf Stream is a warm current, heated by the tropical waters of the Caribbean Sea; in turn, the North Atlantic Current is a cold current, cooled by Artic winds and other ocean currents. See National Geographic, 'Ocean Gyre'...

research vessels, and 62% collected buoyant millimetre plastic pieces originated from consumer products.[354] In some places the team found more than 167 thousand bits of trash per square kilometre.

These scientists also tried to determine the geographic origin of the debris, which is neither traceable through current patterns nor through the recovered plastic samples. Consequently, during the period of 1989-2009, 1600 drifters (satellite-tracked drifting surface buoys) were deployed in the North Atlantic with the aims of examining the pathways into and out of the central region of high plastic concentration, and providing an important baseline for future monitoring efforts. As a result, they concluded the following: the floating plastic debris may have origin in the subtropical western North Atlantic where currents act to retain it; the minimum time for surface tracer to reach the centre coming from the USA eastern seaboard was less than 60 days; the influence of the Gulf Stream was particularly evident, making the tracer travel along the coast before entering the gyre interior, and reducing the propagation times to 40 days from Washington, DC, and from Miami, Florida, for example. In conclusion, although they are not indicative of the size or location of the land-based sources, or of the debris age, these estimates demonstrate how quickly plastic entering the ocean near major USA population centres can affect an area more than one thousand kilometres offshore.[355]

Turning again to the South Hemisphere – where 81% of the Earth's surface is seawater –, we must note that the paucity of records of marine plastic debris does not mean that the problem is not severe in the less industrialised south. A study from 1980 suggested that already in the 1970s there were more industrial pellets in the southeast Atlantic Ocean west of 12ºE than closer to the Cape Basin area.[356] Large floating marine debris (>1cm) were only surveyed in 2013, between Cape Town and the island Tristan da Cunha, crossing the southern edge of the South Atlantic Gyre.[357] Most litter was made of plastic (97%

[354] Kara Lavender Law and others, 'Plastic Accumulation in the North Atlantic Subtropical Gyre' (2010) 329(5996) Science 1186.
[355] ibid.
[356] RJ Morris, 'Plastic Debris in the Surface Waters of the South Atlantic' (1980) 11 MPB 164-6.
[357] The South Atlantic Gyre is the subtropical gyre in the south Atlantic Ocean, bordered by the east coast of South America and the west coast of Africa. In the southern portion of the gyre, north-westerly winds drive eastward-flowing currents – mainly the South Atlantic current – that are difficult to distinguish from the northern boundary of the Antarctic Circumpolar Current or the also called West Wind Drift. This current, that is the largest ocean current, flows from West to East around Antarctica. This current allows Antarctica to maintain its huge ice sheet by keeping warm ocean waters away. The Brazil Current is the western boundary warm current of the gyre, flowing south along the Brazilian coast to the Rio de la Plata. South Equatorial current at the top and Benguela current, running up the coast of southern Africa, bringing cold Antarctic water toward the equator. The gyre is affected by

corresponding to 273 items), being packages the most common, especially in coastal waters. Fishery-related items (mainly pieces of fish trays) made up a greater proportion of litter offshore, as did unidentified pieces of plastic. Litter density decreased from coastal waters off Cape Town (>100 items km^{-2}) to oceanic waters (<10 items km^{-2}), and was consistently higher (6.2 ± 1.3 items km^{-2}) from 3ºE to 8ºE than in adjacent oceanic waters (2.7 ± 0.3 items km^{-2}) or in the central South Atlantic around Tristan da Cunha (1.0 ± 0.4 items km^{-2}).[358]

At last, it seems that Arctic Ocean's gyres are no exception to the global trend, even though major sources are non-existent nearby. The Arctic Ocean is actually the *dead end* for the surface transport of floating plastics in the North Atlantic branch of the thermohaline circulation. It is not a coincidence that the fragmentation and typology of the plastic suggested an abundant presence of aged debris originated from distant sources.[359]

Plastic particles were found inside the sea ice, in the ice-free waters and in the deep sea. In 2012, an analysis of four ice cores collected across the Arctic Circle revealed a considerable abundance of microplastics into the sea ice.[360] With respect to ice-free waters, in 2013, high concentrations of plastic debris (hundreds of thousands of pieces per square kilometre) were found in the northernmost and easternmost areas of the Greenland and Barents seas, where actually 95% of the plastic load estimated for the Arctic is confined.[361] In terms of results, it is worth mention that most of the surface ice-free waters in the Arctic

the Southeast Trade Winds and the Westerlies global winds. See Scott Guhin and others, 'The South Atlantic Current'... and 'From the Endeavour on our Ocean Voyages'...

358 Peter G Ryan, 'Litter Survey Detects the South Atlantic "Garbage Patch"' (2014) 79(1-2) MPB 220.

359 Compared with other accumulation zones of floating debris, the Arctic Ocean showed the lowest relative abundances for plastic sizes larger than 12.6mm, whereas the highest proportion of large plastic debris was found in the Mediterranean Sea. However, no statistically significant differences were found between the Arctic and the subtropical ocean gyres. The typology of plastic items in the Arctic was also similar to that found in the gyres, but diverged from the plastic composition in the Mediterranean Sea, which had a higher proportion of film-type plastic (12% compared to 1.7%) – results that support the hypothesis that a significant fraction of the plastic accumulation in the Arctic comes from distant sources. Assuming that photodegradation and fragmentation of floating plastic debris are directly related to exposure time in the environment, the paucity of large-sized plastic in the Arctic waters in relation to the Mediterranean Sea (with the shortest pathway to the coastal areas of release) is indicative of a low proportion of recently introduced plastic objects. In addition, other reasonable hypotheses, such as an accelerated fragmentation by the cycles of freezing and melting at high latitudes, could explain the relative scarcity of large items. The relatively low percentage of film-type plastic debris in the Arctic Ocean also suggests that an important fraction of the Arctic plastic pollution is aged debris that is released from distant sources. Film-type plastics may undergo a faster removal from the ocean surface than other plastic types because its higher surface-to-volume ratio favours ballasting by epiphytic growth and subsequent sinking. See Andrés Cózar and others, 'The Arctic Ocean as a Dead End for Floating Plastics in the North Atlantic Branch of the Thermohaline Circulation' (2017) 3(4) Science Advances 2-4.

360 See Rachel W Obbard and others, 'Global Warming Releases Microplastic Legacy Frozen in Arctic Sea Ice' (2014) 2 Earth's Future 315-20.

361 Andrés Cózar and others, 'The Arctic Ocean..., 1-2. This was the first extensive survey ever conducted comprehending 42 sites along the circumarctic track.

Polar Circle were slightly polluted with plastic debris, with 37% of the surface net tows of the circumpolar track being free of plastic (accounting for items larger than 0.5mm only and excluding fibres). However, plastic debris was abundant and widespread in the Greenland and Barents seas. Maximum concentrations of floating plastic measured in this sector of the Arctic Ocean were considerably lower than those in the subtropical accumulation zones, but the median values were similar, especially in units of number of items. The total load of floating plastic in the ice-free waters of the Arctic Ocean was estimated to range from around 100 to 1200 tonnes, with 400 tonnes composed of an estimated 300 billion plastic items as a midrange estimate.[362]

Concerning the deep sea, it was stated that the seafloor beneath Greenland and Barents seas is acting as an important sink of plastic debris. Images from the *Hausgarten Observatory*, that owns 21 permanent stations affixed in between 250m and 5500m water deep in the eastern Fram Strait west of Svalbard, were taken in 2002, 2004, 2007, 2008 and 2011 at 2500m depth. Its analysis indicated that litter – of which 59% was plastic – increased from 3635 to 7710 items km^{-2} between 2002 and 2011.[363] Yet, it is not just in this allegedly *dead end* that plastic is sinking into the deep sea.

The uniqueness of the Arctic ecosystem makes the potential ecological implications of exposure to plastic debris of special concern. Moreover, the growing level of human activity in an increasingly warm and ice-free Arctic, with wider open areas available for the spread of microplastics, suggests that high loads of marine plastic debris may become prevalent in the Arctic in the future.

D. Plastic Lost to Deep Sea

Although every garbage patch is a mystery, the scientific community consensually advocates that these patches are almost entirely made up of microplastics – the tiny bits of plastic that are not always visible to the naked eye and much less visible from space. The patches are not real compact islands of plastic waste. In truth, patches are like confetti or a thin soup of tiny particles (thickest in the middle of the gyres), which partially justifies the difficulty in

[362] See ibid 1 and check table 1 on page 3.
[363] See Melanie Bergmann and Michael Klages, 'Increase of Litter at the Arctic Deep-sea Observatory HAUSGARTEN' (2012) 64 MPB 2734-41.

measuring the size of the so-called patches and, at the same time, the total amount of units, weight and volume of plastic particles existent on the sea.

It is thus highly improbable to disclose with accuracy the real figures, and there are several reasons. Gyres, and therefore patches, are vast, remote and are always shifting with weather conditions, currents and other physical processes within the oceans. The two most famous patches are relatively well documented, but little is known about plastic accumulation in other gyres, and even less about the vast majority of the sea surface outside the gyres (that remains unsurveyed).

One of the most detailed analysis of the distribution of plastic among the five major ocean repositories dates back to 2014. It took into account 24 expeditions across all five sub-tropical gyres occurred between 2007 and 2013, and estimated that the gyre in the North Pacific represented nearly one-third (containing 37.9% and 35.8% by particle count and mass, respectively) of the plastic pollution in all oceans, counting two trillion pieces. With 1.3 trillion pieces, the Indian Ocean had the second-largest volume of plastic. The North Pacific and the Indian Ocean contained thus 56% of all particles. The third was the North Atlantic, with 930 billion pieces, the fourth was the South Pacific, with 491 billion pieces and the fifth was the South Atlantic, with 297 billion pieces.[364]

Beyond question, accumulation rates vary widely in accordance with many challenging factors. The nature of the gyres itself makes it hard to measure accurately. In the open sea, bodies of water are bounded by atmospheric pressure systems and by the currents those systems create. In other words, air defines the body of water. When air pressure systems move, the body of water moves as well.[365] Floating debris is constantly moving, shifting with seasonal weather, and consequently its shape, size and density are also changing. In sum, one trawl may pick up next to nothing, because it missed the most concentrated spots, while the following one can be full of plastic debris.

Adverse meteorological conditions are also a constraint. It has been demonstrated that the trawls carried out during strong winds tend to capture fewer floating microplastics than during calm conditions. Due to wind-driven mixing, plastic debris is vertically distributed within the upper water column, becoming out of reach of surface-trawling nets.[366] It is

[364] Marcus Eriksen and others, 'Plastic Pollution in the World's Oceans..., 8.
[365] Charles Moore, 'Trashed'...
[366] Surface net tows cannot account for the total amount of plastic pieces in the upper ocean mixed layer, except in low wind conditions ($u_{10} < 5$ m/s), see Tobias Kukulka and others, 'The Effect of Wind Mixing on the Vertical Distribution of Buoyant Plastic Debris' (2012) 39 Geophysical Research Letters 5.

possible, though, to combine surface and subsurface observations with one-dimensional column model, in order to estimate the total amount of plastic in the wind-mixed surface layer. Improved estimates of plastic concentration in the subtropical North Atlantic predicted an average integrated concentration 2.5 times the measured surface value, with a maximum of 27 times the surface value.[367] Concluding, surface tow measurements significantly underestimate the total plastic content even for moderate wind conditions, which requires a reinterpretation of the existing marine plastic debris data sets.

Not all trash floats on the surface, but it is not always the wind's fault. *Plastic* is a collective term for a variety of synthetic polymers with variable material properties, including density. This means that some consumer plastics, such as PET, PVC and PS are denser than seawater and sink, centimetres or several meters.[368] Density analysis of plastic samples collected at the sea surface revealed that 99% were less dense than seawater.[369]

Additionally, plastics gradually lose buoyancy in seawater due to biofilm formation. Under the weight of fouling by a wide variety of bacteria, algae, animals and accumulated sediment, plastics can sink to the seabed.[370]

The last factor influencing the imprecision of the measures is the lack of standardised methodology used for the identification and quantification of microplastics in the marine environment. Small differences in the models can definitely contribute to different estimates, and, in fact, only standardised sampling procedures – already proposed by the Marine Strategy Framework Directive – will allow the spatiotemporal comparison (and monitoring) of microplastic abundance across marine environments.[371]

Although the scientific community recognises all the factors above described, they are not sufficient, not in any way, to answer to a very recently placed question.

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[367] ibid.

[368] Erik van Sebille, 'How Much Plastic is There in the Ocean?' (*World Economic Forum*, 12 January 2016) <www.weforum.org/agenda/2016/01/how-much-plastic-is-there-in-the-ocean/> accessed 31 July 2017 and Alexander G J Driedger and others, 'Plastic Debris in the Laurentian Great Lakes: A Review' (2015) 41(1) Journal of Great Lakes Research 10.

[369] Kara Lavender Law and others, 'Plastic Accumulation in the North Atlantic Subtropical Gyre'..., 1187.

[370] Elemental analysis of plastic samples revealed the presence of nitrogen, which is absent in virgin polyethylene and polypropylene and is thus indicative of bioaccumulation. See Kara Lavender Law and others, 'Plastic Accumulation in the North Atlantic Subtropical Gyre'..., 1187. Biofouling occurs more quickly in soft and thin plastic fragments, but neither the magnitude nor the speed of this process across different types of small fragments has been reported. See Julia Reisser and others, 'Marine Plastic Pollution in Waters around Australia: Characteristics, Concentrations, and Pathways' (2013) 8(11) Plos One 7.

[371] Valeria Hidalgo-Ruz and others, 'Microplastics in the Marine Environment..., 3060.

The first map ever of marine litter, prepared by the marine ecologist Andrés Cózar and a team of researchers, showed a worldwide distribution of plastic on the surface of the open sea, mostly accumulating in the convergence zones of each of the five subtropical gyres, with a comparable density. The most important was the revelation of an important gap in the size distribution of floating plastic debris as well as the finding that the global surface load of plastic in the ocean was well below, on the order of tens of thousands of tons, of what was expected compared with production and ocean leakage rates (already exposed above).[372] These observations, published in 2014, on the size distribution of floating plastic debris point to important size-selective sinks, removing millimetre-sized fragments of floating plastics on a large scale. Besides the lack of observed increasing temporal trends in surface plastic concentration,[373] these new findings provide strong support to the hypothesis of substantial losses of plastic from the ocean surface.

Four main possibilities have been thus proposed: shore deposition, fragmentation, sedimentation/biofouling and ingestion.[374] Although a rigorous attribution of losses to each of these mechanisms is not yet possible, 'resolving the fate of the missing plastic debris is of fundamental importance to determine the nature and significance of the impacts of plastic pollution in the ocean',[375] and to work on solving the problem.

As mentioned above, the 15 to 51 trillion particles of plastic debris on the open sea, weighing between 93 and 236 thousand metric tons, only correspond to 1% of global plastic waste estimated to enter the sea in the year 2010.[376] It was also estimated that: about 15% of marine debris floats on the sea surface; another 15% remains in the water column; and 70%

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[372] Andrés Cózar and others, 'Plastic Debris in the Open Ocean'..., 10241.
[373] Richard Thompson published in 2004 the first assessment of microplastic abundance over time. He found that while the amount of microplastics measured between the British Isles and Iceland increased from the 1960s and 1970s to the 1980s and 1990s, no significant increase was observed between the later decades. See Richard Thompson and others, 'Lost at Sea..., 838. Similarly, the 22-year-study on the North Pacific, organised by the Sea Education Association and published in 2010, found no significant increase in annual mean concentrations of floating microplastics in the western North Atlantic subtropical gyre between 1986 and 2008, nor in the eastern North Pacific subtropical gyre between 2001 and 2012. See Kara Lavender Law and others, 'Plastic Accumulation in the North Atlantic Subtropical Gyre'..., 1185-6. Another previous analysis focusing the *missing plastic* can be found in Kara Lavender Law and others, 'Distribution of Surface Plastic Debris in the Eastern Pacific Ocean from an 11-Year Data Set' (2014) 48(9) EST 4732-8.
[374] Biofouling and ingestion are interconnected. Recent laboratory studies have demonstrated that microplastics are readily consumed by copepods and that these microplastics are later egested along with waste organic matter in faecal pellets. Sinking faecal matter represents thus a mechanism by which floating plastics can be vertically transported away from surface waters. See Mathew Cole and others, 'Microplastics Alter the Properties and Sinking Rates of Zooplankton Faecal Pellets' (2016) 50 EST 3239-40.
[375] Andrés Cózar and others, 'Plastic Debris in the Open Ocean'..., 10239.
[376] Erik van Sebille and others, 'A Global Inventory..., 1.

rests on the seabed.[377] These figures mean that plastic debris estimates in the oceans may have been vastly underestimate. In reality, there is greater plastic accumulation than what was previously suspected.

It was known that the deep sea – the deeper parts of the ocean, especially those beyond the edge of the continental shelf, in the range of 200m to 2500m – could be a plastic debris repository, but not at this scale. A study from 2014, exposed that microplastics, in the form of fibres, were up to four orders of magnitude more abundant (per unit volume) in deep-sea sediments from the Atlantic Ocean, Mediterranean Sea and Indian Ocean than in contaminated sea surface waters.[378] Given the vastness of the deep sea and the prevalence of microplastics at all sites investigated, the deep sea floor appears to provide an answer to the question *where is all the plastic?*

Due to technical challenges and prohibitive costs of conducting research in the deep sea, little is known about the abundance, types, sources, the depth in which debris is penetrating and its impacts on this vast habitat. Opportunely, more and more studies are being carried out and the most recent came from Japan.[379] From 1982 to 2015, plastic debris occurrences in the deep sea of six oceanic regions (South Atlantic, North Atlantic, Indian Ocean, South Pacific, Eastern North Pacific, and Western North Pacific) were archived in a database. Its analysis revealed that 3425 man-made debris items have been found in 5010 dives. More than 33% of this debris was macro-plastic, 89% of which was single-use products. In areas deeper than 6000m, these ratios increased to 52% and 92%, respectively. It is noteworthy that the relative dominance of plastic debris was larger at greater depths than at shallower depths (18-22% at >1000 m) and it was almost exclusively single-use plastic.[380]

[377] European Commission, 'Commission Staff Working Document - Overview of EU Policies, Legislation and Initiatives Related to Marine Litter' SWD(2012) 365 final, 3.

[378] Plastic microfiber abundance in the sediments ranged from 1.4 to 40 pieces per 50ml, and samples from four locations in the Indian Ocean showed that microplastics had also accumulated on the surface of octocorals. Rayon, a semi-synthetic fibre was detected in all samples, contributing to 56.9% of the total number of fibres seen. Of the remaining fibres, polyester was the most prevalent (53.4%), followed by other plastics, which included polyamides and acetate (34.1%), then acrylic (12.4%). See Lucy C Woodall and others, 'The Deep Sea is a Major Sink for Microplastic Debris' (2014) 1 Royal Society Open Science 5.

[379] The Global Oceanographic Data Centre of the Japan Agency for Marine-Earth Science and Technology launched in March 2017 the Deep-sea Debris Database for public use, where photographs and videos of debris that have been collected since 1983 by deep-sea submersibles and remotely operated vehicles were archived. See Sanae Chiba and others, 'Human Footprint in the Abyss: 30 Year Records of Deep-sea Plastic Debris' (2018) Marine Policy 1-9, available at <https://doi.org/10.1016/j.marpol.2018.03.022>. In this study, evidence of distribution of plastic debris was shown in the abyssal zone (4000-6000m) and for the first time in the hadal zone (>6000m), that includes the world's deepest trench at over 10000m deep.

[380] ibid 1 and 4. In a study off the California coast, the relative occurrence of plastic debris increased in the 2000-4000m depth range compared to that in the upper 1500m. The same study also reported dominance of single-use

These results may indicate that previous studies may have greatly underestimated the extent of anthropogenic marine debris on the seafloor due to limitations in observing deeper regions. The deepest record was a plastic bag at 10898m in the Mariana Trench, which is actually designated as a Marine National Monument Marine Protected Area by the USA. However, and has seen before, this designation cannot prevent the hazards of plastic pollution.[381]

The data showed that, in addition to resource exploitation and industrial development, the influence of land-based human activities, even in the form of single-use products, has reached the deepest parts of the sea in areas more than 1000km from the mainland. Additionally, this study showed that association of plastic debris and deep-sea biota occurs at a relatively high frequency especially bearing in mind the low biomass and/or sporadic distribution of deep-sea ecosystems. Nearly 17% of debris images were found with at least one organism, and entanglement of plastic bags were detected even in the cold seep communities. There are reasons to believe that all pelagic, mesopelagic, and deep-sea species may be at risk.[382]

European deep waters were also surveyed, by various European institutions between 1999 and 2011.[383] Across 32 sites, plastic (bags, derelict fishing lines and nets) was the most prevalent waste item found on the seafloor. Waste was found at all sites and all depths sampled, but the sites with the highest waste density were found principally closer to shore – with the exception of the Gulf of Lion –, such as the Lisbon Canyon, the Blanes Canyon, the Guilvinec Canyon and the Setúbal Canyon. Waste was even found in deepest and remote locations, such as the Charlie-Gibbs Fracture Zone across the Mid-Atlantic Ridge.

Similar conclusions were taken after the remotely operated vehicle dives in Portugal

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plastic among the plastic debris. It is plausible that single-use plastic, having high buoyancy, tends to be transported far distances via oceanic currents and other physical mechanisms from coastal regions before settling and accumulating on the deep-sea floor. Additionally, the findings provide evidence that submarine canyons – and there are as many as 660 submarine canyons worldwide with an estimated 15% with nearshore heads that receive substantial coastal sediment inputs – *collect* debris and act as conduits for debris transport from coastal to deep sea. See Kyra Schlining and others, 'Debris in the Deep: Using a 22-year Video Annotation Data Base to Survey Marine Litter in Monterey Canyon, Central California, USA' (2013) 79 Deep-Sea Research 96-105. To elaborate this study, the team reviewed 1149 video records of marine debris from 22-years of remotely operated vehicle deployments in Monterey Bay, covering depths from 25m to 3971m. The majority of debris was plastic (33%) and metal (23%).

[381] ibid 1 and 6.

[382] ibid 5 and 6.

[383] Christopher K Pham and others, 'Marine Litter Distribution and Density in European Seas, from the Shelves to Deep Basins' (2014) 9(4) Plos One 1-13. Surveyed sites were located on continental shelves and slopes, submarine canyons (where litter originating from land accumulates in large quantities), seamounts, banks, mounds, ocean ridges and deep basins, at depths ranging from 35 to 4500m.

submarine canyons of Lisbon, Setúbal, Cascais and Nazaré.[384] Waste was more abundant at sites closer to the coastline and population centres than those further out to sea, suggesting the majority of the litter was land sourced. As a matter of fact, although plastic (fragments, sheets, bags, bottles, polystyrene cups, packaging, buoys, rubber gloves, boots, tyres) was the dominant type of marine debris, followed by fishing gear, the fact is that the dimension of the cities and the existence or not of rivers influenced the amount and the type of plastic waste. That is why fishing gear represented 37% of the total waste in Nazaré, and juts 9% in the other canyons.

As more areas of seafloor are being explored, benthic waste is progressively being revealed to be more widespread than previously assumed. In reality, understanding spatial patterns in waste abundance and distribution in the deep sea is challenging, owing to the lack of standardisation in the sampling and analytical methodologies used. Furthermore, the high cost of sampling the deep sea limits the ability to perform standardised surveys across large areas to better understand the extent of marine plastic pollution.[385] Few doubts exist though regarding the degradation process. If most polymers are highly persistent in the marine environment, in the depths where oxygen concentrations are lower and light is absent, the degradation is much slower.[386] That is mostly why the accumulation trends in the deep sea are of special concern.

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[384] Gideon Mordecai, 'Litter in Submarine Canyons off the West Coast of Portugal' (2011) 58 Deep-Sea Research II 2489-96. For more reliable data on Portuguese waters see Sara Sá and others, 'Spatial Distribution if Floating Marine Debris in Offshore Continental Portuguese Waters' (2015) 104(1-2) MPB 269-78.
[385] Christopher K Pham and others, 'Marine Litter Distribution..., 3.
[386] David K A Barnes and others, 'Accumulation and Fragmentation..., 1992.

V. Sources of Marine Plastic Debris

As expected, plastic pollution has a large number of concrete sources. Its identification – when possible – is important to: determine accurately the quantities of plastics and microplastics entering the sea; provide an indication of regional and local sources; determine the feasibility of introducing management measures; reduce the inputs; and even to solve the problem by adjusting legislative measures or by creating new ones.

Plastic materials are manufactured onshore, but plastic waste can be produced in land, far or near the shore or other water sources, and at sea. At any phase of plastic's lifecycle, product can get lost, becoming waste, if it was not already classified as waste at the time. As already demonstrated, plastic waste is ending up in the sea and the pathways are water, especially riverine transport – and this is the main reason why we will also address rivers in this section –, the atmosphere (wind and storms) and direct deposition into the sea.

In view of the above, marine debris researchers traditionally classify debris sources as either *land*- or *ocean-based*, depending on where debris enters the water. In 1991, GESAMP estimated that globally 80% of marine litter was coming from land-based sources, and 20% from ocean-based sources.[387] Although adopted by the scientific community over the years, we note that these estimates may not be the most accurate since they were grounded in the belief that plastic waste was typically buoyant and that much of it could be found floating across the ocean in large gyres – circumstance that does not correspond to reality, as already explained.[388] More consensual is the fact that these sources are often related to human activities or industry sectors, and that they can generate both microplastic and macroplastic litter.[389] Furthermore, the waste distribution in the oceans is influenced by nature, by the scale

[387] GESAMP, *The State of the Marine Environment - GESAMP Reports and Studies No 39* (UNEP, 1990) 88. The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) is a group of independent scientific experts, established in 1969, that advises the United Nations system on the scientific aspects of marine environmental protection. At present GESAMP is jointly sponsored by ten UN organisations with responsibilities relating to the marine environment (IMO, FAO, UNESCO-IOC, WMO, IAEA, UN, UNEP, UNIDO, UNDP and ISA), and they utilise GESAMP as a mechanism for coordination and collaboration among them. By 1991, its principal task was to provide scientific advice on marine pollution problems to the Sponsoring Agencies and to the IOC.

[388] Ocean Conservancy, 'Stemming the Tide..., 13.

[389] More complete information can be found in UNEP, *Marine Plastic Debris and Microplastics - Global Lessons and Research to Inspire Action and Guide Policy Change* (UNEP, Nairobi, 2016) 36-64. See also GESAMP, *The State of the Marine Environment...,* 7-52.

and the location of these activities, by seasons and by the existing policies regulating all these matters. There are indeed major inputs of plastic litter from land-based sources in densely populated or industrialised areas, most in the form of packaging.

A. Land-Based Plastic Debris

Regarding solid waste disposal, both legal and illegal waste handling practices contribute to marine debris.[390] Waste, of all types, but especially domestic and industrial, is often placed in landfills, or other solid waste sites, located in coastal areas or near rivers, finding thus its way into the marine environment. In addition, garbage may also be lost to the marine environment during its collection or transportation to landfills if waste management procedures are inadequate.[391] As already referred, this mismanagement happens mostly in countries where sanitary disposal in landfills has not been implemented or where waste sites are poorly managed and controlled.[392]

Another related source is public littering: litter carelessly dropped by residents, workers (in forestry, agriculture, construction and mining operations) and tourists, in towns, beaches, parks and in any other public place. Litter from inland areas can become marine debris after getting into streams or rivers, not to mention beachgoers and the recreational use of coastal areas, which justifies a significant increase of litter by the coast. This litter includes items such as food packaging, beverage containers, cigarette butts and plastic beach toys.[393]

Industrial activity may also result in a relevant plastic waste discharge into the sea. Nurdles, also known as *mermaid tears*, are plastic resin pellets, spherical or cylindrical, with a diameter of 2mm to 6mm, that are used as raw material for the manufacture of plastic products. These primary microplastics are improperly (deliberately or accidently) disposed of or are lost during transport or handling at port facilities, including when cleaning the transport vessel. Their presence has been reported in most of the world's oceans, even in the

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[390] Seba B Sheavly, 'Marine Debris - an Overview of a Critical Issue for Our Oceans' (Sixth Meeting of the UN Open-ended Informal Consultative Process on Oceans & the Law of the Sea, June 2005), 2 <www.un.org/depts/los/consultative_process/documents/6_sheavly.pdf> accessed 5 November 2017.
[391] Michelle Allsopp and others, *Plastic Debris in the World's Oceans* (Greenpeace, November 2006), 11 <www.greenpeace.org/archive-international/en/publications/reports/plastic_ocean_report/> accessed 16 November 2017.
[392] BIO Intelligence Service, *Plastic Waste...,* 117.
[393] Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 11.

most remote, non-industrialised areas in the Southwest Pacific such as Tonga, Rarotonga and Fiji.[394] At the end of the 1980s, New Zealand beaches were already a repository of quite considerable amounts, in counts of over 100,000 per meter of coast, of raw plastic granules, with greatest concentration near important industrial centres.[395] Nowadays, nurdles can be found by the thousand on beaches and floating at the sea surface.

Storm water discharges are also a recognised source of marine plastic debris. Storm drains collect runoff water generated during heavy rain events.[396] The drains directly discharge this wastewater – containing roadside litter, rubbish from streets, from forestry and agriculture and containing also construction waste – into nearby streams, rivers or directly to the sea.[397] Moreover, these storms can influence the sewage performance, contributing to combined sewer overflows along with storm water. As a rule, public wastewater treatment facilities are prohibited from discharging plastics and other material to the marine environment,[398] but under abnormal weather conditions, the wastewater treatment system may be exceeded and the sewage plus storm water is directly discharged into the sea or nearby rivers. This waste can include condoms, tampon applicators, syringes and street litter. Since 1994 – in the absence of more up-to-date information – waste from combined sewer overflows is one of the major land-based sources of marine plastic debris in the USA.[399] As for the UK, there are approximately 31,000 combined sewer overflows, whose sole purpose is to act as emergency discharge valves in the sewerage system, discharging untreated sewage and wastewater when the system comes close to bursting.[400]

Moreover, sewage transports a lot of microplastics. The most notorious are microbeads and textile fibres. Microbeads, also called microspheres or nanospheres, are spherical or amorphous plastic particles used in personal care and cosmetic products. Plastic

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394 ibid 12.
395 José G B Derraik, 'The Pollution of the..., 844.
396 Increases in coastal population density, climate change, and the rapid growth of plastic production have led to catastrophic events like hurricanes, floods and tsunamis leaving a legacy of plastic waste. Although these events are isolated cases, the contribution of plastic pollution is significant. For example, Hurricane Katrina (2005) created an estimated 118 million cubic yards of debris. Additionally, the Japanese tsunami, occurred in 2011, also tossed debris to the sea surface, of which 98% were plastic, representing bottles, shoes, combs, crates and buckets, toys, fishing gear, foam insulation attached to building materials, a truck tire, and half of a fiberglass fishing boat. See Marcus Eriksen, 'The Plastisphere..., 157.
397 Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 11 and BIO Intelligence Service, *Plastic Waste...*, 116.
398 Up until the late 1990s, many developed countries dumped sewage sludge at sea, which is still a common practice in other areas of the world. See UNEP, *Plastic in Cosmetics...,* 17.
399 Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 11.
400 Surfers Against Sewage, *Marine Litter Report...*, 12.

ingredients are applied in a variety of leave-on and rinse-off formulations such as: deodorant, shampoo, conditioner, shower gel, lipstick, hair colouring, shaving cream, sunscreen, insect repellent, anti-wrinkle creams, moisturisers, hair spray, facial masks, baby care products, eye shadow, mascara, blush powders and nail polish.[401] While some of these synthetic polymers – such as PE, PP, PET, PMMA (acrylic) and nylon – are large enough to be easily visible to the naked eye (50 to 1000μm), other microbeads on the market are as small as 1μm, depending on the function of the cosmetic formulation.[402]

These products with plastic microbeads are intended to be washed or rinsed down the drain, during or after their use, and presumably captured by municipal wastewater treatment facilities. However, most waste water treatment facilities are not designed to monitor microplastics in influent or effluent streams, and least of all, to monitor microbeads (not even in advanced economies countries).[403] Microbeads are effectively too small to be sifted out at sewage treatment plants. Worse still is the fact that most of the world does not treat its wastewater or incinerate sewage sludge[404] and so most particles flow directly into the aquatic environment, ending up in the sea, where the plastic becomes a persistent pollutant. In practical terms, this means that people washing their faces can result in an act of pollution[405] – circumstance that was first noticed around the 1990s.[406] And this is extremely pernicious since some of these products contain as much plastic added as ingredients as the plastic they are packaged in. Whereas packaging can potentially be recycled, these plastic ingredients

[401] UNEP, *Plastic in Cosmetics* (UNEP, Nairobi, 2015) 6. Based on these example, it is easy to understand that the functions of these polymers clearly go beyond the well-known scrubbing effect of microbeads. So, depending on the polymer type, composition, size and shape, the plastic ingredients have been included in formulations with a vast number of functions including: viscosity regulators, emulsifiers, film formers, opacifying agents, liquid absorbents binders, bulking agents, for an 'optical blurring' effect (of wrinkles), glitters, skin conditioning, exfoliants, abrasives, oral care such as tooth polishing, gellants in denture adhesives, for controlled time release of various active ingredients, sorptive phase (for delivery of fragrances, vitamins, oils, moisturisers, insect repellents, sun filters and a variety of other active ingredients), and prolonging shelf life by trapping degradable active ingredients in the porous particle matrix (effectively shielding the active ingredient from bacteria, which are too big to enter particle pores). See UNEP, *Plastic in Cosmetics...,* 14-5.
[402] ibid 6.
[403] Many WWTPs in the Great Lakes region are not equipped with such treatment systems. In the State of New York, which borders sections of Lakes Ontario and Erie, 66% of WWTPs do not use advanced treatment methods. See Alexander G J Driedger and others, 'Plastic Debris in the Laurentian Great Lakes..., 12. A good example to refer are the modern plants in Sweden and in Saint Petersburg that were reported to retain over 96% of microplastics by filtration. UNEP, *Marine Plastic Debris and Microplastics...*, 41.
[404] UNEP, *Plastic in Cosmetics...,* 27.
[405] For a study focused on the presence of microbeads on facial cleansers, see Lisa S Fendall and Mary A Sewell, 'Contributing to Marine Pollution by Washing Your Face: Microplastics in Facial Cleansers' (2009) 58(8) MPB 1225-8.
[406] José G B Derraik, 'The Pollution of the..., 846.

cannot.[407]

Apart from the difficulty already reported in measuring the quantities of microplastics, microbeads are tougher to measure: they are interspersed with large concentrations of organic matter; it is difficult to distinguish uniform spheres, ellipses and granules with a biofilm from natural particles;[408] and most of the sea water surveys focus on microplastics which are greater than 333μm in size, representing only a fraction of cosmetics formulation plastic particulates.[409] Nonetheless, there are some data we can share: a total amount of 4360 tonnes of microplastic beads were used in 2012 across all European Union countries plus Norway and Switzerland according to a Cosmetics Europe survey; and PE beads represented 93% of the total amount, equalling to 4037 tonnes.[410] In the UK it was estimated that between 4,594 and 94,500 microbeads could pass into the sewage system in a single use.[411] As for the USA, estimates point that the per capita consumption of microplastic used in personal care was approximately 2.4mg per person per day, or 263 tonnes per year of PE microplastic.[412] It was even estimated that 209.6 trillion plastic microbeads enter the water from China every year, which is equivalent to 306,900kg microplastic.[413]

Sewage effluent also contains microfibers from the washing of synthetic textiles. Worldwide, over 40 million tonnes of plastics were converted into textile fibre (mainly nylon, polyester and acrylics) for use in apparel manufacture.[414] Thus, in the last 50 years, the clothing industry has used textiles containing 170% more of synthetic fibre than natural ones

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[407] UNEP, *Plastic in Cosmetics...,* 9.
[408] Mark A Browne, 'Sources and Pathways of Microplastics to Habitats' in Bergmann M, Gutow L and Klages M (eds), *Marine Anthropogenic Litter* (Springer International Publishing, 2015) 233.
[409] UNEP, *Plastic in Cosmetics...,* 20.
[410] T Gouin and others, 'Use of Micro-Plastic Beads in Cosmetic Products in Europe and Their Estimated Emissions to the North Sea Environment' (2015) 141(3) SOFW Journal 44.
[411] Imogen E Napper and others, 'Characterisation, Quantity and Sorptive Properties of Microplastics Extracted from Cosmetics' (2015) 99(1-2) MPB 182. These figures were discovered taking into consideration the following facts: the common application of facial scrub exfoliants occurs once per day, and it has been estimated that they are used by around 1.1 million women in the UK; they focused then on specific products and assumed that the typical daily amount used was 5ml. See ibid.
[412] Imogen E Napper and others, 'Characterisation, Quantity..., 179 citing Gouin T and others, 'A Thermodynamic Approach for Assessing the Environmental Exposure of Chemicals Absorbed to Microplastic' (2011) 45 EST 1466-72.
[413] Saskia Honcoop, '209 Trillion Microbeads enter the Sea from China' (*Beat the Microbead*, 19 June 2017) <www.beatthemicrobead.org/209-trillion-microbeads-enter-the-sea-from-china/> accessed 5 November 2017. The researchers examined nine facial scrubs, whose content varied between 5,219 and 50,391 plastic beads per gram. Taking an average of 1.85g for each use, the researchers estimated that between 10,000 and 100,000 microbeads disappear down the drain every time someone uses a facial scrub.
[414] Anthony L Andrady and Mike A Neal, 'Applications and..., 1980.

(cotton, wool, silk).[415] Once washed the garments, a variable proportion of fibres will be retained by wastewater treatment plants, depending on the existence, design and efficacy of treatment facilities. Although, as happens with the microbeads, a significant number of textile fibres do enter the marine environment, being found, in relatively large numbers, in shorelines and nearshore sediments close to urban population centres.[416] Experiments sampling wastewater from domestic washing machines demonstrated that a single garment can produce plus 1900 fibres per wash. All garments (polyester blankets, fleeces and shirts) released >100 fibres per litre of effluent, with >180% more from fleeces. Problem that gets worse in winter, when the washing machine usage in households is 700% bigger.[417] A more recent study estimated that over 700,000 fibres could be released from an average 6kg wash load of acrylic fabric.[418]

To end the topic of sewage, it is mandatory to refer the impact of sewage sludge in case it contains microbeads and fibres. An Austrian report presented a *from water to soil* perspective, which concluded for the accumulation of plastic particles and fibres in the sewage sludge, ranging from 1,000 to more than 20,000 particles per kilogram of dry mass. Once applied onto farm land for fertilising purposes, they might potentially pass through the soil and reach the ground water.[419] Although microplastics have already been detected in soil after sewage sludge application,[420] the detection of microplastics in ground water has not yet been reported. In fact, soil and sediments build a natural barrier to particles, whose effectiveness is influenced by the particle properties (size, shape, surface charge and density), as well as by the soil properties such as pore size, preferential flow paths, and organic content.[421] To avoid this risk and to effectively remove microbeads and textiles fibres from

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[415] Polycotton clothing contains high levels of PET plastic and high-performance clothing is almost exclusively plastics (polyesters, fluoropolymers and nylons). Fleece clothing is 100% PET and can be made from recycled materials. Most footwear also relies heavily on plastics: the footbed and outsoles are made from polyurethane or other elastomeric material while the uppers might be made of vinyl or another synthetic polymer. See ibid 1980.
[416] UNEP, *Marine Plastic Debris and Microplastics...*, 41. Significant regional differences may be expected due to differences in choice of fabrics (synthetic or natural, length of spun threads), access to mechanical washing facilities, the type of detergents used and frequency of washing.
[417] Mark Anthony Browne and others, 'Accumulations of Microplastic on Shorelines Worldwide: Sources and Sinks' (2011) 45(21) EST 9175 and 9177.
[418] Imogen E Napper and Richard C Thompson, 'Release of Synthetic Microplastic Plastic Fibres from Domestic Washing Machines: Effects of Fabric Type and Washing Conditions' (2016) 112(1-2) MPB 39.
[419] In the UK, over 11km^3 sewage sludge from treatment plants is discharged into inland waters, estuaries and the sea, each year. See Mark Anthony Browne and others, 'Accumulations of Microplastic on Shorelines..., 3.
[420] Philipp Hohenblum, Bettina Liebmann and Marcel Liedermann, *Plastic and Microplastic in The Environment* (Umweltbundesamt GmbH, Vienna, 2015) 16.
[421] Philipp Hohenblum, Bettina Liebmann and Marcel Liedermann, *Plastic and Microplastic...,* 7 and 11-8.

the sludge, a form of advanced filtration is definitely required.[422]

B. Freshwater Pathways: The Prime Intermediary

Rivers are the principal mean of transportation of plastic waste to the sea. All the plastic waste that we have referred (municipal solid waste, construction and demolition waste, pellets and other industrial and agricultural waste, microbeads, textile fibres and other primary or secondary microplastics) can be introduced into marine environments by rivers and streams, regardless of the distance between the water source and the local where the waste was produced. Accordingly, since the 1980s it is known that 88 billion tons of water are estimated to pour from the rivers of the world into the oceans on average every day, carrying eleven and one-half million tons of dissolved matter into the ocean.[423]

Therefore, it is not surprising that some studies report the presence of macro and microplastics in continental waters, in both sediments (predominantly lakeshores but also riverbanks) and water samples (predominantly surface water of lakes and rivers). There are in fact few studies, but they are sufficiently clear to demonstrate that freshwater ecosystems also act, increasingly, as a sink for plastic particles – sometimes in densities comparable to the sea plastic particles –,[424] and pose a threat to the environment almost as great as plastic in the sea. That said, it is of utmost importance to elucidate the fate, fluxes, and some of the impacts of microplastics in lakes and rivers.

In Geneva Lake, in Switzerland, macroplastics and microplastics (primary and secondary, with about eleven years) have been found in significant quantities on the beaches and in the lake surface: fibres, pellets, hard plastics and polystyrene. Polystyrene was the most abundant and was also found largely in seagull faeces throughout the lake's coasts.[425] A posterior study showed that microplastic concentrations varied from 2,656.25 to 5,018.75

[422] Marcus Eriksen, 'The Plastisphere..., 156-7.
[423] Gerard J Mangone, *Law for the World Ocean: Tagore Law Lectures* (Stevens & Sons, London, 1981) 2.
[424] Alexander G J Driedger and others, 'Plastic Debris in the Laurentian Great Lakes..., 10.
[425] Florian Faure and others, 'Pollution due to Plastics and Microplastics in Lake Geneva and in the Mediterranean Sea' (2012) 65 Archives des Sciences 161-2.

particles/m^2, far greater numbers than the highest concentration reported in lakeshore sediments of Lake Garda.[426]

Lake Garda, in Italy, totalled at the north shore of the lake, according to a 2013 study, 483 ± 236 macroplastic particles/m^2 and 1,108 ± 983 microplastic particles/m^2. Since the lake is located close to remote alpine areas, the study predicted that contamination with plastic debris may be of even higher significance in Italian low-land lakes and streams. Nevertheless, this lake is one of northern Italy's most popular tourist destinations, so most waste derived from post-consumer products: cigarette filters, food wrappers and containers. This situation is particularly worrying because the lake is used as a drinking water supply. It has also been shown that a wide range of freshwater invertebrates of different feeding guilds had ingested microplastics, that are visible in their entire gut system.[427]

The Great Lakes of North America have also been surveyed for plastic pollution. Two studies[428] revealed that plastic debris – microplastic beads, pellets, waste from beachgoers, shipping and fishing activities – was present in each of the five lakes and that, along the shorelines, they comprised more than 80% of anthropogenic litter. In certain areas, surface water densities of plastics were as high as those reported for areas of litter accumulation within oceanic gyres, perhaps because these lakes have been polluted since the beginning of plastic mass production. According to the researches, there was a much greater percentage of <1mm microplastic debris in the surface waters of the Great Lakes (81%) comparatively to five other marine and freshwater studies: <1mm plastic pellets represented 58% of the lakes' plastic debris; instead, <1mm plastic debris represented less than 1% of the debris in the North and South Pacific Gyres, while fragments represented 73% and 94%, respectively.

With an average microplastic density of 20,264 particles/km^2, Lake Hovsgol, in Mongolia, is more heavily polluted than the Great Lakes. Lake Hovsgol is characterised by low population density, lack of industry and agriculture and non-existence of modern wastewater or sewage treatment facilities. Lake Hovsgol's high-level of microplastic pollution is thus resultant of the lack of a modern waste management system, as evidenced

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426 Rachid Dris and others, 'Beyond the Ocean: Contamination of Freshwater Ecosystems with (micro-) plastic Particles' (2015) Environmental Chemistry 6.

427 Hannes K Imhof and others, 'Contamination of Beach Sediments of a Subalpine Lake with Microplastic Particles' (2013) 23(19) Current Biology 867.

428 Alexander G J Driedger and others, 'Plastic Debris in the Laurentian Great Lakes..., 9, 10 and 14, and Marcus Eriksen and others 'Microplastic Pollution in the Surface Waters of the Laurentian Great Lakes' (2013) 77(1-2) MPB 177-82.

by the predominance of household plastics, in the form of micro and macroplastic, existent in the lake and its shorelines. In fact, lots of household plastics (fragments and films), a few pellets and no plastic microbeads were observed, especially in the most populated and accessible section of the lake. So, according to the researchers, these facts and figures demonstrated that without proper waste management, low-density populations can heavily pollute freshwater systems with consumer plastics. The study concluded saying that there are laws and plans in place to regulate waste management and reduce waste production in Mongolia, but the infrastructures are almost non-existent.[429]

With respect to rivers, Thames River is actually a vehicle of trash. In 2012, during a three-months-period, waste was collected at seven localities in the upper Thames estuary. As a result, 8,490 submerged plastic items were intercepted in eel fyke nets anchored to the river bed. The items were plastic cups and cutlery, food wrappers, tobacco packaging, sanitary products (representing over 20%, and containing sanitary towels and condoms), plastic bags and other plastic items. Fortunately, for many years the Port of London Authority collected around 250 tonnes of debris each year. In addition, various clean-up programmes regularly remove large quantities of litter from the foreshore and riverbed of the Thames tidal at low water, preventing some waste from entering the sea.[430]

Danube River is also polluted by plastic. A scientific study revealed that plastic abundance in this river was of $316.8 \pm 4{,}664.6$ items/1,000m^3 during the two-year survey between 2010 and 2012. The corresponding plastic input via the Danube into the Black Sea was estimated at 4.2 tonnes/day. Industrial raw materials (pellets, flakes and spherules) accounted for substantial portions (79.4%) of the plastic debris.[431] This river crosses nine borders and its basin extends into the territories of nineteen countries, thus being considered the most international river basin in the world. On that account, an Austrian report highlighted that only international cooperation could cope with the problem of plastic contamination.[432]

The abundance and composition of floating plastic debris, focusing macroplastic, along the Seine River, in France, was also investigated. Twenty-seven tonnes of plastic debris

[429] Christopher M Free and others, 'High-levels of Microplastic Pollution in a Large, Remote, Mountain Lake' (2014) 85(1) MPB 156-63.
[430] David Morritt and others, 'Plastic in the Thames: A River Runs Through It' (2014) 78(1-2) MPB 196.
[431] Rachid Dris and others, 'Beyond the Ocean..., 10-1 citing Lechner A and others, 'The Danube so Colourful: A Potpourri of Plastic Litter Outnumbers Fish Larvae in Europe's Second Largest River' (2014) 188 Environmental Pollution 177-81.
[432] Philipp Hohenblum, Bettina Liebmann and Marcel Liedermann, *Plastic and Microplastic...,* 7.

are intercepted annually by a regional network of floating debris retention booms. A significant proportion of buoyant plastic debris consisted of food wrappers, containers and plastic cutlery.[433]

Lastly, we cannot forget the most polluted rivers of the world, that certainly transport significant quantities of plastic, mainly macroplastics: Buriganga River, in Bangladesh, where 4,500 tonnes of solid waste is dumped every day; Yellow River, in China, where billion tonnes of sewage and other industrial toxic waste are dumped; Yamuna/Jamuna River, in India, whose water is polluted with sewage, municipal waste and agricultural runoff (fertilisers, herbicides, and pesticides) and industrial activities; Ganges River, in India, where many people dump all their waste; and Citarum River, in Indonesia, known as the world's most polluted river, receiving effluents (dyes and chemicals) from over 200 textile factories, and also with plastic and other detritus.[434]

A recent study focusing 240 individual samples from 79 sites near 57 rivers of various sizes around the world, concluded that the quantity of plastic per cubic metre of water was significantly higher in larger rivers than in smaller ones, and that the plastic loads of larger rivers increase disproportionately in relation to the increase of plastic debris available for transport. Furthermore, scientists estimated – using mismanaged plastic waste as a predictor –,[435] that the ten top-ranked rivers transport 88%-95% of the global plastic load into the sea. These rivers – Yangtze, Yellow, Hai, Pearl, Amur, Mekong, Indus and Ganges Delta in Asia, and the Niger and Nile in Africa – have two things in common: a generally high population living in the surrounding region, sometimes into the hundreds of millions;[436] and a less than ideal waste management process.

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433 Rachid Dris and others, 'Beyond the Ocean..., 12 citing Gasperi J and others, 'Assessment of Floating Plastic Debris in Surface Water Along the Seine River' (2014) 194 Environmental Pollution 163-6.

434 For further information, see Golam Kibria, *World Rivers in Crisis: Water Quality and Water Dependent Biodiversity are at Risk - Threats of Pollution, Climate Change and Dams Development* (2016) available at <www.researchgate.net/publication/263852254_World_Rivers_in_Crisis_Water_Quality_and_Water_Dependent_Biodiversity_Are_at_Risk-_Threats_of_Pollution_Climate_Change_and_Dams_Development>.

435 Christian Schmidt, Tobias Krauth and Stephan Wagner, 'Export of Plastic Debris by Rivers into the Sea' (2017) 51(21) EST 12246-53. In short, to predict plastic inputs via rivers into the sea, scientists combined plastic concentrations in rivers with the amount of mismanaged plastic waste generated in the catchments, assuming that the entire river catchment was connected to the coastal sea via the river network.

436 The Yangtze is Asia's longest river and also one of world's most ecologically important rivers, but is also the biggest carrier of plastic pollution to the sea, dumping an estimated 1.5 million metric tons of plastic waste into the Yellow Sea. Its basin is home to almost 500 million people (more than one third of China's population).

C. Ocean-Based Plastic Debris

Maritime activities utilise a wide variety of different types of plastics, of variable sizes, for short-term (packaging) or longer-term use (fishing gear, ropes). Inevitably, some of the items become waste and end up in the sea, and all types of boats, ships and offshore industrial platforms are potential sources.

The debris may originate from accidental loss, indiscriminate littering or illegal disposal, and they can also be the result of waste management disposal practices that were carried out in the past (historical waste management practices).[437-438]

Commercial fisheries sector has adopted plastics widely, because of the many advantages they offer over more traditional natural fibres. Commercial fishermen generate marine debris when they fail to retrieve fishing gear or when they discard fishing gear or other rubbish overboard.[439] This is commonly referred to as abandoned, lost or otherwise discarded fishing gear, and probably represents the largest category in terms of volume and potential impact out of all the sea-based sources.[440] Losses in the fisheries sector comprise loss of fishing gear (nets, ropes, floats, fishing line), loss of ancillary items (gloves, fish boxes, strapping bands), galley waste and release of fibres and other fragments due to normal wear and tear (use of ground ropes).[441]

The quantities lost each year are not well known. The same happens with the type and quantities of fisheries-related marine litter, that change regionally.[442] Yet we know that abandoned, lost or otherwise discarded fishing gear can have a significant impact both on depleting commercial fish and shellfish stocks, causing unnecessary impacts on non-target species and habitats.[443] Crude estimates give a global figure of 640 thousand tonnes per year,[444] with fishing nets being the majority of this debris.

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[437] Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 11 and Seba B Sheavly, 'Marine Debris..., 2.
[438] To deepen the historical argument: 'In 1975, the estimated annual flux of litter of all materials to the ocean was 6.4 million tons [5.8 million metric tons], based only on discharges from ocean vessels, military operations, and ship casualties', José G B Derraik, 'The Pollution of the..., 843. A few years later, in 1982, PV Horsman estimated that merchant ships dumped 639,000 plastic containers each day around the world. See Jenna R Jambeck and others, 'Plastic Waste Inputs..., 768.
[439] Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 12.
[440] UNEP, *Marine Plastic Debris and Microplastics...*, 44.
[441] ibid.
[442] For example, shipping and fisheries are significant contributors in the East Asian Seas region and in the southern North Sea. European Commission, 'Plastic Waste: Ecological and Human Health Impacts'..., 5.
[443] UNEP, *Marine Plastic Debris and Microplastics...*, 44.
[444] ibid citing Macfadyen G, Huntington T and Cappell R, *Abandoned, Lost or Otherwise Discarded Fishing Gear* (FAO, 2009).

Concerning merchant shipping, there have been many occurrences – despite the ban – of loss of cargo, particularly containers which in some cases resulted in spillages of pellets. These losses can be motivated by several contributory factors: overloading of individual containers, fixings in poor condition, placing heavy containers on top of lighter ones, and a lack of appreciation by crews of the additional loadings placed on container stacks in heavy seas and winds leading to a failure to adjust ship speed and heading.[445] These ships may be carrying either commercial goods or waste – transboundary waste movement – to be disposed or treated in other parts of the world. In case of loss, everything becomes waste.

Maritime-based tourism includes cruise ships and another small recreational boats. A cruise ship typically houses several thousand people and generates a waste amount equivalent to that produced on land. Modern vessels have very sophisticated liquid and solid waste management systems, but very often solid waste (galley waste but also sewage-related) is put ashore at ports on small islands with inadequate waste infrastructures. In addition, some cruise companies also indulge in the dubious practice of multiple balloon releases, despite the clear ecological damage it can cause.[446] This type of tourism is a major source of plastic debris in the Mediterranean Sea.[447] In turn, although the actual quantities lost are not known, fishing line and hooks from recreational fishers are commonplace in some regions, such as NW Europe and the Korean Peninsula.[448]

These three activities – and sources – have in common the fact that all of them are propitious to originate household waste (bags, food wrappers, containers, straws, plastic tableware) and sewage water. Diminishing the amount of waste before moor in the seaports is correlated with the reduction of the fees that ships are obliged to pay for the collection and processing of ship-generated waste. Reimbursement, incentives and/or exemptions are not that attractive and sometimes they do not exist at all.

Offshore oil and gas platforms' activities may generate items which are deliberately or accidentally released into the marine environment including hard hats, gloves, 55-gallon

[445] UNEP, *Marine Plastic Debris and Microplastics...*, 45.
[446] Balloon releases are a common practice at parties and weddings. Likewise, Chinese lanterns releases are perilous. As everything that goes up, comes down, these items end up provoking entanglements in threads and metal wires, and its ingestion can cause serious risks of choking.
[447] European Commission, 'Plastic Waste: Ecological and Human Health Impacts'..., 5. In fact, 30% of the world's maritime traffic pass through the Mediterranean Sea. In addition to this, this almost completely enclosed by land, has densely populated coasts and highly developed tourism, which represents additional inputs of litter. Naturally, it registers some of the highest densities of plastic marine litter stranded on the sea floor. See UNEP/MAP, *Marine Litter Assessment in the Mediterranean 2015* (UNEP/MAP, Greece, 2015), 5 and 17.
[448] UNEP, *Marine Plastic Debris and Microplastics...*, 45.

storage drums, survey materials, besides galley waste and sewage-related. Undersea exploration and resource extraction also contribute to marine debris.[449]

Aquaculture, whether it is inland or marine aquaculture, uses plastic hugely. To have an idea, these structures also require many lines (mostly non-buoyant plastics) and cages of various types (thin and thick filament net plastics, buoyant or non-buoyant). Unfortunately, aquaculture structures can be lost due to wear and tear of anchor ropes, due to accidents or conflicts with other maritime users and during storms. If weather conditions are very harsh, they can cause widespread damage to aquaculture structures, generating large quantities of marine debris.[450]

After analysing the sources of marine plastic debris, we can conclude, similarly to the reflexions above, that the plastic waste presently floating in the sea is mainly the result of poor waste management and poor individual behaviour. Another conclusion is that, even though the top countries ranked by mass of mismanaged plastic waste are identified, it is almost impossible to go further than that in determining who is the specific waste producer.[451] There are a few types of sources of plastic waste, but there are a multitude of point and non-point sources. At least, the consequences are easier to determine and some of them are as plain as sad for everyone to see.

[449] Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 12.
[450] UNEP, *Marine Plastic Debris and Microplastics...*, 45.
[451] An exception that is worth to be presented: 'In some cases, it is possible to link the presence of microplastics to particular industrial sectors. For example, data from shorelines in southern Korea indicate that the great majority of microplastic fragments are composed of EPS (Heo et al. 2013). The prevalence in this region is explained by the wide scale use of EPS in buoys for aquaculture installations. Similar high occurrences of EPS have been reported from Japan and Chile, also linked to coastal aquaculture. In most other regions the composition of microplastics will be much more varied and less dominated by a single component, presenting great difficulties in attributing occurrence to a particular source', see GESAMP, *Sources, Fate and Effects of Microplastics in the Marine Environment: A Global Assessment - Reports and Studies GESAMP No. 90* (PJ Kershaw (ed), 2015) 23. This report from GESAMP provides one of the first comprehensive global assessments of microplastics in the marine environment.

VI. The Impacts of Marine Plastic Pollution

A. On Nature

Marine plastic pollution is diffuse, global, with a tendency to be perennial. Therefore, its impacts can potentially affect every marine and aquatic animal.[452] Given that marine plastic debris can be found in all sizes and formats, it is clear that they pose several, and wide ranging, threats to marine life. The chemical composition of the debris, as well as the amount of debris an animal encounters can also damage marine ecosystems and its components.

Only in the last twenty years, the threat posed by plastic to the marine environment, and its seriousness, has been recognised. At the same time, reports on the referred effects have been increasing in quantity and quality, actually demonstrating marine debris impacts.

Two distinct types of effects resulting from the encounters with marine plastic litter can be identified: direct effects, related mostly to plastic physical properties, comprising interactions, entanglement and ingestion; and indirect effects, related mostly to the toxicity associated to ingestion.

Interactions are simpler and in general less harming than the other impacts referred. It includes 'non-entangling contact with debris, such as collision or blanketing, as well as debris presenting an obstruction, providing shelter, or acting as a substrate for growth and/or transport'.[453] In particular, derelict fishing gear has been shown to cause tissue abrasion and

[452] Plastics can indeed harm any animal, either on land or water. On land, plastics dominate desert landscapes, and wind-driven micro and nanoplastic particles can reach distant terrestrial biomes, evidenced by the inadvertent collection of these particles by pollinating insects. See Marcus Eriksen, 'The Plastisphere..., 155 citing Zylstra E, 'Accumulation of Wind-Dispersed Trash in Desert Environments' (2013) 89 Journal of Arid Environments 13-15, and Liebezeit G and Liebezeit E, 'Non-Pollen Particulates in Honey and Sugar' (2013) 30 Food Additives & Contaminants: Part A 2136-40. In deserts, plastic pollution has reached 'epidemic' proportions, as evidenced in Marc Breulmann and others, *The Camel: From Tradition To Modern Times – A Proposal Towards Combating Desertification – via the Establishment of Camel Farms Based on Fodder Production From Indigenous Plants and Halophytes* (UNESCO Doha Office, 2007) 17-8: 'in general, every year hundreds of animals face agonizing deaths by ingestion of plastic in the deserts, the seas and even in the cities. (...) Over the last decade many animals which were necropsied at the Central Veterinary Research Laboratory (CVRL) in Dubai, died from trash ingestion; including camels, cattle, sheep, goats, gazelles, ostriches and houbara bustards'. Dr. Ulrich Wernery, scientific director at the Central Veterinary Research Laboratory in Dubai, unveiled that camels can accumulate, in their stomachs, rocks of calcified plastic weighing up to 60kg, so it is no wonder that one in every two camels dies from plastic ingestion. See 'Plastic Bags Kill Hundreds of Camels: UAE Vet' (*Al Arabiya News*, 24 January 2008) <www.alarabiya.net/articles/2008/01/24/44652.html> accessed 7 April 2017.
[453] Kara Lavender Law, 'Plastics in the Marine Environment'(2017) 9 Annual Review of Marine Science, 218.

breakage when colliding with sessile invertebrates, in coral reef ecosystems.[454] In addition, the same fishing gear can keep on breaking the reef until it becomes too heavy with the attached coral and sinks, or it can be incorporated into the reef structure. In some places, the weight and shading effects of the biggest debris will reduce light levels needed for growth, which can suffocate plants (and smother seedlings), reduce photosynthetic rates and lead to eventual senescence of above-ground biomass.[455] Scenarios like this were observed in mangrove forests in Papua New Guinea,[456] in two species of seagrass sited in Florida Keys National Marine Sanctuary,[457] and in coral colonies existent in Majuro lagoon, Republic of the Marshall Islands,[458] and in Oahu, Hawaii.[459]

Another effect is the use of plastic debris (regardless of their size), by a large number of organisms ranging from microorganisms to sessile and mobile invertebrates, as rafts to grow, colonise and travel great distances in the oceans, transported by currents and winds. Indeed, marine plastic debris' high abundance and lengthy durability provide a substrate that lasts much longer than most natural floating substrates (macroalgae and tree trunks). This way, marine plastic debris become a major potential vector for the dispersal of organisms, and not only of POPs, as seen above. This rafting process is, more and more, a mechanism for dispersal of species, which can settle in areas where they are non-native and that can lead to massive population growth of *alien species*, and perhaps harm or out-compete the native ones and damage littoral, intertidal and shoreline ecosystems. The truth is that long-distance

[454] BIO Intelligence Service, *Plastic Waste...*, 115 citing NOAA and US Department of Commerce, *Coral Reef Restoration Through Marine Debris Mitigation* (NOAA, 2005).
[455] Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter on Marine Life' in Bergmann M, Gutow L and Klages M (eds), *Marine Anthropogenic Litter* (Springer International Publishing, 2015) 84.
[456] Stephen DA Smith, 'Marine Debris: A Proximate Threat to Marine Sustainability in Bootless Bay, Papua New Guinea' (2012) 64(9) MPB 1880-3.
[457] Thalassia testudinum and syringodium filiforme had significantly decreased shoot densities after experimental deployment of traps on the sea bed. See Amy V Uhrin, Mark S Fonseca and Gregory P DiDomenico, 'Effect of Caribbean Spiny Lobster Traps on Seagrass Beds of the Florida Keys National Marine Sanctuary: Damage Assessment and Evaluation of Recovery' (2005) 41 American Fisheries Society Symposium 579-88.
[458] It was observed a significant negative relationship between the level of marine litter cover and coral cover, demonstrating that marine debris can cause suffocation, shading, tissue abrasion and mortality of corals. See Zoe T Richards and Maria Beger, 'A Quantification of the Standing Stock of Macro-debris in Majuro Lagoon and its Effect on Hard Coral Communities' (2011) 62(8) MPB 1693-701. A recent study, that covered 159 reefs in the Asia-Pacific region from 2011 to 2014, assessed the influence of plastic waste on disease risk in 124,000 reef-building corals, and the results were: the likelihood of disease increased from 4% to 89% when corals are in contact with plastic. See Joleah B Lamb and others, 'Plastic Waste Associated with Disease on Coral Reefs' (2018) 359(6374) Science 460-2.
[459] In 1998, it was reported that 65% of cauliflower coral colonies in Oahu, Hawaii were covered with fishing lines, and that 80% of colonies were either entirely or partially dead due to fishing lines. See Tomoko Yoshikawa and Kazue Asoh, 'Entanglement of Monofilament Fishing Lines and Coral Death' (2004) 117(5) BC 557-60.

transportation of floating debris with associated organisms is known to occur,[460] but the establishment of non-native or potentially invasive species transported by plastic floating debris has never been solidly demonstrated.[461]

Plastic serves, therefore, as a novel ecological habitat in the open ocean – fact that determined the introduction of the new term *plastisphere community* –,[462] but the same thing happens onshore as well. At the beach, some crustaceans find plastic debris where they choose to live or take shelter, instead of choosing a true shell. In fact, plastic debris existent on the beaches have an influence on the quantity and types of organisms living and breeding at that spot. There are a few reports on the difficulty that marine turtles face during hatchling migration, and the reason is that some beaches are so polluted with plastic debris that turtles are not able to dig a nest at an appropriate site.[463]

a. Entanglement

Any animal living in the ocean, or living off the sea (and rivers), is a potential victim of entanglement. Meso and macroplastic debris can encircle, constrict or entrap marine animals, and the same can happen with the so-called ghost fishing.

There are, however, several behavioural traits that increase the likelihood of entanglement: plastic debris harms particularly sea turtles and marine mammals, such as fur

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460 Kara Lavender Law, 'Plastics in the Marine Environment'..., 221 citing Calder DR and others, 'Hydroids (Cnidaria: Hydrozoa) from Japanese Tsunami Marine Debris Washing Ashore in the Northwestern United States' (2014) 9(4) Aquatic Invasions 425-40. See also Sarah C Gall and Richard C Thompson, 'The Impact of Debris on Marine Life' (2015) 92 MPB 174.

461 Chelsea M Rochman and others, 'The Ecological Impacts of Marine Debris: Unraveling the Demonstrated Evidence from what is Perceived' (2016) 97(2) Ecology 303. Mark Anthony Browne and others, 'Linking Effects of Anthropogenic Debris to Ecological Impacts' (2015) 282 PTRSB 4, explained the following: 'animals and plants on stranded litter are frequently found dead, but whether they were alive when they reached the shore is not known. If not, there is no possibility of serious impacts. Linkages between the documented presence of algae and invertebrates on debris floating in the open ocean, their arrival, survival and capability of reproduction in novel habitats, and, thus, their subsequent establishment of viable populations, have not been established'. A different perspective, assuring that 'reproductively active organisms have been observed on numerous occasions' can be found in Tim Kiessling, Lars Gutow and Martin Thiel, 'Marine Litter as Habitat and Dispersal Vector' in Bergmann M, Gutow L and Klages M (eds), *Marine Anthropogenic Litter* (Springer International Publishing, 2015) 141-81, especially 156.

462 *Plastisphere community* term was introduced for microbial communities, being defined as representing a 'diverse microbial community of heterotrophs, autotrophs, predators, and symbionts'. See Erik R Zettler, Tracy J Mincer and Linda A Amaral-Zettler, 'Life in the "Plastisphere": Microbial Communities on Plastic Marine Debris' (2016) 47 EST 7137.

463 Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 85.

seals and sea lions, especially the younger.[464] These mammals feed themselves on the surface of the ocean, and they are attracted to floating debris because they are curious and playful. So, they dive and roll over them, ending up poking their heads into loops, six pack rings and plastic bags that can easily slip onto their necks. The lie of their long guard hairs prevents the plastic from slipping off, and as a consequence, many seal pups grow up with plastic collars, that, as they get tighter, can cause deep wounds and strangulation.[465]

In turn, ghost fishing is a particular form of entanglement. It is estimated that 10% of all waste entering the oceans every year consists of ghost nets.[466] Discarded or lost fishing nets and lines – once made of cotton and other biodegradable materials that quickly disintegrated in salted water –, crab/shrimp pots and other recreational or commercial fishing equipment[467] continue to trap and catch fish and others even when they are no longer in use. Organisms trapped in these nets and pots may die and/or attract predators, that may also become trapped. In essence, 'ghost nets are perpetual killing machines that never stop fishing (Estaban 2002)',[468] and the following examples demonstrate precisely this. In 1978, south of the Aleutian Island, it was found a 1500-metre-long ghost net, which contained 99 dead seabirds, two dead salmon-sharks and over two hundred dead salmons. Presumably, this net was adrift for about a month and travelled over 60 miles.[469] In 1984, in a survey held off the coast of Japan, it was estimated that 533 fur seals were entangled and drowned in nets lost in

[464] Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 80-2. Age is really a worrying factor. Along with lack of experience, age plays a significant role in pinnipeds, as younger seals are more often entangled than adults. Gannets and many other seabird species use seaweed to build their nests and frequently incorporate ropes, nets and other anthropogenic debris. Evidently, the risk of mortal entanglement for both adult birds and chicks increases. In three of the six North American gannet populations, close to 75% of the gannet nests contained fishing debris. Its frequency can be linked to the level of gillnet fishing effort in the waters around the colonies. See ibid 81 citing Bond AL and others, 'Prevalence and Composition of Fishing Gear Debris in the Nests of Northern Gannets (Morus bassanus) are related to Fishing Effort' (2012) 64 MPB 907-11.

[465] José G B Derraik, 'The Pollution of the..., 846.

[466] Francois Galgani and others, 'Marine Litter within the European Marine Strategy Framework Directive' (2013) 70(6) ICES Journal of Marine Science 1057, citing Macfadyen, G, Huntington, T, and Cappell, R, 'Abandoned, Lost or Otherwise Discarded Fishing Gear' (UNEP Regional Seas Reports and Studies 185 and FAO Fisheries and Aquaculture Technical Paper 523, 2009).

[467] Fish aggregating devices – which are man-made floating objects using plastic nets to attract pelagic species such as tuna – also constitute a form of lost or abandoned fishing gear that has the potential to entangle marine species, including juvenile tuna, turtles, rays and sharks. See Stephanie Newman, Emma Watkins and Andrew Farmer, *How to Improve EU Legislation to Tackle Marine Litte*r (Institute for European Environmental Policy, London, 2013) 24.

[468] Seba B Sheavly, 'Marine Debris..., 3. Environmental conditions have an important influence on the lifetime of a net: nets lost in calm waters near oceanic convergence zones may continue to fish for decades while nets that are lost in areas of large swell and storm activity may be rapidly torn apart and destroyed. See BIO Intelligence Service, *Plastic Waste...*, 114.

[469] José G B Derraik, 'The Pollution of the..., 846 citing DeGange AR and Newby TC, 'Mortality of Seabirds and Fish in a Lost Salon Driftnet' (1980) 1 MPB 322-3.

the area.[470]

Regardless of how it occurs, entanglement in plastic debris can provoke very serious consequences to marine animals: bodily harm, such as injury to dermal tissue, causing sepsis; interference with growth, potentially causing deformations;[471] and restricted movement affecting swimming, feeding, and the ability to escape predators. The result can be death by drowning, strangulation, and starvation due to reduced feeding efficiency or predation.[472] Ironically, as we already mentioned, once the entangled animal dies and decomposes, the plastic item is free again to be picked up by another victim.[473] Specifically, cetaceans are prone to injuries in caudal peduncles, pectoral flippers and mouths. Seabirds become entangled around the bill, wings and feet with rope-like materials, including balloons, which constrains their ability to fly or forage properly. Turtles entanglement, at sea or on land, can cause skin infections, amputations of legs and septic processes. Sharks' mouth opening is reduced, impairing foraging and gill ventilation. Crabs, octopuses, fishes and a wide range of smaller marine biota are known to get caught in derelict traps on the seafloor and die from stress, injuries or starvation, as escape is difficult or impossible.[474] When an entangled animal is signalised, action is taken immediately, whether by scientists or fishermen. However, the rescue is not always possible.

To conclude, we note, with no surprise, that entanglement has frequently been described as a serious mortality factor, leading to potential losses in biodiversity. The decline of deep-water sharks in the North Atlantic has actually been linked to ghost fishing in the region.[475] Besides resulting in economic losses for fisheries, entanglement raises concern about the conservation of fish stocks in some areas.[476]

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[470] ibid citing Laist D, 'Overview of the Biological Effects of Lost and Discarded Plastic Debris in the Marine Environment' (1987) 18(6) MPB 319-26.

[471] The effects of entanglement can last forever. *Mae West* turtle was found in the late 1990s, in New Orleans, with a plastic ring from the neck of a milk jug bound around its waist. The constriction from the plastic ring prevented the shell and vertebrae from fusing, resulting in an hourglass-shaped carapace. See Marcus Eriksen, 'The Plastisphere..., 158. The turtle is still alive and lives in a natural reserve where it is shown as an example of the harmfulness of plastic.

[472] Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 6 and G Wurpel and others, *Plastics do not Belong in the Ocean. Towards a Roadmap for a Clean North Sea* (IMSA Amsterdam, 2009) 41.

[473] Kara Lavender Law, 'Plastics in the Marine Environment'..., 219.

[474] Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 79.

[475] Francois Galgani and others, 'Marine Litter..., 1057 citing Large PA and others, 'Lost and Abandoned Nets in Deep-water Gillnet Fisheries in the Northeast Atlantic: Retrieval Exercises and Outcomes' (2009) 66 ICES Journal of Marine Science 323-3.

[476] Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 6.

b. Ingestion of Debris

Once in the water, all plastic debris can be eaten by the animals that inhabit marine and freshwater ecosystems. Reports of ingestion of plastic debris are widespread and increase as investigators study a broader range of marine organisms, from planktonic invertebrates to large marine mammals.[477] These findings suggest that ingestion of plastic debris may be intentional or accidental (secondary or indirect). Animals do it intentionally because they mistakenly think, due to an olfactory stimulus, that plastic debris is food. A 2016 study demonstrated experimentally ‘that marine-seasoned microplastics produce a dimethyl sulfide (DMS) signature that is also a keystone odorant for natural trophic interactions’.[478] The scientists further demonstrated ‘a positive relationship between DMS responsiveness and plastic ingestion frequency using procellariiform seabirds as a model taxonomic group’,[479] and so ‘together, these results suggested that plastic debris emits the scent of a marine infochemical, creating an olfactory trap for susceptible marine wildlife’.[480]

In addition, other reasons – that vary among different animal groups – can explain why some animals intentionally ingest plastic debris: foraging strategy, age and debris colour. Foraging strategy is most closely linked to seabirds, especially with pursuit-diving birds, which have the highest frequency of plastic uptake, followed by surface-seizing and dipping seabirds.[481] Omnivores are most likely to confuse plastic for preys than animals with specific diets, that only misidentify plastic if a particular type resembles their prey.[482] Gull species frequently go to rubbish bins and landfill areas, in addition to foraging in marine habitats,

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[477] Kara Lavender Law, ‘Plastics in the Marine Environment’..., 218.
[478] Matthew S Savoca and others, ‘Marine Plastic Debris Emits a Keystone Infochemical for Olfactory Foraging Seabirds’ (2016) 2(11) Science Advances 1. DMS and its chemical precursor, dimethylsulfoniopropionate (DMSP), were found to be the ideal candidate molecules for this kind of investigation once they serve as infochemicals for microfauna to macrofauna in foraging cascades.
[479] ibid. Members of procellariiform order (which include albatrosses, petrels and shearwaters) are highly olfactory, pelagic and wide-ranging, foraging over vast expanses of the open ocean. It turned out that the results from controlled experimental studies performed at sea have demonstrated that some procellariiform species responded to DMS and used it as a cue to localise prey, whereas other species were more responsive to odours associated with higher trophic interactions. Procellariiform order was not chosen to survey by chance: this order has been severely affected by plastic consumption, and sufficient data were already in place to test hypotheses about whether plastic ingestion may be linked or not to olfactory foraging across this phylogenetic group.
[480] ibid. It happens that three different types of plastic (HDPE, LDPE, and PP) took on the odour signature of DMS at concentrations of 10^{-5} to 10^{-8} M. This process occurred in less than one month of exposure at the offshore sites tested (at two oceanographic buoys in the California current: Bodega Marine Laboratory and Hopkins Marine Station), ibid 3.
[481] Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, ‘Deleterious Effects of Litter..., 87-8.
[482] ibid 88 citing Ryan PG, ‘The Incidence and Characteristics of Plastic Particles Ingested by Seabirds’ (1987) 23 Marine Environmental Research 175-206.

while marine turtles frequently ingest plastic bags – especially during winter and during their younger oceanic life stages – that can be mistaken for jellyfish, a common component of their diet, but a little scarce in winter.[483] In addition, moved by curiosity, large predatory fishes and birds are known to frequently inspect plastic debris and take bites out of larger plastic items.[484]

Although the reasons are not entirely clear,[485] younger animals are the most affected. Indeed, immature turtles,[486] chicks of Laysan albatrosses,[487] younger northern fulmars,[488] younger Franciscana dolphins off the Argentinian coast,[489] and younger harbour seals in the Netherlands have more plastic in their stomachs than adults.[490] In the case of seabirds, mainly albatrosses and petrels, this could partly be explained by parental delivery of food by regurgitation to chicks at the nest. As they grow, they develop the ability to regurgitate, but sometimes it is too late: most dead Laysan albatross chicks on Midway Atoll have been found to contain plastics in their guts, with items such as disposal cigarette lighters, toys and fishing gear.[491]

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[483] The physiology of some species of turtles makes it extremely difficult for the animal to eliminate the material already ingested. It is no wonder that dead turtles frequently have large quantities of plastic sheeting and plastic bags in their gut compartments: 'plastics have been found in the guts of Loggerhead turtles in the Adriatic Sea (Lazar and Gracan 2011) and western Mediterranean (Camedda et al. 2014), the eastern Atlantic around the Azores (Barreiros and Raykov 2014) and in the SW Indian Ocean around Reunion Island (Hoarau et al. 2014)', see UNEP, *Marine Plastic Debris and Microplastics...*, 93.

[484] Bite marks – to test materials – of sharks and large predatory fishes on plastic debris wash ashore in Hawaii very often. About 16% of the plastic items collected have these marks. See Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 88 citing Carson HS and others, 'Tracking the Sources and Sinks of Local Marine Debris in Hawaii' (2013) 84 Marine Environmental Research 76-83.

[485] ibid 90.

[486] After analysing 37 studies published from 1985 to 2012, the scientists concluded that 'smaller oceanic turtles are more likely to ingest debris than larger turtles (Plotkin & Amos 1990; Schuyler et al. 2012). Balazs (1985) presented similar results: 69% of ingested debris, whereas 31% of adult turtles ingested debris'. In addition, their relatively small and thinner digestive systems will be more vulnerable to impaction and perforation from the debris. See Qamar Schuyler and others, 'Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles' (2013) 28(1) Conservation Biology 129 and 136.

[487] See Holly Gray, Gwendolyn Lattin and Charles J Moore, 'Incidence, Mass and Variety of Plastics Ingested by Laysan (Phoebastria immutabilis) and Black-footed Albatrosses (P. nigripes) Recovered as by-catch in the North Pacific Ocean' (2012) 64 MPB 2190-2.

[488] Jan A van Franeker and others, 'Monitoring Plastic Ingestion by the Northern Fulmar *Fulmarus glacialis* in the North Sea' (2011) 159 Environmental Pollution 2609-11.

[489] Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 90 citing Denuncio P and others, 'Plastic Ingestion in Franciscana Dolphins, Pontoporia Blainvillei (Gervais and D'Orbigny, 1844), from Argentina' (2011) 62 MPB 1836-41.

[490] Elisa L Bravo Rebolledo and others, 'Plastic Ingestion by Harbour Seals (*Phoca vitulina*) in The Netherlands' (2013) 67(1-2) MPB 200-1.

[491] UNEP, *Marine Plastic Debris and Microplastics...*, 94. In such chicks, elevated loads of plastic can be the consequence of being fed by two parents, each transferring much of its own plastic load. In addition, the less developed grinding action in the gizzards of young birds slows the mechanical break-down of plastic and removal through the intestines. See Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 90.

At last, debris colours seem to have some influence in their rate of consumption. Specific colours might attract predators when resembling the colours of their preys.[492]

In turn, accidental plastic ingestion occurs when animals feed on prey, directly (swallowed as a whole[493] or scavenging)[494] or by filter feeding. In both cases, especially in the first, the prey – ranging in size from zooplankton,[495] crustaceans, shellfish and other

[492] To further support the influence of colour on bioavailability, see Stephanie L Wright, Richard C Thompson and Tamara S Galloway, 'The Physical Impacts of Microplastics on Marine Organisms: A Review' (2013) 178 Environmental Pollution 485, and the cases listed in Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 89.

[493] In seabirds, 'skuas are known to forage on smaller seabirds that consume plastic (Ryan 1987). Great skuas (Stercorarius skua) from the South Atlantic Ocean predate several seabird species, and their regurgitated boluses showed a link with the amount of secondarily ingested plastic and their main prey species (Bourne and Imber 1982; Ryan and Fraser 1988)', see Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 92. Plastics and other non-food items were found in stomachs of harbour seals in the Netherlands and it was considered 'to have been accidentally ingested when catching prey fishes (Bravo Rebolledo et al. 2013). A similar route for plastic ingestion was proposed by Di Beneditto and Ramos (2014), who showed that plastic in franciscana dolphins was related to benthic feeding habits, in which disturbance of sediment probably induced accidental intake of plastic debris', ibid. A special case of such accidental ingestion is known for the Laysan albatross who take up plastic particles in combination with eggs strings of flying fish. The fishes used to attach their eggs to floating items such as seaweed and bits of wood or pumice, but nowadays they resort to plastic objects. This phenomenon has also been observed in loggerhead turtles, whose stomachs' plastic items were sometimes covered by the eggs of the insect Halobates micans. See ibid 91.

[494] In the monitoring study on northern fulmars (*Fulmarus glacialis*), in the North Sea, intact stomachs from scavenged fulmars or black-legged kittiwakes (*Rissa tridactyla*) were occasionally found, and they contained plastic, see van Franeker and others, 'Monitoring Plastic Ingestion... 2609-15.

[495] Resorting to an acid digestion method, microplastic fibres and fragments were detected in two species of zooplankton (calanoid copepod *Neocalanus cristatus* and euphausiid *Euphausia pacifia*) sampled at multiple sites in the northeast Pacific Ocean. Encounter rates were: 25 plastic particles detected after digestion of 960 individual copepods resulting in an encounter rate of approximately one particle/every 34 copepod analysed; for euphausiids, a total of 24 particles were detected from 413 individuals resulting in an encounter rate of one particle/every 17 euphausiids. See Jean-Pierre W Desforges, Moira Galbraith and Peter S Ross, 'Ingestion of Microplastics by Zooplankton in the Northeast Pacific Ocean' (2015) 69(3) Archives of Environmental Contamination and Toxicology 320 and 324. Another experience, in which were used fluorescent polystyrene beads and coherent anti-stokes Raman scattering microscopy, demonstrated that 13 zooplankton taxa, including holoplankton, meroplankton, and microzooplankton, had the capacity to ingest (with uptake varying by taxa, life-stage and bead-size) polystyrene beads in the absence of natural food. Not only copepods egested faecal pellets laden with microplastics, but also microplastics have adhered to the external carapace and appendages of the exposed zooplankton. See Matthew Cole and others, 'Microplastic Ingestion by Zooplankton' (2013) 47(12) EST 6646. For experiments carried out in the Baltic Sea, see Outi Setälä, Vivi Fleming-Lehtinen and Maiju Lehtiniemi, 'Ingestion and Transfer of Microplastics in the Planktonic Food Web' (2014) 185 Environmental Pollution 77-83.

invertebrates,[496] to fishes[497] and seabirds[498] –, had already ingested plastic debris. It has also been proven that microplastics can be trophically transferred through predator-prey interactions from copepods to mysid shrimp, mussels to crabs, and from fish to langoustine.[499] Seaweeds also represent an efficient pathway for microplastics from the water to marine benthic herbivores.[500]

In relation to filter feeding, animals feed themselves by separating food particles from water. During this process, they intake the plastic debris contained in the large volume of water filtered. Non-food items can be ejected before passaging through the digestive system, but that does not happen with the majority of animals. In their natural habitat, ingested plastics have been found in filter feeding crustaceans such as goose barnacles,[501] sea cucumbers,[502]

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[496] Lisbeth van Cauwenberghe and others, 'Microplastics are taken up by Mussels..., 10-7. In the summer of 2011, two species of marine invertebrates representing different feeding strategies – the filter feeding blue mussel Mytilus edulis (filter feeder) and the nonselective feeding lugworm Arenicola marina (deposit feeder) – were collected at six locations along an 80km stretch of coast, covering the entire Belgian coastline and adjacent areas in France and the Netherlands. Microplastics were present in all organisms collected in the field: on average 0.2 ± 0.3 microplastics per gram tissue (M. edulis) and 1.2 ± 2.8 particles per gram tissue (A. marina). Lugworms feed on the organic fraction of ingested sediment and as a result process a wide range of particles. In turn, considering these mussels can filter nearly 24L of seawater per day and considering the average concentrations of microplastics in seawater measured (0.4 ± 0.3 particles L^{-1}), it is possible to estimate that a mussel will be exposed to, and potentially take up, approximately 10particles/day.

[497] The presence of small plastic particles in the faeces of fur seals on Macquarie Island was attributed to secondary ingestion through the consumption of myctophid fishes. In fact, the high abundance of small plastic in myctophid fishes, in combination with the fact that this type of fish is a common prey for many larger marine predators, suggests that secondary ingestion may be more common than reported. See Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 92.

[498] The first assessment of plastic ingestion in Mediterranean seabirds dates from 2013. Spanish investigators quantified and measured plastics accumulated in the stomach of 171 birds from 9 species accidentally caught by longliners in the western Mediterranean from 2003 to 2010. The following 3 threatened species were particularly exposed to plastic accumulation: 'Cory's shearwaters (Calonectris diomedea) showed the highest occurrence (94%) and large numbers of small plastic particles per affected bird (on average N= 15.3 ± 24.4 plastics and mass= 23.4 ± 49.6 mg), followed by Yelkouan shearwaters (Puffinus yelkouan, 70%, N= 7.0 ± 7.9, 42.1 ± 100.0 mg), Balearic shearwaters (Puffinus mauretanicus, 70%, N= 3.6 ± 2.9, 5.5 ± 9.7 mg) and the rest of species (below 33%, N= 2.7, 113.6 ± 128.4 mg)'. Plastic characteristics did not differ between sexes and were not related to the physical conditions of the birds. See Marina Codina-García and others, 'Plastic Debris in Mediterranean Seabirds' (2013) 77(1-2) MPB 220.

[499] Mathew Cole and others, 'Microplastics Alter the Properties..., 3244.

[500] It was proven that 'the numbers of microplastics that adhered to the algae correlated with the concentrations of suspended particles in the water. In choice feeding assays L. littorea did not distinguish between algae with adherent microplastics and clean algae without microplastics, indicating that the snails do not recognize solid nonfood particles in the submillimeter size range as deleterious'. In periwinkles that were feeding on contaminated algae, microplastics were found in the stomach and in the gut (but none in the midgut gland) and most were released with the faeces. See Lars Gutow and others, 'Experimental Evaluation of Seaweeds as a Vector for Microplastics into Marine Food Webs' (2016) 50(2) EST 915.

[501] Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 91 citing Goldstein MC and Goodwin DS 'Gooseneck Barnacles (Lepas spp.) Ingest Microplastic Debris in the North Pacific Subtropical Gyre' (2013) 1(e184) PeerJ 17.

[502] Lisbeth van Cauwenberghe and others, 'Microplastics are taken up by Mussels..., 11 citing Graham ER and Thompson JT, 'Deposit- and Suspension-feeding Sea Cucumbers (Echinodermata) Ingest Plastic Fragments' (2009) 368(1) Journal of Experimental Marine Biology Ecology 22-9.

mussels, herrings and horse mackerels from the North Sea and the English Channel,[503] and large baleen whales.[504]

Considering everything said above, it is evident that plastic debris, especially microplastics, are spread throughout the trophic levels of the marine food web. The small size of the plastic particles makes them bioavailable to almost all organisms throughout the food web, and this represents a severe threat to marine biota. Zooplankton ingest microplastics, that are naturally expelled. These faecal pellets – now containing microplastics – are a source of food for marine organisms, contributing to the oceanic vertical flux of particulate organic matter as part of the biological pump (transporting polyoxymethylene, nutrients, carbon and energy to deeper waters and the benthos), thus providing its absorption by a wider range of organisms. Moreover, it was already clearly demonstrated that microplastics inferior to one millimetre encompassed within copepod Calanus typicus faecal pellets could be transferred to a larger copepod (Calanus helgolandicus) via coprophagy.[505]

As an aggravating factor, plastics items, including resin pellets, fragments and microscopic particles, contain organic compounds used as additives,[506] as described in the Section D of Chapter II. In the marine environment it is no different,[507] and the organic compounds can be transferred from plastic to organisms, as assured both by mathematical model using equilibrium partitioning and by experimental data.[508] But the problem gets even more serious because plastics carry not only additive-derived chemicals but they also absorb, on their surface, the persistent organic pollutants agglomerated in the surrounding waters.[509-510] Consequently, plastic particles become concentrators and transporters of an excessive

503 See Foekema EM and others, 'Plastic in North Sea Fish' (2013) 47(15) EST 8818-24 and Lusher AL, McHugh M and Thompson RC, 'Occurrence of Microplastics in the Gastrointestinal Tract of Pelagic and Demersal Fish from the English Channel' (2013) 67(1-2) MPB 94-9.

504 Examples of which have already been presented in the introduction of this thesis. See also Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 91.

505 Mathew Cole and others, 'Microplastics Alter the Properties..., 3239-44.

506 Organic compounds include polyfluorinated compounds (PFC) and polybrominated diphenyls (PBDEs), and 'polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons, petroleum hydrocarbons, organochlorine pesticides (2,20-bis(p-chlorophenyl)-1,1,1-trichloroethane, hexachlorinated hexanes), polybrominated diphenylethers, alkylphenols and bisphenol A'. See Emma L Teuten and others, 'Transport and Release of Chemicals from Plastics to the Environment and to Wildlife' (2009) 364 PTRSB 2027-8.

507 In terrestrial environments, plasticisers, other plastics additives and constitutional monomers also present potential threats because they can leach from waste disposal sites into groundwater and/or surface waters.

508 ibid 2027.

509 Lorena Rios, Charles Moore and Patrick Jones, 'Persistent Organic Pollutants Carried by Synthetic Polymers in the Ocean Environment' (2007) 54(8) MPB 1230-7.

510 Plastics also sorb heavy metals from seawater: primary microplastics produced for air blasting technology – which are used repeatedly until they diminish in size and their cutting power is lost – often become contaminated

quantity of hydrophobic toxic chemicals in the marine environment,[511] and these organic pollutants can become orders of magnitude more concentrated on the surface of the plastic than in the surrounding water.[512]

As a result of predator-prey interactions, some harmful compounds are passed on or accumulated, in higher concentrations, along the food chain – phenomenon called biomagnification – making them available to an array of marine invertebrates commonly not affected by larger marine debris.[513]

Many of these chemicals are already known to have adverse effects on organisms. However, getting to know the extent of the transfer of chemicals from plastic to the animal tissue upon ingestion will depend on the chemical concentration in the plastic[514] and on the body burden already present in the animal (from other exposure pathways, such as through the food web or uptake from seawater through the dermis or gills). In addition, chemical transference depends on the fugacity gradient between the ingested plastic and gut tissue, which can be affected by the presence of natural food, as well as the residence time of plastic

with heavy metals (such as cadmium, chromium and lead). See Matthew Cole and others, 'Microplastics as Contaminants in the Marine Environment: A Review' (2010) 62 MPB 2589.

[511] Hisashi Hirai and others, 'Organic Micropollutants in Marine Plastics Debris from the Open Ocean and Remote and Urban Beaches' (2011) 62 MPB 1683-92. Worldwide plastic pellets' distribution and its POPs are registered by International Pellet Watch (IPW). It is a volunteer-based global monitoring program designed to monitor the pollution status of the oceans, by analysing pollutants in pellets. Since its launch in 2005, 80 groups and individuals from 50 countries have been participating in this project to cover nearly 200 locations around the world. The website associated is <www.pelletwatch.org/index>. In 2012, the IPW monitored of a wide range of organic micropollutants from nine locations on the Portuguese coast (Matosinhos, Costa Nova, Vieira de Leiria, Alcobaça, Gamboa, Guincho, Algés, São Torpes and Bordeira) using plastic resin pellets: 'concentrations of a sum of 13 PCBs were one order of magnitude higher in two major cities (Porto: 307 ng/g-pellet; Lisboa: 273 ng/g-pellet) than in the seven rural sites. Lower chlorinated congeners were more abundant in the rural sites than in the cities, suggesting atmospheric dispersion'. This investigation 'demonstrated that multiple sample locations, including locations in both urban and remote areas, are necessary for country-scale pellet watch', see Kaoruko Mizukawa and others, 'Monitoring of a Wide Range of Organic Micropollutants on the Portuguese Coast Using Plastic Resin Pellets' (2013) 70 (1-2) MPB 296-302.

[512] Emma L Teuten and others, 'Transport and Release..., 2038. In fact, because of their strong attraction to persistent, bioaccumulative and toxic substances, some plastics are utilised as passive sampling devices to measure chemical contaminants in a variety of environmental matrices, see Kara Lavender Law, 'Plastics in the Marine Environment'..., 219.

[513] Stephanie L Wright, Richard C Thompson and Tamara S Galloway, 'The Physical Impacts..., 484 and 487.

[514] The rate and extent of accumulation depend on the polymer type, the physical and chemical properties of the plastic (especially those resulting from weathering and biofilm formation), the particle surface area, and the chemical exposure throughout the particle's drift history, see Kara Lavender Law, 'Plastics in the Marine Environment'..., 219. Moreover, the surface-area-to-volume ratio of particles is a very important criterion. The smaller the microplastic is, the higher is the surface/volume ratio, which means that a greater amount of environmental toxicants can be carried in direct proportion to a decrease in particle size. Nanoplastics are therefore more worrying. See UNEP, *Marine Plastic Debris and Microplastics...*, X and 105. In addition, even if one knows the concentrations of chemicals at the time of manufacture, it is too difficult to know how much additive is left, or was added, in the plastic by the time it becomes bite-size to a fish.

in the gut.[515] All in all, and because of the practically innumerable potential mixtures of hazardous chemicals that might be associated with plastic debris and the multitude of environmental factors governing their transfer into marine organisms, generalising the biological impact of this type of contamination may not be possible. However, Kara Lavender Law, is of the opinion that well-designed risk assessment for particular organisms or habitats and particular plastic types and chemicals could be useful to quantify harm and inform management strategies.[516]

For now, we know that PFCs, that have been used for years as components in non-stick surfaces for pans and in outdoor jackets, have recently been detected in the tissue of polar bears, which means they are concentrated in the nutrient chain.[517] Additionally, a 1988 feeding experiment indicated that PCBs can be transferred from contaminated plastics to streaked shearwater chicks, and then lead to reproductive disorders, increase the risk of diseases and alter hormone level.[518] Regarding fishes, Japanese medaka (Oryzias latipes) were found to be contaminated with the organic compounds PAHs, PCBs and PBDEs contained in PE particles. Virgin particles caused only physiological stresses, but contaminated particles caused liver toxicity and pathology.[519]

Phthalates and BPA[520] have been shown to affect reproduction in all studied animal groups – with a focus on annelids (both aquatic and terrestrial), molluscs, crustaceans, insects,

[515] Albert A Koelmans, 'Modeling the Role of Microplastics in Bioaccumulation of Organic Chemicals to Marine Aquatic Organisms. A Critical Review' in Bergmann M, Gutow L and Klages M (eds), *Marine Anthropogenic Litter* (Springer International Publishing, 2015) 313.
[516] Kara Lavender Law, 'Plastics in the Marine Environment'..., 220.
[517] Moritz Bollmann and others, *World Ocean Review: Living with the oceans* (Maribus GmbH, Germany, 2010) 212.
[518] Emma L Teuten and others, 'Transport and Release..., 2027-8.
[519] See Chelsea M Rochman and others, 'Ingested Plastic Transfers Hazardous Chemicals to Fish and Induces Hepatic Stress' (2013) 3(3263) Scientific Reports 1-7.
[520] For a better understanding, we explain that phthalates – such as dibutyl phthalate, diethylhexyl phthalate, dimethyl phthalate and butyl benzyl phthalate – have been applied as polyvinyl chloride (PVC) additives since 1926. Its emollient properties have driven their widespread use in the production of many mass-produced products including medical devices, food packaging, perfumes, cosmetics, children's toys, flooring materials, computers and CDs. See Jörg Oehlmann and others, 'A Critical Analysis of the Biological Impacts of Plasticizers on Wildlife' (2009) 364 PTRSB 2047. BPA is a compound used in the manufacture of polycarbonate, a type of transparent plastic and more resistant to heat. It is the most common monomer among the polycarbonates used in food packaging. BPA is also one of the epoxy resin components present, for example, in the inner coating of cans to prevent rust. BPA is also widely used as an adjunct to plastic materials for a variety of uses, such as the production of baby bottles, toys, household utensils, reusable water containers, beers and soft drinks, bottles for baby food or, still, in the pharmaceutical area in resins of medical and dental implants.

fish and amphibians –, to impair development in crustaceans and amphibians and to induce genetic aberrations.[521-522]

In addition to everything that has already been said, there are still other consequences to mention. The consumption of microplastics by marine biota can result in a range of adverse health effects including reduced feeding,[523] the depletion of energetic reserves,[524] heightened immune response,[525] and decrease of ecophysiological function as a result of physical internal injury (obstructions, perforated gut, ulcerative lesions or gastric rupture) and physiological stress.[526] These sublethal effects vary among different groups of organisms,[527] and depend

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[521] Reproductive and developmental disturbances include alterations in the number of offspring produced, reduced hatching success, disruption of larval development and, in insects, delayed emergence. Molluscs, crustaceans and amphibians appear to be especially sensitive to these compounds: 'in adult marine tubeworms *Pomatoceros lamarckii*, exposure to DMP was shown to decrease fertilization success at a threshold concentration of 1×10^{-5} M DMP (1.94 mg l^{-1}) and induce a significant increase in the number of aberrations in chromosome separations in oocytes at anaphase at concentrations $\geq 1\times10^{-7}$ M (19.4 μg l^{-1}) (Dixon *et al.* 1999; Wilson *et al.* 2002)'; 'focusing on toxicity, Larsson & Thurén (1987) found that exposure of *Rana arvalis* eggs to DEHP via sediment decreased successful hatchings with increasing concentrations and deduced a no observed effect concentration (NOEC) of 10 mg kg^{-1} fresh weight', ibid 2050 and 2052.

[522] Oyster reproduction, especially offspring, is also affected when exposed to polystyrene microplastics, as reported by an analysis based on ecophysiological parameters, cellular, transcriptomic and proteomic responses, fecundity and offspring development of the Pacific oyster. See Rossana Sussarellu and others, 'Oyster Reproduction is Affected by Exposure to Polystyrene Microplastics' (2016) 113(9) PNAS 2430-5.

[523] Ingested plastics reduce meal size by reducing the storage volume of the stomach and the feeding stimulus. Worrying data indicates that, in laboratory experiments with lugworms ingesting plastic particles laden with PBDEs, the lugworms desorbed the chemical, which resulted in a marked reduction in feeding response. See Mark Anthony Browne and others, 'Microplastic Moves Pollutants and Additives to Worms, Reducing Functions linked to Health and Biodiversity' (2013) 23 Current Biology 2388, 2389 and 2391.

[524] Dietary dilution can lead inter alia to starvation and malnutrition. Seabirds with large plastic loads have reduced food consumption, which limited their ability to lay down fat deposits, thus reducing fitness. For information on polychaete worms' energetic reserves and bioturbation activity see Stephanie L Wright, 'Microplastic Ingestion Decreases Energy Reserves in Marine Worms' (2013) 23(23) Current Biology 1031-3.

[525] We know, since 1995, that xenobiotic microplastic particles accumulating in organs and tissues may evoke an immune response, foreign body reaction and granuloma formation. A few studies of marine organisms have clearly demonstrated such direct particle toxicity effects of microplastics translocated from gut to body fluids into organs, cells and even organelles. After being exposed to primary HDPE plastic powder (>0-80μm), which was absorbed by digestive gland vacuoles, it was demonstrated that these particles can accumulate in epithelial cells of the digestive system of the blue mussel Mytilus edulis L, provoking a strong inflammatory response, after only three hours of exposure. See Nadia von Moos, Patricia Burkhardt-Holm and Angela Köhler, 'Uptake and Effects of Microplastics on Cells and Tissue of the Blue Mussel Mytilus edulis L. after an Experimental Exposure' (2013) 46(20) EST 11327-35. Once ingested, microplastics have even the potential to translocate from the digestive tract to the circulatory system of the organisms. See Mark A Browne and others, 'Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel Mytilus edulis (L.)' (2008) 42 EST 42(13) 5026-31.

[526] Different biochemical responses and impacts at the cellular level caused by ingestion of plastics have also been demonstrated in laboratory: 'oxidative stress (Browne *et al*. 2013), changes in metabolic parameters (Cedervall *et al.* 2012), reduced enzyme activity (Oliveira *et al.* 2013), and cellular necrosis (Rochman *et al.* 2013c)'. See Kara Lavender Law, 'Plastics in the Marine Environment'..., 220.

[527] When it comes to isopods, the particles pass through their digestive tract and are simply excreted. As bottom feeders, it is natural that they often swallow small particles, like the tiny shells of diatoms, or grains of sand. So, their digestive systems include a proper filter, which prevents micro particles from finding their way to sensitive organs. See Alfred Wegener Institute, 'Tracking Down Microplastic' (*Alfred Wegener Institute*, 21 February 2017) <www.awi.de/en/focus/marine-litter/tracking-down-microplastic.html> accessed 6 April 2017.

on their size, whether they feed selectively or not, and depend on how easily substances pass from the digestive tract to other parts of the body.

In any case, the risks are several and severe, and death is amongst them. At least eight studies demonstrated that several organisms – manatees,[528] sperm whales, sea turtles, penguins, lugworms[529] and copepods[530] – died because of plastic debris ingestion.[531] In relation to turtles, although many studies do not report their mortality, 'for those that did, about 4% of the total number of turtles necropsied (n=1106) were reportedly killed by plastic ingestion. Of those turtles that ingested debris (n=454), 42 (9%) were killed by it (range 0-35%)'.[532] With regard to penguins, the one with the highest load of ingested debris, had its stomach perforated by a plastic straw, and that was the direct cause of his death.[533]

c. Latest Estimates and Balance

In our opinion, no animal should experience the suffering described. Some events are really disturbing and increasingly alarmingly, especially going through the long process of starvation to death with the stomach full of plastic. Nevertheless, figures are important to understand the extent of the damage caused to biodiversity.

Even though figures on entanglement and ingestion vary slightly from study to study, we can certainly tell that entanglement and ingestion was already recorded in tens of thousands of individual animals and at least 558 species – more than the double of the 267 species reported for the year 1997 –, including all known species (seven) of sea turtles, 66% of all species of marine mammals (123 species), and 50% of all species of seabirds (406 species). Among marine mammals, 68% of all species of whales (80 species) and 67% of

[528] Cathy A Beck and Nélio B Barros, 'The Impact of Debris on the Florida Manatee' (1991) 22 MPB 508-10.
[529] Mark Anthony Browne and others, 'Microplastic Moves Pollutants..., 2388-92.
[530] See KW Lee and others, 'Size-Dependent Effects of Micro Polystyrene Particles in the Marine Copepod Tigriopus japonicus' (2013) 47(19) EST 11278-83.
[531] Kara Lavender Law, 'Plastics in the Marine Environment'..., 220. The Table 1, on pages 217-8, presents a list of peer-reviewed studies demonstrating evidence of impacts of marine plastic debris.
[532] Qamar Schuyler and others, 'Global Analysis of..., 135.
[533] Martha L Brandão, Karina M Braga and José L Luque, 'Marine Debris Ingestion by Magellanic Penguins, *Spheniscus magellanicus* (Aves: Sphenisciformes), from the Brazilian Coastal Zone' (2011) 62(10) MPB 2246-9. In 2008 and 2010, plastic items and other marine debris were found in the stomachs and intestines of 15% of 175 dead penguins collected in Lagos Region, *Rio de Janeiro*, Brazil. Penguins are not known for ingesting litter and there are few records of penguins ingesting plastic litter. Hence, the presented data means that all seabirds are susceptible to plastic pollution, and scientists considered this figures substantial and highlighted the need for further data as well as the continuous monitoring of these seabirds.

seal species (22 of 32 species) were affected.[534]

We note though that the existing statistical data may be highly underestimated since most victims are likely to go undiscovered over vast ocean areas, sunken or eaten by predators. Moreover, the effects of entanglement are more readily obvious – do not always require necropsy –, allowing more conclusive and frequently reporting than ingestion. In turn, entanglement corresponds to a unique event, whereas ingestion goes far beyond that, perpetuating the sublethal effects through the food chain.

For the moment, there are no studies confirming impacts on a population.[535] All the numbers referred so far concern affected species, and not to the percentage of each population's individuals. It is certain, however, that the lack of evidences does not mean necessarily the absence of ecologically relevant impacts, affecting wildlife at higher levels of biological organisation.[536] For example, combined with other anthropogenic stressors, marine debris can contribute to harm considerably populations or species that are already reported as *near threatened*, *vulnerable*, *endangered* or *critically endangered* in the IUCN Red List.[537] Marine debris may also affect indirectly trophic interactions and assemblages which could be particularly important if a keystone species is involved.

There is, though, a situation that raises a growing concern at the population level: the northern fulmars from the North Sea. Although this seabird has been studied since the early 1980s, the most worrying data concerns the years between 2003 and 2007: 95% of 1295 individuals washed ashore dead contained plastic debris in their stomachs (on average 35 pieces weighing 0.31g), and 58% of these contained quantities exceeding the OSPAR

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[534] Information collected from Chelsea M Rochman and others, 'The Ecological Impacts..., 303 and Susanne Kühn, Elisa L Bravo Rebolledo and Jan A van Franeker, 'Deleterious Effects of Litter..., 96. This latter paper contains four tables, each containing specific figures on entanglement and ingestion of marine debris that affected species and groups of marine organisms, since the first events recorded until December 2014. See pages 78, 86 and 97 to 102.

[535] Kara Lavender Law, 'Plastics in the Marine Environment'..., 220.

[536] This lack of evidences is apparent in the Figure 4 of the Kara Lavender Law, 'Plastics in the Marine Environment'..., 216, which presents a scheme of marine plastic debris' impacts correlating debris size and the level of biological organisation. A unique situation of direct impact was hypothesised and properly tested but the results were negative: 'a study by Browne et al. (2008), who observed laboratory ingestion by and translocation of micron-sized plastic particles in mussels without significant short-term effects on the animals', see Kara Lavender Law, 'Plastics in the Marine Environment'..., 221. But we cannot forget that in most cases the necessary studies to test more ecologically relevant impacts, namely at the population level, have yet to be done. Besides, given the multiple stressors in the natural environment, it may be difficult to tease apart the ecological impacts caused solely by marine plastic debris.

[537] Sarah C Gall and Richard C Thompson, 'The Impact of Debris on Marine Life'..., 175-6. Particular concern is associated with species listed in the IUCN Red List as these are at the greatest risk of extinction from a diverse range of impacts. Worst is the fact that around 17% of species ingesting or becoming entangled in marine debris are listed as *near threatened*, *vulnerable*, *endangered* or *critically endangered*. See ibid 174.

Ecological Quality Objective (EcoQO), which defines acceptable ecological quality as the situation where no more than 10% of fulmars exceed a critical level of 0.1g of plastic in the stomach.[538] The strength of these data has led to the suggestion that plastic content in this population could be used as a monitoring indicator to assess spatial and temporal changes in surface debris concentrations on a regional basis within the north-eastern Atlantic, giving the scientists the chance to gauge (similarly to the remote islands) how much plastic is out there in the open sea.[539]

All in all, marine plastic debris represent a significant additional and escalating anthropogenic factor affecting marine habitats and biodiversity.

B. Impacts on Humans

a. Food Chain and Health Issues

It was already demonstrated that microplastics have entered the marine food chain. We will now reveal that plastic particles are also present in fish and shellfish caught and sold for human consumption.

A 2014 investigation disclosed that microplastics were recovered from the soft tissues of two species of commercially grown bivalves: the blue mussel Mytilus edulis and the Pacific oyster Crassostrea gigas. The first ones were acquired directly from a mussel farm in Germany that caught them in the North Sea. The oysters, original from Brittany, France, were bought in a supermarket. The analysis revealed that without depuration, M. edulis contained on average 0.36 ± 0.07 particles g^{-1}ww (meaning wet weight), while the plastic load of C. gigas was 0.47 ± 0.16 particles g^{-1}ww. In turn, after the three-day depuration period, only 0.24 ± 0.07 particles g^{-1}ww and 0.35 ± 0.05 particles g^{-1}ww were recovered, respectively.[540]

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538 Northern fulmars ingesting plastic debris are frequent in other locations: 'in the Clyde Sea 83 per cent of Nephrops sampled contained plastics (mainly fibres) in their stomachs (Murray and Cowie, 2011), and in the English Channel 36.5 per cent of individuals sampled (spanning ten pelagic and demersal fish species) had plastics in their gastrointestinal tracts (Lusher et al, 2013)', see Stephanie Newman, Emma Watkins and Andrew Farmer, *How to Improve EU Legislation...,* 3. The Convention for the Protection of the Marine Environment of the North-East Atlantic is known as the OSPAR Convention. It will be duly addressed in Part II.

539 Sarah C Gall and Richard C Thompson, 'The Impact of Debris on Marine Life'..., 176-7.

540 Lisbeth van Cauwenberghe and Colin R Janssen, 'Microplastics in Bivalves Cultured for Human Consumption' (2014) 193 Environmental Pollution 66.

Also in 2014, samples of fishes (that span across habitats – reef, pelagic, benthic zones – and trophic levels), fish gastrointestinal tracts and bivalves were directly collected from fish markets (in Paotere Fish Market in Makassar, Sulawesi, Indonesia and in Half Moon Bay and in Princeton, California, USA) and from Californian fisherman, totalling 152 units. In Indonesia, anthropogenic debris were found in 28% of individual fish and in 55% of all species.[541] Likewise, in the USA, anthropogenic debris were found in 25% of individual fish and in 67% of all species.[542] Anthropogenic debris were also found in 33% of individual shellfish (Pacific oyster C. gigas from aquaculture in California) sampled.[543]

Although the number of debris inside the fishes was similar, it was observed that individual Indonesian fish contained a higher number of particles. In addition, all of the anthropogenic debris recovered from fish in Indonesia were plastic, whereas anthropogenic debris recovered from fish in the USA were primarily fibres.[544] In the opinion of the scientists, these differences are a reflection of different waste sources and management strategies between these two countries. It is a fact that both Indonesia and the USA belong to the top twenty countries by mass of mismanaged plastic waste – they are in the 2nd and in the 20th position, respectively –,[545] but while the use of plastic and textiles in the USA is superior

[541] Overall, 21 out of 76 (28%) fish sampled across 11 different species (tilapia, skipjack tuna, Indian mackerel, shortfin scad, silver-stripe round herring, rabbitfish, humpback red snapper, oxeye scad and fishes from the family Carangidae) had anthropogenic debris in their gastrointestinal tract. The number of debris particles in individual fish ranged from 0-21 individual pieces. The 105 total pieces of anthropogenic debris recovered from fish included 63 plastic fragments (60%), 0 fibres, 39 pieces of plastic foam (37%), 2 plastic film (2%) and 1 plastic monofilament line (1%). See Chelsea M Rochman and others, 'Anthropogenic Debris in Seafood: Plastic Debris and Fibers from Textiles in Fish and Bivalves Sold for Human Consumption' (2014) 5 Scientific Reports 2-4.

[542] Overall, 16 out of 64 (25%) fish across 12 different species (Jacksmelt, Chinook salmon, Pacific anchovy, yellowtail rockfish, striped bass, Pacific mackerel, albacore tuna, blue rockfish, Pacific sanddab, lingcod copper rockfish and vermilion rockfish) had anthropogenic debris in their gastrointestinal tract. Of all species purchased, anthropogenic debris were present in the gut content of 8 (67%) of all fish species sampled. The number of anthropogenic particles in individual fish ranged from 0-10 individual pieces and in individual oysters from 0-2 individual pieces. Of the anthropogenic debris identified (>500 µm) in samples from California, the majority were fibres from textiles. Only 6 individual fish contained debris that were not fibres and thus could be confidently identified as plastic. The 30 total pieces of anthropogenic debris recovered from fish included 1 fragment (3.33%), 24 fibres (80%), 1 piece of foam (3.33%), 3 film (10%) and 1 monofilament line (3.33%). See ibid 2-5.

[543] Four out of twelve (33%) individual shellfish were contaminated with anthropogenic debris (fibres). Seven pieces were counted. See ibid 2-5.

[544] In Indonesia, plastic debris was found in 28% of fish. In USA, only 9% of fish had plastic. Regarding fibres, Indonesia fish count none, but 19% of USA samples had fibres. See ibid 6. These fibres were not categorised as plastic debris because the material type was not confirmed due to the absence of FTIR and Raman Spectroscopy. Still, 'the lack of fibers in fish from Indonesia helps confirm that our procedures were robust. While there is a chance that gutting of some USA fish by fishermen might have introduced fibers to gut contents, we also found fibers in the guts of whole fish. Thus, we conclude that the presence of fibers in samples from the USA occurred from ingestion in nature prior to sampling' see ibid 4 and 6.

[545] Jenna R Jambeck and others, 'Plastic Waste Inputs..., 769. In 2010, Indonesia's mismanaged plastic waste was 3.22 million metric tons. In the USA, it was 0.28 millions of metric tons.

than in Indonesia, waste management is more advanced in the USA. In Makassar, Indonesia, where fish was collected, 30% of solid waste generated is not processed and an increasing amount of waste is directly discarded along the coast, rivers and into drainage channels.[546] In turn, the higher concentration of fibres off the California coast is explained by a more advanced waste management system.[547]

Considering that the amount of global fish supplies is constantly growing – having registered in 2014 an increase of 27% in relation to the year 2000 and of 47% compared to 1990 –,[548] it is obvious that human beings will ingest microplastics through seafood. Evidently, ingestion varies according consumption – if in Belgium, the per capita consumption of shellfish is 72.1g day^{-1}, in France and Ireland it is just 11.8 g day^{-1}, for both countries.[549] Generically, per year, the top consumers of M. edulis plus C. gigas might ingest 11,000 microplastics, while minor consumers might ingest 1800 microplastics.[550]

Most likely, humans are ingesting microplastics along with another seafood species. However, inadvertent consumption of plastic has more sources. Recent studies suggested that microplastics have reached tap water, bottled water and table salt. In 2017, tap water was collected 159 times in fourteen countries.[551] Of these samples, 81% contained anthropogenic particles. In total, 539 particles were found, and the vast majority (98.3%) were identified as fibres, and the remaining particles were identified as fragments (n = 7) or films (n = 2).[552]

546 Chelsea M Rochman and others, 'Anthropogenic Debris in Seafood..., 6 citing Tjandraatmadja G and others, *Context and Challenges in Urban Water and Wastewater Services for Makassar, South Sulawesi, Indonesia. A Report Prepared for the CSIRO-AusAID Research Alliance* (CSIRO, Canberra, 2012).

547 As a matter of fact, 'there are more than 200 wastewater treatment plants discharging billions of litres of treated final effluent just offshore in California. Even though treatment results in a reduction of many contaminants, synthetic fibers from washing machines can remain in sewage effluent, and may be delivered to aquatic habitats in large concentrations via wastewater outfalls. One study found one fiber per L of wastewater effluent. In this sense, we might expect that billions of fibers are discarded into the Pacific Ocean from wastewater treatment plants in California everyday', see ibid 6.

548 For the years 1990, 2000 and 2014, the world production indices (2004-06=100) presented for fish were 72, 92 and 119, respectively. With respect to meat, the values were quite similar: 74, 91 and 118. See the FAO document available at <www.fao.org/faostat/en/#country>.

549 Figures collected from European Food Safety Authority, 'Use of the EFSA Comprehensive European Food Consumption Database in Exposure Assessment' (2011) 9(3):2097 EFSA Journal 1-34.

550 Lisbeth van Cauwenberghe and Colin R Janssen, 'Microplastics in Bivalves..., 68. It has been proven that an average portion of mussels (250g ww) contains around 90 particles, and that an average portion of 6 oysters (100g ww) contains almost 50 particles. See ibid.

551 Mary Kosuth, Sherri A Mason, Elizabeth V Wattenberg, 'Anthropogenic Contamination of Tap Water, Beer, and Sea Salt' (2018) 13(4) Plos One 2-3. The following samples were collected in Cuba (1), Ecuador (24), England (3), France (1), Germany (2), India (17), Indonesia (21), Ireland (1), Italy (1), Lebanon (16), Slovakia (8), Switzerland (2), Uganda (26), and USA (36). The samples came from developed countries and from developing countries and represented both rural and urban communities. See Table 1 for more information about the sources of the samples. In fact, 3 samples from the USA were water bottles, but they were examined all together with tap water.

552 ibid 8.

The range was 0 to 61 particles/L, with an overall mean of 5.45 particles/L. The highest mean for any country was found in the USA with 9.24 particles/L while the four lowest means were from Italy, Germany, France and Ireland.[553] Interestingly, water sourced from more developed nations (EU, US, and Lebanon) had an average density of 6.85 particles/L, while water sourced from less developed nations (Cuba, Ecuador, India, Indonesia, Uganda) had an average density of 4.26 particles/L. In the end, the study concluded that, considering the recommended amount of beverage per day (2.2L for women and 3L for men), women might consume as many as 12 anthropogenic particles a day, while men might consume up to 16.[554]

Purchased from nineteen locations in nine countries, 93% of all the 259 individual bottles from 27 different lots across 11 brands, showed some sign of microplastic contamination.[555] When averaged across all lots and all brands, 325 microplastic particles per litre (MPP/L) were found within the bottled water tested, broken down as an average of 10.4 MPP/L occurring within the larger size range (>100μm) and an average 315 MPP/L within the smaller size range (6.5-100μm), which corresponded to 95% of the particles.[556] Regardless of the size range, the densities of microplastic contamination were quite variable ranging from the seventeen bottles with no contamination to one bottle that showed an excess of 10,000 microplastic particles per litre.

Of all the lots tested, one was packaged in glass. The samples revealed less microplastic contamination when compared with the plastic bottle lots, even with plastic

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553 See Table 4 in ibid. Of all the countries tested, the USA not only had the largest sample size, it also involved samples collected in the entire country and from municipalities either densely or sparsely populated. Ibid 12-3.
554 ibid 13.
555 See David Shukman, 'Plastic particles found in bottled water' (*BBC News*, 15 March 2018) <www.bbc.com/news/science-environment-43388870> accessed 9 Mary 2018, where the article *Synthetic Polymer Contamination in Bottled Water*, authored by Sherri A Mason, Victoria Welch and Joseph Neratko, from the State University of New York at Fredonia, was made available before publication in a scientific journal (it can be found at <http://news.bbc.co.uk/2/shared/bsp/hi/pdfs/14_03_13_finalbottled.pdf>). According to the article, sample lots were purchased from different locations in order to cover the following aspects: 1) geographic diversity (five continents are represented); 2) the size of the national packaged drinking water market (China, USA, Brazil, India, Indonesia and Mexico); and 3) high per capita consumption of packaged drinking water (Lebanon, Mexico, Thailand and USA). Leading international brands in this study included Aquafina, Dasani, Evian, Nestle Pure Life, and San Pellegrino. Leading national brands included Aqua (Indonesia), Bisleri (India), Epura (Mexico), Gerolsteiner (Germany), Minalba (Brazil), and Wahaha (China). Averaging across lots by brand, Nestle Pure Life and Gerolsteiner showed the highest average densities at 930 and 807 MPP/L, respectively, while San Pellegrino and Minalba showed the lowest microplastic contamination with 30.0 and 63.1 MPP/L, respectively.
556 The Nile Red stain method, which adsorbs to polymeric material and fluoresces under specific wavelengths of incident light, allowed for smaller particles to be detected. However, the smaller particles could not be analysed for polymer identification given the analytical limits of the laboratory. Regarding the larger particles (5%), polypropylene was found to be the most common polymeric material (54%), nylon was the second most abundant (16%), followed by polyethylene (10%). The morphology of these microplastics was as follows: fragments (66%), films (14%), fibres (13%), foam (5%) and pellets (3%).

bottles of the same brand (Gerolsteiner). Although these packaged waters had the same water source, there were considerably less microplastic contamination within the water bottled in glass as compared to that packaged in plastic (204 and 1410 MPP/L, respectively). This indicates that some of the microplastic contamination is likely coming from the water source, but a larger contribution might be originating from the packaging itself. In fact, given the fragment morphology (of all the larger particles) combined with the fact that 4% of the particles were found to have signatures of industrial lubricants, the data seemed to suggest that at least some of the plastic contamination may be coming from the industrial process of bottling the water itself. Moreover, as polypropylene was the most common polymer found, the fragments could also be breaking off the cap, even entering the water through the simple act of opening the bottle. Scientists concluded that plastic is pervading water, which is of particular concern because it is difficult to recommend practical strategies for avoiding water ingestion, something truly essential for human life.

Additionally, it seems that commercial sea salt is also a vehicle for microplastics. Samples purchased in China were contaminated with microplastics: 550-681 particles/kg were found in sea salts, 43-364 particles/kg in lake salts and 7-204 particles/kg in rock/well salts. According to these numbers, if people consume less than 5g of salt per day, as recommended by the World Health Organisation, they would ingest approximately one thousand microplastic particles each year, just from table salts.[557] After this initial survey, a global study was conducted.[558] Twelve international brands of commercial sea salt, purchased in Minneapolis, USA, in August of 2016, registered an average of 212 particles/kg, with a range of 46.7 to 806 particles/kg. Among all samples analysed, a total of 461 anthropogenic particles were identified. The vast majority (99.3%) of these were classified as fibres, while the remaining particles (n = 3) were identified as fragments. The average length of each fibre was 1.09 mm with a range of 0.1 mm to 5 mm.

Definitely, food safety is being threatened. What about human health?

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557 Dongqi Yang and others, 'Microplastic Pollution in Table Salts from China' (2015) 49 EST 13622-7. During October and November 2014, fifteen different brands of salts were bought in random supermarkets across China. In sea salts, fragments and fibres were the prevalent types of particles compared with pellets and sheets. Microplastics measuring less than 200μm represented the majority of the particles, accounting for 55% of the total microplastics. The most common microplastics were polyethylene terephthalate, followed by polyethylene and cellophane.

558 Mary Kosuth, Sherri A Mason, Elizabeth V Wattenberg, 'Anthropogenic Contamination... Salt brands were sourced from oceans (Hawaiian Sea, Baja Sea, Atlantic Sea and Pacific Sea), from seas (North Sea, Celtic Sea, Sicilian Sea and Mediterranean Sea), and from salt mines (Himalayan Rock and Utah Sea).

Presumably, once inside the human digestive tract, intestinal uptake of the ingested plastic particles may occur. At least, translocation of various types of micro particulates across the mammalian gut is a process that has been demonstrated in multiple studies involving rodents, rabbits, dogs and humans.[559] Will this happen with plastic micro particulates? What will occur if they reach humans intestines or their lymphatic system? Will they be encapsulated by the tissue and be forgotten by the body, or will they cause inflammations and diseases? For now, all the scientific reports concluded the same thing: it is not yet possible to estimate the risks that the ingestion of microplastics can cause to human health. It is though certain that they will accumulate in the body over time, in increasing amounts, and that they will stay for a while.[560] There are also doubts regarding chemicals: will plastic release chemicals and will they be toxic to the human body?[561]

In truth, plastic accidental ingestion happens not only through food. Many common and daily plastic products people touch, wear, sit on, use to drink or to eat can leach synthetic compounds into their bodies. It seems that polymerisation leaves some monomers unbounded and free to migrate from food containers, bottles and utensils. Moreover, if one wraps himself in a polar scarf, plastic fibres can be inhaled, and if someone uses facial scrubs with microbeads plastic can be ingested.

In principle, in the gastrointestinal tract, the acidic pH of the stomach and the presence of gastro-intestinal enzymes will remove adsorbed chemicals from the microplastic surface, while in the less acidic bowel lumen reabsorption of new molecules (such as luminal proteins and glycoproteins) can occur.[562] Some of these compounds will bioaccumulate in human bodies, increasing the burden of hazardous chemicals in humans. Certain substances, as

[559] The particles size was 0.03-40µm, 0.1-10µm, 3-100µm, 0.16-150µm, respectively. See Lisbeth van Cauwenberghe and Colin R Janssen, 'Microplastics in Bivalves..., 68 citing Hussain N, Jaitley V and Florence AT, 'Recent Advances in the Understanding of Uptake of Microparticulates Across the Gastrointestinal Lymphatics' (2001) 50 Advanced Drug Delivery Reviews 107-42. To date, the microfold cells in the Peyer's patches (small intestine) are considered the predominant site of uptake. Through these cells micro particulates can enter the lymphatic system.

[560] Thomas Moore, 'Microplastics in Seafood Could be a Health Risk, Experts Fear' (*Sky News*, 25 January 2017) <https://news.sky.com/story/microplastics-in-seafood-could-be-a-health-risk-experts-fear-10739835> accessed 5 November 2017.

[561] ibid.

[562] Vandermeersch Griet and others, 'A Critical View on Microplastic Quantification in Aquatic Organisms' (2015) 143(B) Environmental Research 47 citing Powell J and others, 'Origin and Fate of Dietary Nanoparticles and Micro Particles in the Gastro Intestinal Tract' (2010) 34 J. Autoimmun 226-33.

phthalates and BPA have been firmly proven to have endocrine disrupting properties, including early puberty, obesity, insulin inhibition, hyperactivity and learning disabilities.[563]

Health impacts directly caused by plastic waste ingestion are uncertain. This is partly because it is not clear what level of exposure is caused by plastic waste, and partly because the mechanisms by which the chemicals from plastic may have an impact on humans and animals are not fully established.[564] Due to significant lack of supporting studies, a comprehensive assessment of the hazards associated with microplastics is not possible. Continuous research is thus needed so that these hazards can become clear, and it is particular important to clarify the answers to the following three interconnected key questions: *to what extent do plastics transfer pollutants and additives to organisms upon ingestion?*, *what contribution are plastics making to the contaminant burden in organisms above and beyond their exposures through water, sediments, and food?*, and finally, *what proportion of humans' exposure to plastic ingredients and environmental pollutants occurs through seafood?*[565]

In turn, what is less uncertain is the possibility of scuba divers, snorkelers and surfers suffer accidents caused by encounters with submerged debris, especially with abandoned fishing nets and lines. Even less remote are the physical injuries that sunbathers and swimmers can suffer because of the litter on the beach and in the sea.[566]

b. Economic and Social Impacts

Extensive and overwhelmingly negative socio-economic impacts can represent direct costs to individual entrepreneurs, industry, local authorities and governments, and can compromise

[563] See FAO and WHO, *Toxicological and Health Aspects of Bisphenol A* (Canada, 2011), containing an evaluation of the potential impacts of BPA exposure on human health and related uncertainties and knowledge gaps.
[564] We already know that 'monomers leaching from plastic can cause both acute and chronic effects in humans, such as cancer (e.g. vinyl chloride (Awara et al., 1998)) and neurological effects (e.g. styrene (ATSDR Agency for Toxic Substances and Disease Registry, 2010))' see Lisbeth van Cauwenberghe and Colin R Janssen, 'Microplastics in Bivalves..., 68. See also Holger M Koch and Antonia M Calafat, 'Human Body Burdens of Chemicals Used in Plastic Manufacture' (2009) 364 PTRSB 2063-78 and Chris E Talsness and others, 'Components of Plastic: Experimental Studies in Animals and Relevance for Human Health' (2009) 364 PTRSB 2079-96.
[565] See Nate Seltenrich, 'New Link in the Food Chain? Marine Plastic Pollution and Seafood Safety' (2015) 132(2) Environmental Health Perspectives 38.
[566] See UNEP, *Marine Litter: A Global Challenge* (UNEP, Nairobi, 2009) 14. Solid waste associated with sewage such as sanitary towels, condoms and cotton buds, degrades the quality of the bathing water and may pose health risks. There is even the possibility of sharp and dangerous items (glass, syringes or other medical wastes) wash up on beaches, causing danger to beachgoers.

millions of jobs.[567] Furthermore, since marine plastic pollution is a transboundary problem, these costs may affect entities located far from the point of origin of the debris. Commercial fishing, shipping and other marine industries, as well as recreation and tourism are the most common affected areas. However, in order to assess properly this kind of impacts it is essential that common methodologies and reporting mechanisms are developed. So far, the researches available are limited and the overall economic impact of plastic pollution is still unclear.

Offshore, the principal and most direct causes of revenue loss are ship failure and fish stocks decrease. Derelict fishing gear can cause serious damage to vessels or to any other boat – entangled propellers and rudders, clogged water pipes and burned-out cooling systems – resulting in: costly or hard to reach repairs; disablement and loss of time; and danger both to boats and crews.[568] This way, commercial fishing objectives become more difficult to achieve. In addition, ghost fishing, discarded gear and random plastic items may contribute to significant losses of commercially valuable fish and other marine species, diminishing the viability of the already stressed fisheries. It is no longer possible to be sure that fisheries can support over 15% of the global protein supply,[569] especially if we take into account that the world population will continue to grow. For instance, 'the amount of monkfish trapped by ghost nets in the Cantabrian Sea may be equivalent to around 1.5% of the commercial landings in that region', while 'trapped lobsters in the United States have been estimated to be worth $250m (almost €200m)'.[570] A more recent study elaborated in Puget Sound, Washington, USA, estimated that over 175,000 Dungeness crabs were killed each year, at least until 2009, by derelict fishing traps, which was equivalent to around 586,000 euros or 4.5% of the average annual harvest.[571]

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[567] Especially jobs supported by tourism and fishing. See Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel - GEF, *Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions* (Technical Series No. 67, Montreal, 2012) 5.
[568] Seba B Sheavly, 'Marine Debris..., 3.
[569] Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel - GEF, *Impacts of Marine Debris...*, 5.
[570] BIO Intelligence Service, *Plastic Waste...*, 115 citing Sancho G and others 'Catch Rates of Monkfish (Lophius spp.) by Lost Tangle Nets in the Cantabrian Sea (Northern Spain)' (2003) 64 Fisheries Research 129-39 and JNCC, *Marine Advice - Fisheries* (2005) available at <www.jncc.gov.uk/page-1567>.
[571] Stephanie Newman and others, 'The Economics of Marine Litter' in Bergmann M, Gutow L and Klages M (eds), *Marine Anthropogenic Litter* (Springer International Publishing, 2015) 373 citing Antonelis K and others, 'Dungeness Crab Mortality Due to Lost Traps and a Cost-benefit Analysis of Trap Removal in Washington State Waters of the Salish Sea' (2011) 31(5) North American Journal of Fisheries Management 880-93.

To these expenditures, we need to add costs with vessels repairs, periods of inactivity, nets and harbours cleaning, among others. However, considering most incidents with vessels go unreported, it is difficult to estimate accurately the costs implied. It is, though, possible to know that in 2008 there were 286 rescues to vessels with fouled propellers in UK waters, costing between 830,000 euros and 2,189,000 euros. Similarly, in 2005, the USA Coastguard made 269 rescues involving marine litter, that caused 15 deaths, 116 injuries and three million dollars in property damage.[572] Concerning the fishing industry as a whole, the best known example is the Scottish whose costs with marine litter go from 11.7 to 13 million euros every year, knocking 5% off the fleets' total annual revenue.[573] In the Asia-Pacific region, 'the cost of marine litter has been estimated at €950 million, equivalent to 0.3% of the gross domestic product (GDP) for the marine sector of the region' [574]. The same study extrapolated these numbers to other regions of the globe based only on the respective marine GDP, and concluded that 'the cost of marine litter can be estimated at approximately €1 billion for the US and Canada alone and €1.2 billion for Europe. Globally, plastic waste has been estimated to cause an annual financial damage of €11.5 billion'. Besides this data, pertaining only to the maritime economy, there are still elevated costs regarding soils and air contamination by plastic and plastic-containing materials.[575]

Onshore, recreation (sport fishing, submarine tours, turtle and whale watching trips, snorkelling, scuba diving and spear fishing) and tourism are the most affected activities. All

[572] Stephanie Newman, Emma Watkins and Andrew Farmer, *How to Improve EU Legislation...*, 4 citing Mouat J, Lozano RL and Bateson H, *Economic Impacts of Marine Litter* (KIMO International, 2010).
[573] Stephanie Newman and others, 'The Economics of Marine Litter'..., 373.
[574] João Pinto da Costa and others, '(Nano)plastics in the Environment..., 22 citing McIlgorm A, Campbell HF and Rule MJ, 'The Economic Cost and Control of Marine Debris Damage in the Asia-Pacific Region' (2011) 54 Ocean & Coastal Management, 643-51.
[575] ibid 22.

over the world, there are beaches full of garbage: India,[576] Hong Kong,[577] Belgium,[578] Cornwall,[579] Portugal,[580] Bermuda and Bahamas,[581] Brazil,[582] and many other places.[583]

Moreover, waste is largely unaesthetic and makes shorelines unattractive and potentially hazardous for public and animal health. Evidently, only a clean and safe environment attracts people and boosts the economy. It is imperative to keep beaches and sea clean, but that represents an additional expense, not yet quantified. Anyhow, the costs of cleaning up are lesser than the costs of inaction.[584] So far, we know that the costs associated with removing beach litter each year for local municipalities is 'approximately €18 million in the UK, and €10.4 million in the Netherlands and Belgium'.[585] Fortunately, beach clean-up activities have broad public support and mobilise large volunteer groups.[586]

To maintain public health, it is also mandatory to remove stranded animals, which imply considerable costs, in general proportional to the size of the animal. For example, recovery, decomposition and investigation of a stranded cachalot may cost around 250,000 euros. Also related with public health are the natural disasters events exacerbated by plastic

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576 Sky News, 'Special Report: A Plastic Tide | #OceanRescue' (24 January 2017) <www.youtube.com/watch?v=D35YnZ7_WxM> accessed 23 February 2017.
577 Kylie Knott and Adam Wright, 'Hong Kong Officials Blame China Floods for Tide of Filth Washing Up on City Beaches' (*South China Morning Post*, 6 July 2016) <www.scmp.com/lifestyle/article/1986137/hong-kong-officials-blame-china-floods-tide-filth-washing-city-beaches?utm_source=&utm_medium=&utm_campaign=SCMPSocialNewsfeed> accessed 6 April 2017.
578 See Michiel Claessens and others, 'Occurrence and Distribution of Microplastics in Marine Sediments Along the Belgian Coast' (2011) 62 MPB 2199-2204.
579 Sky News, 'Special Report: A Plastic Tide...
580 Marine anthropogenic litter was analysed in eleven beaches (Matosinhos, Espinho, Mira, Vieira de Leiria, Paredes de Vitória, Peniche, Cresmina, Fonte da Telha, Sines, Bordeira and Ancão) along the Portuguese coast, over a two-year period (2011–2013). Of all collected items, 99% were plastic and 68% were microplastics (1-5mm in diameter). Higher microplastics concentrations were found in winter/autumn, near industrial areas and/or port facilities and in beaches exposed to dominant winds. Resin pellets (79%) were the dominant category close to industrial areas and high concentrations of fragments and polymeric foams were found near fishing ports. More information available in Joana Antunes, João Frias and Paula Sobral, 'Microplastics on the Portuguese Coast' (2018) 131 MPB 294-302.
581 Kara Lavender Law and others, 'Plastic Accumulation in the North Atlantic Subtropical Gyre'..., 1187.
582 See Isaac R Santos, Ana Cláudia Friedrich and Juliana Assunção Ivar do Sul, 'Marine Debris Contamination Along Undeveloped Tropical Beaches from Northeast Brazil' (2009) 148 Environmental Monitoring and Assessment 455-62.
583 See Mark Anthony Browne and others, 'Accumulations of Microplastic on Shorelines..., 9175-9 to know what sediments were collected from sandy beaches in Australia, Japan, Oman, United Arab Emirates, Chile, Philippines, Portugal, including Azores, USA, South Africa, Mozambique and the UK from 2004 to 2007.
584 Stephanie Newman and others, 'The Economics of Marine Litter'..., 377. The indirect costs can be even greater: most coastal communities rely on the income generated by seaside businesses and on the clientele that supports them. In fact, the existence of marine debris discourages people from fishing, boating, swimming, and visiting coastal areas. See Seba B Sheavly, 'Marine Debris..., 3.
585 European Commission, 'Plastic Waste: Ecological and Human Health Impacts'..., 26.
586 This way, it is possible to reduce costs with labour. According to the Alliance for the Great Lakes, 'in 2012, the monetary value of the hours spent by volunteers cleaning up beaches around the Great Lakes represented over US $250,000'. See Alexander G J Driedger and others, 'Plastic Debris in the Laurentian Great Lakes..., 15.

bags blocking drains and waterways. In 1988, poor drainage resulting from plastic bag litter clogging drains contributed to devastating floods in Bangladesh, causing several deaths as two-thirds of the country was submerged. Occurrences like this one, although less severe, are frequent in other developing countries.[587]

In global terms, considering the amount of plastic waste that finds its way into the oceans each year, the annual economic damage plastics impart on the world marine ecosystem is at least USD 13 billion.[588]

That said, we reinforce that many aspects require further research.[589] Moreover, the definition of comparable datasets will allow an effective evaluation of direct and indirect costs and loss of income to interested parties all over the world. Determining more realistic costs may result in more powerful incentives for removing and preventing beach litter.[590]

[587] UNEP, *Single-use Plastics:...*, 13. See case study 4.3.2.
[588] UNEP, *Valuing Plastics: The Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry* (UNEP, Nairobi, 2014) 7.
[589] There are lots of aspects to analyse, being 'important to differentiate between actual economic costs linked to expenditure (e.g. costs of cleanup of beaches; costs associated with damage to or loss of fishing gear or obstruction of motors; eventual cost of hospitalisation from marine debris related health impacts), economic costs of loss of output or revenue (e.g. loss of revenue from fish or loss of income from tourism) and assessment of welfare costs in economic terms (e.g. health impacts from marine debris; assessing the economic value of loss of cultural values such as recreation or landscape aesthetics)', see Stephanie Newman and others, 'The Economics of Marine Litter'..., 368. For distinctive examples of economic impacts of marine plastic pollution see Paul E Hagen, 'The International Community Confronts Plastics Pollution from Ships: MARPOL Annex V and the Problem That Won't Go Away' (1990) 5(2) American University International Law Review 440ff.
[590] European Commission, 'Plastic Waste: Ecological and Human Health Impacts'..., 26 citing Mouat J, Lopez Lozano M and Bateson H, *Economic Impacts of Marine Litter* (KIMO International, 2010).

PART II

MARINE PLASTIC POLLUTION UNDER THE RULE OF LAW

VII. Introduction and Principles

We have already traced the never-ending journey of plastic in the oceans and we concluded that even though the actual levels of consumption are depleting natural resources, plastic is known for its also never-ending utility and the way it changed the quality of human life. However, it has also boosted people's desire to consume, which has been increasing ever since. Likewise, the plastic waste produced worldwide has barely stopped growing, and it is happening at a much faster pace than the implementation of waste management systems or its legal regulation. Consequently, and due to poor waste management, inadequate infrastructure and insufficient public understanding of the consequences of inappropriate waste disposal, plastic waste rapidly reached levels of massive pollution. The consequences of this pollution are considerable, borderless and timeless, and once in the sea, plastic waste can cause suffering and death to lots of animals, *poison* the human food chain, and undermine several economic activities.

Even though the information gathered in Part I needs further development, it is enough – and that is consensual – to compel all the players and stakeholders to search and enforce appropriate solutions. It is clear that marine pollution is not a new phenomenon, nor are the attempts to prevent it – which began nearly 45 years ago –, but the fact is that plastic is still a relatively new material. This means that the problem of plastic waste has only recently and gradually been receiving policy makers' attention, which is the reason why there are few legislative measures contemplating plastic, solo or as marine litter.

Once marine plastic pollution is widely diffused and has many different sources and entry points, it is essential to take a multi-sectoral approach, to combine multiple interventions and measures and to coordinate actions between stakeholders. This is a global challenge, that extends beyond the jurisdictional authority or ability of any institution or global entity. It demands thus a global response, strongly dependent on good cooperation, at national, regional and international level.

Therefore, in Part II, the core question – *how to prevent plastic waste from entering the ocean?* – will be answered during the analysis of existing legal instruments of international law and European Union Law. Evidently, the main focus will be on

Environmental Law,[591] covering themes as marine pollution, waste management, nature and biodiversity, but we will also pay attention to other areas such as energy, economics, fisheries, trade and external relations and transports.

Nevertheless, we must previously introduce the underlying principles of Environmental Law, and particularly of Waste Law – because, as said before, the wider problem of marine plastic debris is fundamentally associated with inadequate waste management –, that might help answer the core question. Acting as universal vectors of environmental action, these juridical principles, that condition and mould environmental legislation's interpretation and application, ensure the unity and coherence of the legal regime and promote a higher level of protection of the environment.

Moreover, both Environmental and Waste Law regulate continuously evolving sectors, which give principles a greater importance. The increasing amount of waste, in parallel with the growing variety of waste types, obliges economic operators to develop more sophisticated and complex processes of valuing or eliminating them. Since these processes are under strong regulatory pressure, imposing heavy taxes and charges, and requiring sophisticated environmental machinery, the legal frameworks tend to be outpaced by the dynamism of economic activity that frequently comes up with new and sometimes unusual waste management solutions. If the law fails to keep up, the principles will always lead the way to the solution.

Having said that, the principles that are important to highlight are: a) the principles of prevention, correction at source, polluter-pays, and integration, which are Environmental Law principles also directly applied to Waste Law; and b) the Waste Law exclusive principles of waste hierarchy, self-sufficiency, proximity and planning.

Whether Environmental Law is perceived from an anthropocentric point of view – valuing nature just as a vehicle for the satisfaction of humans' vital needs and well-being – or from an ecocentric one – valuing nature for its own sake –, its keystone principle is invariably the prevention principle. Considering environmental goods' frailty and their possible non-regeneration, it is mandatory to anticipate the harmful effects that human activities may cause than to repair them – which, whenever possible, is generally very

[591] Environmental Law can be defined as the set of principles and norms that discipline human interventions on natural environmental goods, in order to prevent irreversible destruction, to raise awareness to environment quality, to punish conducts that damage the integrity and regenerative capacity of those goods, and to repair and/or compensate ecological damages. See Carla Amado Gomes, *Introdução ao Direito do Ambiente* (AAFDL, Lisboa, 2012) 27.

expensive, and usually costlier than the measures to prevent the occurrence of damages.[592]

Ideally, all subjects must develop their activities without harming the environmental goods. However, in the advanced and perilous society in which we all live, not all harmful effects can be anticipated and avoided. In the majority of cases, damages can only be minimised, which means that prevention cannot be understood as the avoidance of each and every risk. In truth, prevention must be comprehended as the establishment of measures to minimise concrete damages, whose causes are widely known.[593]

Likewise, prevention is strongly correlated with natural resources' rational management. No damage can be caused to non-renewable commodities and the fragility and potential finitude of the resources essential to life must be respected. This compromise must be kept all the time considering that nature is mutable and dynamic. Moreover, being the environment a collective and public good for all the inhabitants of Earth, transcending the individuals and embracing several generations, the preventive actions must be taken at all levels of governance and engage producers, consumers and each and every citizen. Therefore, prevention must be contemplated in every environmental sector management, particularly without compromising the economic and technological advances of society, and must as well go through every sector of production, consumption and waste.

Especially regarding waste, prevention comprehends the measures taken before a substance, material or product become waste, and which have the capacity to reduce: (a) the quantity of waste, including through the re-use of products or the extension of the life span of products; (b) the adverse impacts of the generated waste on the environment and human health; and (c) the content of harmful substances in materials and products.[594]

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[592] It is thus no coincidence that some say that 'pollution prevention pays'. See Alexandra Aragão, *Direito Comunitário do Ambiente* (Cadernos CEDOUA, Almedina, 2002) 16.

[593] In this respect, we will clarify why we disregard the precautionary principle as a probable solution for the waste management problem that is causing marine plastic pollution. Whether it has or not the characteristics to be considered a juridical principle – for more information see Carla Amado Gomes, 'Por Mares Nunca de Antes Navegados: Gestão do Risco e Investigação Científica no Meio Marinho' in Gomes CA, *Textos Dispersos de Direito do Ambiente - Volume IV* (AAFDL, Lisboa, 2014) 244-8 – it will not be analysed here. In sum, in case of potential environmental consequences, the precautionary principle demands action, even before any causal nexus between the action that pollutes and the damage is established with absolute scientific evidence. In turn, prevention principle application implies the adoption of measures before the occurrence of a concrete damage, whose causes are well known, in accordance with the motto of in dubio pro environment. All things considered, precautionary principle cannot be applied in the case of marine plastic pollution, because a damage has already occurred and its a scientifically proved one, as seen in Part I.

[594] The most complete and accurate notion that we found was in Article 3(12) of the Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives [2008] OJ L312/3, already amended by the Commission Regulation (EU) No 1357/2014 of 18 December 2014 [2014] OJ L365/89, the Commission Directive (EU) 2015/1127 of 10 July 2015 [2015] OJ L184/13, the Council Regulation

In this notion, two dimensions can be identified: the quantitative waste prevention, which refers to the reduction of the amount of waste generated either during the production of an object or a service (prevention a priori), or their posterior utilisation and treatment (prevention a posteriori); and the qualitative waste prevention – or prevention of damages –, referring to the removal or reduction of the hazardousness (to humans and to nature) of the materials, the products and the waste generated. Both dimensions promote natural resources' conservation and, at the same time, the reduction of waste management's costs. However, prevention can only be achieved if consumers change their consumption pattern, make informed choices (eco labelling) and have access to sustainable design products or to more durable ones. In turn, qualitative prevention must be accomplished not only by eco conception, implying the addition of more friendly technologies, the revision of productive processes and the incorporation of less noxious substances, but also by a rigorous control of all waste management operations, especially recovery and disposal.[595]

Since the prevention principle covers every moment, from the very beginning, of production and consumption activities, its logical complement is the correction at source principle. It means that environmental damages should be primarily rectified (prevented, eliminated or moderated) at the source, at the place of its origin, and not at the end-of-line of production or consumption, such as solely the application of filters in effluents or the treatment of waste. This principle also implies the prohibition of transporting environmental noxious substances from their production sites – where they should actually be reused or treated – to distant places, even if it involves lower costs to the waste producer.[596]

With regard to costs, it is thus appropriate to introduce the polluter-pays principle. If the prevention principle elucidates when to act – a priori – and the correction at source principle explains where – at the source –, this other major principle clarifies who must pay the economic costs of pollution. It is indeed the polluter, because those who cause pollution must bear their economic costs, but who is the polluter? What does the polluter have to pay? And to whom?

(EU) 2017/997 of 8 June 2017 [2017] OJ L150/1, and the Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 [2018] OJ L150/109.

[595] EEA, 'Waste Generation'... and Alexandra Aragão, 'Princípios Fundamentais do Direito dos Resíduos' in Miranda J and others, *Direito dos Resíduos* (ERSAR, ICJP, CIDP, 2014) 16-7.

[596] Alexandra Aragão, *Direito Comunitário...,* 17-8.

Since, in the context of this thesis, pollution corresponds to the production of waste, the polluter is undoubtedly the waste producer, which in theory can be the economic operator or the consumer.[597] However, in practice, it is not easy to determine, even though we can define *polluter* as the one who directly or indirectly degrades environment or create conditions that lead to such degradation.[598] If pollution occurs in the course of a good's production process, and as a consequence of its productive process, then the polluter will certainly be the producer of the good, because he creates the products with pollutant characteristics and yet he puts them on the market, available to all potential users. In turn, if it is the product itself that pollutes (due to its composition, the type of use, or due to its deterioration), then he polluter is the consumer.[599] At last, if the production process and the consumption process are both polluting, hence the polluter is more difficult to determine. In particular cases of multiple polluters (cumulative pollution and polluters' chains), even considering the two criteria for allocating costs to identify the actual polluter – the economic and administrative efficiency of cost allocation and the ability to internalise costs by those concerned –, the answer is always the producer. In fact, not only the producers are the best payers, but also the activity of producers is easier to control and regulate, and in any case the internalisation of external effects makes more sense if it is operated at production level.[600] Summing up, since the essential purpose of this principle is to prevent further damage to the environment, the polluter is the one who has technological and economic control over the conditions that lead to the occurrence of pollution and can therefore prevent them or take precautions to prevent them from occurring.[601] If it is impossible to determine who is the producer, then the responsible is the current waste holder.

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597 Clearly, the extension of their responsibility differs. In the first case, waste management is professional, going from the cradle to the grave, extending until the final management of post-consumer waste, but not on the second case, that starts in the moment of consumption and lasts until waste sorting. The responsibility of the producer does not end with the loss of possession, but only with the transference, against fee payment ensuring the coverage of collection and management costs, to a waste management licensed operator. Waste never really becomes res nullius (a nobody's thing but that is susceptible of occupation and individual enjoyment). See Alexandra Aragão, 'Direito Administrativo dos Resíduos'..., 26-7.

598 Alexandra Aragão, *O Princípio do Poluidor Pagador: Pedra Angular da Política Comunitária do Ambiente – Volume I* (São Paulo, O Direito por um Planeta Verde, 2014) 130.

599 ibid 128-9

600 ibid 130-1.

601 ibid 137-8. It is true that the consumer is also an indirect polluter, that benefits from a product whose production is harmful to society. However, the consumer does not have at his disposal reasonable means to avoid the occurrence of damage because he does not control the conditions under which pollution occurs. Demanding a total cessation of indirectly polluting activity (the consumption) as a means of controlling pollution is manifestly unreasonable especially because there are other less costly means of avoiding pollution. See ibid 136.

Before we proceed, we must clarify that the scope of this principle is the prevention of future pollution and not the reparation of damages.[602] This principle acts preventively, before and independently of the damages occur and before and independently of the existence of victims. Accordingly, what the polluter must pay are the economic, social and environmental costs of prevention measures and not the costs of damages. The measures can be taken by the polluter itself or by the public authorities competent to prevent normal and accidental pollution, as well as the costs of updating measures. To these must be added the indirect costs that relate to the administrative costs inherent in the development of any environmental policy, the permissible public expenditure on environmental protection, and the restoration of the quality of the environment lost, or of economic aid to victims. It fulfils thus the goal of redistribution.

Although the name suggests that *polluter pays*, it does not mean that polluter pays to be authorised to pollute with impunity.[603] That would mean environmental degradation was being inevitably accepted and that prevention principle was no longer of any use. However, in reality, prevention principle complements polluter-pays principle and together they provide a direct incentive for potential polluters not to pollute, thus promoting an effective environmental protection.

How the polluter will pay is another matter of interest. Environmental policy instruments compatible with the principle are the way, but in each case all the advantages and disadvantages must be considered, since there is no clearly preferable instrument in relation to the others.[604] In general, they promote pollution reducing (incentive function) and finance the costs of any public policy on environmental protection (redistributive function).

In case of cumulative pollution, all the polluters must pay in proportion to the pollution prevention needs of the polluter, since all contribute to pollution in their conduct, and everyone must thus take steps to avoid it. In case of polluters' chains, it is necessary to determine in each case, for each link in the chain, who is the polluter who, by creating the conditions that are the origin of the pollution, can best control them by avoiding the occurrence of pollution. See ibid 139-41.

[602] This principle must not be confused with civil liability. The polluter-pays principle does not provide for the sanction of environmental crimes or misdemeanours related to waste, nor the repair of any environmental damage caused by waste.

[603] Nicolas de Sadeleer, 'The Polluter-pays Principle in EU Law - Bold Case Law and Poor Harmonisation' in *Pro Natura: Festskrift Til Hans Christian Bugge På 70-årsdagen 2. Mars 2012* (Universitetsforlaget, Oslo, 2012) 406.

[604] In fact, the choice of the most appropriate instrument depends on multiple decision factors: the type and severity of the pollution concerned (gradual pollution or accidental pollution, very tolerable or not tolerable); the category and quantity of the polluters (producers or consumers, only one, few or many); the environmental quality objectives for the sector concerned (stabilisation, reduction, or total elimination of pollution); the financial needs of environmental policy (interventionism or abstention); and other factors involved (existence or not of pre-installed administrative structures, knowledge or lack of knowledge of pollution functions, permanence or transitoriness of measures). See Alexandra Aragão, *O Princípio do Poluidor Pagador*..., 169-71.

Nowadays, legislative instruments prescribe behavioural rules of high relevance and they can be licensing procedures, prohibitions, environmental binding standards, emission limit values, best available techniques, administrative orders and sanctions. Other instruments are the economic ones, such as the market based instruments, that are well suited to improve internalisation of environmental costs and include tradable permits, eco-taxes, liability rules, certificates, tax alleviations, and subsidies. There are also soft law instruments, namely voluntary agreements and labelling.

A last note that is particularly relevant for plastic waste concerns repercussion, which is the transfer of the payments made by the polluter to his clients. It is achieved by the inclusion of these expenses, as a cost, in the final price of the products/services, reflexively burdening the respective acquirer. In fact, it is better that pollution costs are reflected in the price of products/services, being thus borne by the person that generated the waste than by the average taxpayer. This way, polluters help to finance public policies to protect the environment by internalising social and environmental costs: a portion of the profits accruing to polluters as the result of their activities is delivered to the public authorities responsible for inspecting, preventing, monitoring, controlling and cleaning the pollution these activities produce, which explains the redistributive function of the polluter-pays principle. The sums collected must be set aside in a special fund for financing environmental policy, not overburdening the overall taxpayers.

The remaining environmental principle is the integration principle, which demands that environmental protection requirements must be not only considered but effectively integrated into the definition and implementation of other policies, whether they are related to economy, industry, energy, transport, agriculture, tourism, waste management or other matters. Indeed, it is everyone's responsibility to protect the environment. Decision-making, public policies, plans, programs, and activities that could adversely impact the environment must respect all the principles herein referred.

With regard to Waste Law exclusive principles, we will first introduce the waste hierarchy principle. It is one of the cornerstone principles of waste policies and legislation and it places waste prevention on top of a priority list which contemplates, in descending order, the best overall environmental options. Prevention is therefore followed by reduction, reuse, recycling, other recovery including energy recovery, and disposal.

Although it is binding, this priority order – inspired by a common-sense rule – of waste management options may suffer adjustments. Since different waste treatment methods can have different environmental impacts, every product and waste stream must be subject to concrete tests to determine which waste management operation is environmentally more suitable and capable of preventing impacts on human health and society. It may happen that a certain recovery operation may produce more serious impacts than a proper disposal, which means that only through life-cycle analyses and through the examination of both recovery and disposal's technical and economic viability, the way forward can be discussed.[605]

The aim of moving towards a recycling and recovery worldwide society implies moving up the waste hierarchy until reaching a zero waste level, but while that is not achievable, other environmental and economic advantages exist. As waste moves up the hierarchy, final loss of raw material can be avoided, such as the waste burden on the natural environment.[606] Apart from that, a more efficient resource use can be developed and new jobs can be created, owing to the fact that the upper tiers of the waste hierarchy (including separate collection, reuse and recycling) are known to be much more labour intensive than waste disposal and incineration.[607] Evidently, all these benefits can only be obtained by the joint effort of all the parties concerned: consumers, producers, policymakers, local authorities, waste treatment facilities, and all other stakeholders.

In addition, before any of these waste management options can be adopted, the self-sufficiency principle must be observed. Applicable both to recovery and disposal, this principle imposes that each country – whether it is isolated or not – has full capacity to

[605] See Alexandra Aragão, 'Princípios Fundamentais..., 22-3. See, from the same author, 'Direito Administrativo dos Resíduos'..., 32-4, where we learn that for example, to meet the objectives of recovery depends on the fulfilment of the economic conditions essential for recovery: for recovery to be an economically acceptable option, its revenues must be greater than the costs inherent, which in turn have to be smaller than disposal costs. Actually recovery costs are higher than the costs of disposal, so disposal becomes easily the most adopted option worldwide. The allocation of subsidies to support recovery can be attributed, but in our opinion the decision that must prevail is the one that allows a more effective environmental protection. So if it seems clear that it is more environmentally efficient to incinerate a material to recover energy than recycling it, then that is the option to be taken. Regarding plastic waste, it shall be recycled when it is clean and separated and it shall be incinerated to recover the energy when it is mixed. In cases where the difference in environmental impact between two options is negligible, then in principle the market should be allowed to find the balance between those two options.

[606] As waste moves up the hierarchy, management options will respect more the environment. Both incineration and landfilling, located at the bottom of the priority list, can cause considerable environmental impacts. From all waste management options, landfills are the biggest source of greenhouse gas emissions, mainly due to their emission of methane. Depending on the way they are built, landfills might also contaminate soil and water. Besides representing a loss of resources, landfills can definitely turn into a future environmental liability. See EEA, *EEA Signals 2014: Well-being...,* 29.

[607] See European Commission, 'Commission Staff Working Document - Executive Summary of the Impact Assessment' SWD(2014) 208 final, 50.

manage all the waste produced in its territory. Consequently, in order to reduce transboundary movements of waste, countries must provide an integrated and adequate network of facilities, apt either for waste disposal or its recovery, and taking into account the best available techniques.

Exceptionally, for geographical reasons or for reasons of scale, countries may refrain from the responsibility of managing their own waste and promote their transportation to another country. If the proximity between the waste production site and a foreign recovery or disposal facility is considerably less than in relation to a national one, the country in question can, recurring to the proximity principle, send its waste, provided it has been authorised by the other countries' competent authorities. Also dependent of an authorisation, a country that does not produce enough waste (such as accumulators, batteries or chlorofluorocarbons) to justify the investment in specialised installations for certain types of waste, can send them abroad. We note that, in general, waste transportation for recovery purposes has a less restricted circulation regime than for elimination purposes.

Although this principle can also be directly applied to a regional or subregional level, it always presupposes an effective cooperation between the countries/regions involved. It happens the same with proximity principle, that advocates that waste should be managed as close as practicable to its point of origin, in one of the nearest appropriate installations, by means of the most appropriate methods and technologies, in order to ensure a high level of protection for the environment and public health. This principle is in fact the expression of the correction at source principle directly applied to waste matters: waste treatment must occur as close as possible to the site of its production, avoiding waste tourism.[608] If a foreign installation is in fact closer to the production site than to the national equivalent installation, the proximity principle must prevail over the self-sufficiency principle. In this way, the most environmentally sustainable waste management option is assured. Additionally, the costs, resource use and emissions of transportation of waste are minimised, and the risks of accidents too.

The last principle to consider is the planning principle. Its fundament is the intricacy of waste management operations and the numerous types of waste and its varied sources. This principle gives place thus to a particularly important obligation: each country has a duty to draw up waste management plans containing general technical standards and provisions

[608] See Alexandra Aragão, 'Princípios Fundamentais..., 21-2.

on types, origin and quantity of waste, on collection, sorting, recovery and disposal measures and on disposal sites and associated facilities.[609] Furthermore, since planning requirement stems from the environmental principle of integration, it gives rise to the duties of *integration of sources*, *integration of means* and *integration of purposes*.[610] The first duty means that all the waste must be considered for planning purposes, which means that even if there are plans just for certain waste fluxes, a global plan for waste management must also be designed to ensure a better coordination of all the sectoral plans. *Means integration* because every waste is different and there is not a unique and ideal solution for each one, which implies that each and every reasonable management operation is considered before deciding how to proceed (for example, tires can be recycled and/or retread). Lastly, *integration of purposes* stands for the application of the waste hierarchy principle, guaranteeing that planning's greatest utility is the establishment of a clear hierarchy between the purposes of waste management. As we have already mentioned, recovery is logically preferable to disposal, but in cases where it is not, that must be defined in the sectoral plans.

This being said, we can conclude for the immense importance plans have. Its comprehensiveness and its unifying role, by gathering all the principles and rules to respect in terms of waste management, are exceptional. It can even help to define how resources can be saved and used in a circular way. The early definition of resources characteristics and applications, and also of waste management strategies has numerous benefits, including the predictability of the whole management of resources, the prevention of waste and of damages and also a better articulation of waste policies between countries.

It is thus demonstrated the meaning and the importance of these juridical principles. We will henceforth illustrate its significance during the analysis of the relevant legal texts and in the end they will help us draw the solutions.

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[609] These provisions must be general and abstract and consequently capable of constituting an organised and coordinated system, see case C-387/97 *Commission of the European Communities v Hellenic Republic* [2000] EU:C:2000:356, paragraph 76 a contrario.

[610] Vision shared by Alexandra Aragão in *O Direito dos Resíduos* (Cadernos CEDOUA, Almedina, 2003) 19. Regardless of the waste stream concerned (such as industrial waste, medical waste, urban solid waste, agricultural waste and others), of the geographical demarcation of the plan (local, municipal, inter-municipal, regional, national and others), or of its subjective scope (states, public entities, waste management facilities, enterprises and others), all the plans have to respect certain environmental requirements and can even be subjected to strategic environmental assessments.

VIII. Tackling Marine Plastic Pollution in International Law

The problem of marine plastic pollution is undoubtedly a global concern. As we already stated, plastic debris can be found in any ocean and sea worldwide, which are indeed all connected to each other. In addition, once it enters the sea, it has no owner, and this makes its management difficult and highly dependent on good international and regional collaboration. There are maritime zones under national sovereignty or jurisdiction – territorial sea, contiguous zone, exclusive economic zone, and continental shelf –,[611] but there are also areas beyond the limits of national jurisdiction, namely the high seas,[612] that cover 45% of the Earth's surface and 64% of the oceans, including all gyres and garbage patches existent. The high seas are open to all States, whether coastal or land-locked, and all of them enjoy

[611] UNCLOS is responsible for the definition of maritime zones and their boundaries, worldwide. Each of these zones have different jurisdictional rights: they become weaker as we move away from the coast. So, in the territorial sea (that can be breadth up to a limit not exceeding twelve nautical miles measured from baselines determined in accordance with this Convention, coastal States are sovereign (see Articles 2(1) and 3 UNCLOS). This sovereignty extends to the air space over the territorial sea as well as to its bed and subsoil, see Article 2(2). In the contiguous zone, adjacent to territorial sea and that may not extend beyond 24 nautical miles from the baselines from which the breadth of the territorial sea is measured, the coastal States may only 'exercise the control necessary to: (a) prevent infringement of its customs, fiscal, immigration or sanitary laws and regulations within its territory or territorial sea; (b) punish infringement of the above laws and regulations committed within its territory or territorial sea' (Article 33). In the exclusive economic zone (EEZ), which is the area beyond and adjacent to the territorial sea that shall not extend beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, the coastal States have: '(a) sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and of the seabed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds; (b) jurisdiction as provided for in the relevant provisions of this Convention with regard to: (i) the establishment and use of artificial islands, installations and structures; (ii) marine scientific research; (iii) the protection and preservation of the marine environment; (c) other rights and duties provided for in this Convention. (see Articles 55, 56 and 57). At last, in the continental shelf – area that 'comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance', see Article 76(1) – the coastal States exercise sovereign rights for the purpose of exploring it and exploiting its natural resources, that 'consist of the mineral and other non-living resources of the seabed and subsoil together with living organisms belonging to sedentary species, that is to say, organisms which, at the harvestable stage, either are immobile on or under the seabed or are unable to move except in constant physical contact with the seabed or the subsoil', see Article 77(1 and 4).

[612] The high seas are defined in Article 86 UNCLOS as 'all parts of the sea that are not included in the exclusive economic zone, in the territorial sea or in the internal waters of a State, or in the archipelagic waters of an archipelagic State'. *Area* is also a maritime area beyond the limits of national jurisdiction, meaning the 'seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction', see Article 1(1(1)). Its resources are the common heritage of mankind and no State shall claim or exercise sovereignty or sovereign rights over any part of the area or its resources, nor shall any State or natural or juridical person appropriate any part thereof, see Articles 136 and 137(1).

freedom of navigation, fishing, and scientific research.[613] These are definitely international waters, that no State can validly subject to its sovereignty,[614] and that can only be regulated by international public law.

However, the optimal solution to handle specifically marine plastic pollution is more specialised than *just* international public law: it is international environmental law. Since its characteristics differ greatly from the ones of classic international public law, it is imperative to clarify them.[615] The main difference is that international environmental law does not regulate only the conducts of the States, and that occurs because environmental harmful practices are caused mostly by private behaviours and not so much by the actions of the States. In addition, these harmful practices are triggered by physical and technological events and not often by political causes (such as wars, human rights protection and trade), which means that the recognition and the resolution of these problems are subject to very high uncertainty levels. Another differentiating factor between environmental and classic international public law is that environmental matters are clearly interconnected and demand a holistic, global and all side approach. Moreover, because of the magnitude and the dynamism of ecological damages, that can cut across all borders, there is a compelling need to share information and scientific knowledge and to continuously update data, numbers and limits associated with biodiversity, ecosystems and environmental goods' usage.

The referred characteristics are perfectly in line with the reality of marine plastic pollution presented in Part I. Moreover, in the light of these facts, international cooperation is of vital importance. International environmental law is thus determining to tackle this pollution problem in a more effective way. To assure that, States need the collaboration of international organisations, such as the United Nations.[616]

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[613] See Article 87(1) UNCLOS, where it is included freedom to lay submarine cables and pipelines and to construct artificial islands and other installations permitted under international law.
[614] Article 89 UNCLOS.
[615] Clarification shared by Carla Amado Gomes in *Introdução ao...*, 50-1.
[616] The United Nations is an international governmental organisation established in 1945 and currently made up of 193 Member States. Respecting the purposes (maintain international peace and security, protect human rights, deliver humanitarian aid, promote sustainable development, and uphold international law) and the principles contained in its founding Charter, the UN can take action – and at the same time promote multilateral relations of mere cooperation between its Member States – on the issues nowadays confronting humanity, such as peace and security, climate change, sustainable development, human rights, disarmament, terrorism, humanitarian and health emergencies, gender equality, governance, food production, and more. To work with such wide scope, it was created the UN system, made up of the UN itself and many affiliated programmes (UNEP and UNDP), funds, and specialised agencies (UNESCO and IMO), all with their own membership, leadership and budget. The specialised agencies are independent international organisations funded by both voluntary and assessed contributions. At last, we add that the UN Charter contains a supremacy clause that makes it the highest authority of international law.

By enabling dialogue between its 193 Members States, and by hosting negotiations on a wide variety of subjects, the United Nations has become a mechanism for governments to cooperate and to find areas of agreement in order to try to solve problems together. With respect to environment, the UN enterprise began in the 1970's, particularly after the *Declaration of the United Nations Conference on the Human Environment*, celebrated in Stockholm, in June 1972.[617] Since then, a range of legal initiatives particularly related to sea pollution, covering all marine debris and most of its sea-based sources have been put in place. They are of great importance, especially because a lot is happening on the high seas, and according to International Maritime Organisation (IMO),[618] over 90% of world trade – being it raw materials, commodities, finished goods, food or fuel – is carried by sea. However, marine plastic pollution is a new problem with particular features. Besides being recognised and taken seriously, – and not only by the UN –, land-based sources must be also regulated and controlled, particularly because they account for as much as 80% of all marine pollution.

Therefore, after explaining how marine plastic litter assumed considerable importance in international scenario, we will enumerate and evaluate the potentiality of some existing policies and instruments in the resolution of the problem, whether they concern water pollution, POPs, waste management, resource efficiency, biodiversity or other related themes.

A. Gaining Understanding and Awareness

It was during the 60th Session of the UN General Assembly, in November 2005, that the UN recognised for the first time the problem of marine litter. The Resolution A/60/30 on oceans

Article 103 states that the UN Charter shall prevail in the event of a conflict between the obligations of the members of the United Nations under the present charter and their obligations under any other international agreement.

617 Although non-binding, this declaration established for the first time an obligation to preserve the environment through a perspective of intergenerational equity (see Principles 1 and 2). In spite of the strait relation between the environment and the subjects of sustainability, quality of life and peace, the merge between Intergenerational Law juridical principles and the environment had important refractions in posterior numerous environmental conventions. Carla Amado Gomes, 'Apontamentos sobre a Protecção do Ambiente na Jurisprudência Internacional' in Gomes CA, *Elementos de Apoio à Disciplina de Direito Internacional do Ambiente* (AAFDL, Lisboa, 2008) 368-9. In Principle 7, States were encouraged to 'take all possible steps to prevent pollution of the seas by substances that are liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea'. Taking into account the cooperative spirit mentioned in Principle 24, it was suggested that the response to pollution and the compensation to attribute to its victims should be handled in cooperation, taking special attention to developing countries (see Principles 7 and 22).

618 'IMO Profile' (*UN-Business Action Hub*) <https://business.un.org/en/entities/13> accessed 19 April 2018.

and the law of the sea highlighted the lack of information and data on marine debris and brought forward the following measures: undertake further studies on the extent and nature of the problem; develop partnerships between States and industry/civil society to raise awareness about the impacts of marine debris on the marine environment and consequent economic loss; integrate the issue of marine debris within national strategies dealing with waste management in the coastal zone, ports and maritime industries, including recycling, reuse, reduction and disposal; encourage the development of appropriate economic incentives (including the development of cost recovery systems that, for instance, provide an incentive to use port reception facilities and discourage ships from discharging marine debris at sea); encourage States to cooperate regionally and subregionally to develop and implement joint prevention and recovery programmes for marine debris; take all appropriate measures to control, reduce and minimise, to the fullest extent possible, marine pollution from land-based sources as part of States' sustainable development strategies and programmes, in an integrated and inclusive manner; and finally start implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA)[619] and the Montreal Declaration on the Protection of the Marine Environment from Land-based

[619] GPA was adopted by 108 Governments and the European Commission at an intergovernmental conference convened for this purpose in Washington, DC, USA, in November 1995. The parties declared 'their commitment to protect and preserve the marine environment from the impacts of land-based activities', through the Washington Declaration on the Protection of the Marine Environment from Land-based Activities, and set as 'their common goal sustained and effective action to deal with all land-based impacts upon the marine environment, specifically those resulting from sewage, persistent organic pollutants, radioactive substances, heavy metals, oils (hydrocarbons), nutrients, sediment mobilization, litter, and physical alteration and destruction of habitat' (para 1). Marine litter was highlighted as a priority source, giving UNEP – which hosts the GPA Coordinating Unit and coordinates some activities in support of the Programme – a strong mandate to continue its work on the subject. As part of its strategy to tackle marine plastic pollution, the GPA secretariat established a global multi-stakeholder partnership that we will present further on. It is the Global Partnership on Marine Litter (GPML).

The GPA was designed to be a source of conceptual and practical guidance to be drawn upon by national and/or regional authorities in the development and implementation of initiatives to tackle transboundary issues, such as devising and implementing sustained action to prevent, reduce, control and eliminate marine degradation from land-based activities. Consequently, the implementation of the GPA is dependent on national policies. Each State must develop national action programmes in close partnership with all stakeholders including local communities, public organisations, non-governmental organisations and the private sector (whereas 7 and paras 2 and 8 Washington Declaration). All these stakeholders must cooperate to build capacities and mobilise resources for the development and implementation of such programmes, and help in particular the least developed countries, countries with economies in transition and small island developing States (para 4). Among the several initiatives planned under the GPA, the main one is to protect and preserve the marine environment from the impacts of land-based activities. It comprehends first and foremost 'taking immediate preventive and remedial action, wherever possible' (para 5), plus 'promoting access to cleaner technologies, knowledge and expertise' (para 6), and 'encouraging and/or making available external financing, given that funding from domestic sources and mechanisms for the implementation of the Global Programme of Action by countries in need of assistance may be insufficient' (para 9).

Activities.[620-621] At the same time, it was recognised the need to build the capacity of developing States to raise awareness and support implementation of improved waste management practices, noting the particular vulnerability of small island developing States to the impact of marine pollution from land-based sources and marine debris.[622]

Because of its influence on the Resolution A/60/30, it is worth mention the first UNEP report entirely dedicated to marine litter that preceded the Resolution: the *Marine Litter - An Analytical Overview*, developed by UNEP's Regional Seas Programme,[623] in cooperation with the GPA. The main data gathered comprised the global distribution of marine litter, quantities, sources and effects, as well measures to prevent and combat marine litter, including analysis and areas for potential action. Overall, it was a very sound and detailed report, where UNEP recognised that marine litter was part of the broader problem of waste management and identified the causes: lack of appropriate systems of waste management, from source to disposal;[624] deficiencies in the implementation and enforcement of existing international and regional environment-related agreements, as well as national regulations and standards; littering practices from the shipping sector; and lack of awareness among main stakeholders and the general public.[625] Consequently, UNEP acknowledged that was necessary a broader approach aiming at creating inter-agency partnerships to deal with the problem, and so UNEP committed itself to play a growing role in addressing marine pollution problem.

In October 2006, the Second IGR Meeting on the Implementation of the GPA took place in Beijing, China.[626] During this event, a new and innovative partnership named Marine

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[620] Implementing properly the GPA implies that States provide for its periodic intergovernmental review (Washington Declaration, para 13(c)). Every five years, the Intergovernmental Review Meetings (IGR) make possible to conduct regular assessments of the state of the marine environment and to define actions to strengthen GPA implementation. The first IGR on the implementation of GPA was held in Montreal, Canada, in November 2001. Representatives of 98 governments expressed their concern about the growing marine environmental degradation caused by pollution from different sources, including marine litter. These representatives also concluded that 'the causative relationship between poverty, human health, unsustainable consumption and production patterns, poorly managed social and economic development, and environmental degradation must be emphasized when implementing the Global Programme of Action', see the Conclusions of the Co-Chairs from the IGR on the Implementation of GPA in Annex I of the UN A/57/57 report of 7 March 2002. The Montreal Declaration can be found in the same Annex. Even though it is an extension of the GPA aims, litter is not mentioned.

[621] All these suggestions can be found in paras 65, 66 and 69 of the Resolution A/60/30.

[622] Para 12.

[623] The Regional Seas Programme, launched in 1974, is responsible for the implementation of many of UN Environment's coastal and marine-related policies. This Programme will be described further on.

[624] UNEP, *Marine Litter - An Analytical Overview* (UNEP, Nairobi, 2005) ii.

[625] ibid 1.

[626] The purposes of this IGR were: strengthen implementation of the GPA at national, regional and global levels; contribute to the achievement of specific targets of the Johannesburg Plan of Implementation as they relate to the

Litter - A Global Challenge was created with the purpose of implement the UNEP Global Initiative on Marine Litter, a cooperative activity of UNEP/GPA and UNEP Regional Seas Programme. This Initiative was established in response to the UN Resolution A/60/30 and fostered not only cooperation, but also coordination of activities for the control and sustainable management of marine litter.[627]

Subsequently, in March 2011, the Fifth International Marine Debris Conference was held in Honolulu, Hawaii. It was organised by UNEP in cooperation with NOAA and other agencies and organisations.[628] The outcome was the *Honolulu Commitment* and the *Honolulu Strategy - A Global Framework for Prevention and Management of Marine Debris*. These two documents were then highly relevant, especially taking into account the sparse number of studies and reports existent in 2011. Currently, they still inspire all marine debris policies and programmes. The Commitment, that represented the first step of the Honolulu Strategy, is a multi-stakeholder pledge that outlines twelve actions able to reduce the occurrence of marine debris, as well as its extensive damage. It summarises a series of cross-sectoral policies, and the first one is to make choices that reduce waste in order to halt and reverse the occurrence of marine debris. To achieve this and more, citizens, environmental organisations, industry and governments must be encouraged to take responsibility for their contribution and to find solutions together (such as improving global knowledge, raising awareness, and sharing openly and freely technical, legal, policy, community-based and economic/market-based solutions). Moreover, governments must adopt initiatives that can turn waste into resources in an environmentally sustainable manner. They must also provide financial support for global, regional, national and local actions capable of contributing to the implementation of the Honolulu Strategy.

In turn, the Honolulu Strategy is a framework for a comprehensive and global collaborative effort to prevent and reduce marine debris worldwide, as well as its ecological, human health and economic impacts. Even though it was acknowledged in the Honolulu Strategy that many countries and international organisations have been tackling for decades the marine debris problem with significant signs of progress, one of the reasons that justified

GPA, the ecosystem approach, and sanitation; and provide guidance on the programme of work for the UNEP/GPA Coordination Office for the period 2007-2011.

[627] See UNEP, *Policy Guidance for Implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities over the period 2012-2016*, UNEP/GPA/IGR.3/3 (1 November 2011) 3.

[628] The Fifth International Marine Debris Conference brought together 440 participants, representing 38 countries, governments, research bodies, corporations and trade associations.

the adoption of this Strategy was the need to support and strengthen these efforts and catalyse new ones around the world, particularly because 'as with other complex environmental problems, no single solution is possible'.[629] Consequently, this framework was not designed for direct implementation by any country, organisation or group, but as a means to support and connect actions implemented by a multitude of stakeholders in various geographic contexts and at different levels of governance.[630]

For better guidance, the Honolulu Strategy is organised by a set of goals and strategies. The three overarching goals, focused on reducing the threats of marine debris, prescribe the reduction of amounts and impacts of (a) land-based litter and solid waste introduced into the marine environment, (b) sea-based sources of marine debris including solid waste, lost cargo, abandoned, lost, or otherwise discarded fishing gear, and abandoned vessels introduced into the sea, and (c) accumulated marine debris on shorelines, in benthic habitats, and in pelagic waters. The strategies presented are several and comprehend education, outreach, legislation, policies, market-based instruments, promotion of best practices and new technologies, capacity for monitoring and enforcement, infrastructures for storm water and solid waste minimisation, capacity to manage removal, removal of solid waste from coastal lands, watersheds, and waterways, and removal of marine debris.

Regarding goal A, the Honolulu Strategy recognised that marine debris was part of a broader problem of solid waste management, affecting all coastal and upland communities, including inland waterways. At the same time, it was also admitted the common lack of capacity and funding to effectively manage solid wastes, particularly in developing countries. These acknowledgements were not new, but they certainly had much greater reach and impact than when they were shared by the UN Resolution A/60/30 in 2005. Most likely, the same happened with the few strategies presented to improve integrated solid waste management, in order to support marine debris prevention and management, such as capacity gaining and identification of funding sources.[631]

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[629] Honolulu Strategy, 1.
[630] Due to its singularity, it is worth sharing the Honolulu Strategy scheme. Having in mind its two main purposes – to describe and catalyse the multi-pronged and holistic response required to solve the problem of marine debris and to guide monitoring and evaluation of global progress on specific strategies at different levels of implementation –, it is possible to individualise the Strategy tools: the planning tool for developing or refining spatially or sector-specific marine debris programs and projects; the common frame of reference for collaboration and sharing of best practices and lessons learned; and the monitoring tool to measure progress across multiple programs and projects. See ibid 1 and 4.
[631] ibid 14.

As was to be expected, in January 2012 the third IGR Meeting on the Implementation of the GPA took place, this time in Manila, Philippines. Immediately before, a Global Conference on Land-Ocean Connections was organised to discuss emerging issues and science-policy interlinkages in order to adequately inform decision makers.[632] This Conference was structured around the proposed priority themes for the GPA, in which marine litter was included, as the Governments decided in Beijing.[633] The several reports that were prepared in anticipation of these two events are a good example of the importance marine litter was given. Marine plastic litter was mentioned for the first time as an emerging environmental issue, and the characteristics of plastics gave rise to serious concerns, especially due to the potential impact of persistent bioaccumulation and the toxic compounds released from such debris on ecosystems and human health.[634] Apart from this, it was noted not only the existence of a causal link between unsustainable production and consumption and marine litter, but also the persistent nature of the impacts that marine litter can cause to coastal water quality, health, livelihoods, and agriculture, and the substantial economic costs and losses associated. In view of this, it was added the need to integrate the issue of marine litter into national strategies dealing with waste management in the coastal zone, ports and maritime industries, and the need to encourage the development of appropriate economic incentives such as the cost recovery system.[635]

Meanwhile, during the Third IGR the *Manilla Declaration on Furthering the Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities* was adopted.[636] Herein, marine litter was

[632] This Conference happened for the first time also in Manila, during the two days preceding the Third IGR.
[633] See paragraph 27 of UNEP/GPA/IGR.3/2, of 9 November 2011.
[634] See para 39 of the *Progress in Implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities at the National, Regional and International Levels over the period 2007-2011* (UNEP/GPA/IGR.3/2, of 9 November 2011). Along the same line, the *Proposed Programme of Work of the United Nations Environment Programme Global Programme of Action Coordination Office for 2012-2016* (UNEP/GPA/IGR.3/4, of 1 November 2011) called for the establishment of five-year partnerships, from 2012 to 2016, on nutrients, wastewater and marine litter in order to secure significant improvements in coastal water (ecosystem-based) management and quality.
[635] See paras 31 and 40 of the *Policy Guidance for Implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities over the period 2012-2016* (UNEP/GPA/IGR.3/3, of 1 November 2011.
[636] UNEP/GPA/IGR.3/CRP.1/Rev.1, of 26 January 2012. This Declaration was endorsed by the representatives of 65 governments and by the European Commission. It contained a total of sixteen provisions focusing on actions inspired by the Honolulu Commitment and the Honolulu Strategy to be taken between 2012 and 2016 at international, regional and local level.

recognised as a problem that was global in scale but underestimated in impacts.[637] It was thus decided that the GPA Coordination Office in the period 2012-2016 should focus its work on nutrients, litter and wastewater, and thus adopt global partnerships for each category. Regarding marine litter, it was suggested the achievement of an effective sustainable planning and management of the land-based activities and the sharing of best practices and technical information on capacity building, and legal, policy, economic and market-based means of preventing, reducing and managing marine litter.[638] Once again, emphasis was placed on the lack of capacities in science and technology, and on the need for integration of research, education, and extension advisory services, in particular of developing countries.[639]

It was finally in June 2012, during the UN Conference on Sustainable Development in Rio de Janeiro, Brazil,[640] that the GPA Coordination Office launched the Global Partnership on Marine Litter (GPML). It was designed to be a wide cooperation platform,[641] and to be operated under the Global Partnership on Waste Management.[642] It seeks to protect

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[637] It was also acknowledged in the Declaration that marine litter (as well wastewater and POPs) could take a severe toll on human health, safety, well-being and economic growth, and a direct threat to coastal and marine ecosystems and food and services they provide. See whereas 6, 7 and 16.
[638] Para 5.
[639] Whereas 9 and 11. See also paras 8 and 11.
[640] This was the third UN Earth Summit. The first Conference on Environment and Development took place in Rio de Janeiro, Brazil, in June 1992. It sought to help governments rethink economic development and find ways to halt the destruction of irreplaceable natural resources and pollution of the planet. The resulting documents were *Agenda 21*, the *Rio Declaration on Environment and Development*, the *Statement of Forest Principles*, and two legally binding Conventions: the Framework Convention on Climate Change; and the Convention on Biological Diversity. Agenda 21 was a comprehensive non-binding plan for global, national and local action to achieve sustainable development – concept whose analysis is beyond the scope of this study. In September 2002 occurred the World Summit on Sustainable Development (Rio+10) in Johannesburg, South Africa. The Johannesburg Plan of Implementation is the most important document. Rio+20 aimed to secure renewed political commitment for sustainable development, assess the progress to date and the remaining gaps in the implementation of the outcomes of the major summits on sustainable development, and address new and emerging challenges. The two most important themes were the green economy in the context of sustainable development and poverty eradication and institutional framework for sustainable development. Governments also adopted the 10-year Framework of Programmes on Sustainable Consumption and Production Patterns, as contained in the document A/CONF.216/5, of 18 June 2012.
[641] GPML provides an opportunity for wide participation of international agencies, governments, NGOs, academia, private sector, civil society and individuals. All these participants can contribute – with financial support, in-kind contributions and/or technical expertise – to the development and implementation of GPML activities.
[642] This relation between partnerships will ensure that marine debris issues, goals and strategies are tied to global efforts to reduce and manage waste. Currently, the thematic areas of UNEP Global Partnership on Waste Management – that is hosted by the United Nations Environment Programme International Environmental Technology Centre since November 2010 – are: waste and climate change; waste agricultural biomass; integrated solid waste management; e-waste management; marine litter; waste minimisation; hazardous waste management; and metal recycling. Regarding all these areas, the following objectives must be pursued: enhance international cooperation, outreach, advocacy, and knowledge management and sharing; identify and fill information gaps in waste management to protect human health and environment; tackle adverse impacts of unsound management of waste; raise awareness, political will and capacity to promote resource conservation and resource efficiency through waste prevention and by recovering valuable material and/or energy from waste. See UN, 'Global Partnership on

human health and the global environment through the reduction and management of marine litter.[643] Indeed, GPML has an immense potential and can play a greater role in engaging all stakeholders in the lifecycle of plastics and encouraging solutions by all sectors.

It was also during this Conference that another significant achievement for marine litter issue was achieved. In the political document entitled *The Future We Want*,[644] States committed to take action to reduce the incidence and impacts of marine pollution on marine ecosystems, and especially to 'take action to, by 2025, based on collected scientific data, achieve significant reductions in marine debris to prevent harm to the coastal and marine environment'.[645] In order to achieve this, States should ensure the effective implementation of the conventions adopted in the framework of the International Maritime Organisation (IMO) – that we will analyse in the next chapter –, and ensure likewise the follow up of the relevant initiatives such as the GPA, as well as the adoption of coordinated strategies.

Waste Management (GPWM)' (*United Nations Partnerships for SDGs*) <https://sustainabledevelopment.un.org/partnership/?p=7462#updates> accessed 27 April 2018.

643 To achieve that, several objectives such as the following were defined: reduce worldwide marine litter impacts; enhance international cooperation and coordination through the promotion and implementation of the Honolulu Commitment and the Honolulu Strategy; promote knowledge management, information sharing and monitoring of progress on the implementation of the Honolulu Strategy; promote resource efficiency and economic development through waste prevention and by recovering valuable material and/or energy from waste; increase awareness on sources of marine litter, their fate and impacts; assess emerging issues related to the fate and potential influence of marine litter, including (micro) plastics uptake in the food web and associated transfer of pollutants and impacts on the conservation and welfare of marine fauna. See UNEP, 'Global Partnership on Marine Litter' (*UNEP*) <www.unenvironment.org/explore-topics/oceans-seas/what-we-do/addressing-land-based-pollution/global-partnership-marine> accessed 27 April 2018.

644 A/RES/66/288, of 27 July 2012. Even without referring marine litter particularly, this document has several provisions that must be taken into account since their observance allows the reduction of marine plastic pollution, and that we will quote: 'We stress the need to adopt measures to significantly reduce water pollution and increase water quality, significantly improve wastewater treatment and water efficiency and reduce water losses' (para 124); 'We note the significant threat that alien invasive species pose to marine ecosystems and resources, and commit to implement measures to prevent the introduction and manage the adverse environmental impacts of alien invasive species' (para 164); 'We commend existing public-private partnerships, and call for continued, new and innovative public-private partnerships among industry, governments, academia and other non-governmental stakeholders, aiming to enhance capacity and technology for environmentally sound chemicals and waste management, including for waste prevention' (para 217); 'We recognize the importance of adopting a life-cycle approach and of further development and implementation of policies for resource efficiency and environmentally sound waste management. We therefore commit to further reduce, reuse and recycle waste (the 3Rs) and to increase energy recovery from waste, with a view to managing the majority of global waste in an environmentally sound manner and, where possible, as a resource. Solid wastes, such as electronic waste and plastics, pose particular challenges, which should be addressed. We call for the development and enforcement of comprehensive national and local waste management policies, strategies, laws and regulations' (para 218); 'We urge countries and other stakeholders to take all possible measures to prevent the unsound management of hazardous wastes and their illegal dumping, particularly in countries where the capacity to deal with these wastes is limited, in a manner consistent with the obligations of countries under relevant international instruments. We adopt the ten-year framework of programmes on sustainable consumption and production patterns' (para 219).

645 Para 163. In this case, marine pollution includes marine debris, especially plastic, POPs, heavy metals and nitrogen-based compounds from a number of marine and land-based sources, including shipping and land runoff.

Following this line of reasoning, we present an important step in the definition of the strategy to tackle marine plastic pollution. In the UN Resolution A/68/70 of 9 December 2013, the States acknowledged with concern that the health of the oceans and marine biodiversity were negatively affected by marine debris, especially plastic, from land-based and marine sources.[646] There was no longer any doubt that the impacts were real. Consequently, it was recognised the need for better understanding of the sources, amounts, pathways, distribution trends, nature and impacts of marine debris.[647] Additionally, States were encouraged to develop partnerships with industry and civil society to raise awareness of the extent of the impact of marine debris on the health and productivity of the marine environment and consequent economic loss.[648] To better achieve these purposes, States were urged to: integrate the issue of marine debris into national and regional strategies dealing with waste management, especially in the coastal zone, ports and maritime industries, including recycling, reuse, reduction and disposal; develop an integrated waste management infrastructure; encourage the development of appropriate economic incentives with the aim of reducing marine debris, including the development of cost recovery systems that provide an incentive to use port reception facilities and discourage ships from discharging marine debris at sea, and support for measures to prevent, reduce and control pollution from any source, including land-based sources, such as community-based coastal and waterway clean-up and monitoring activities; cooperate regionally and subregionally to identify potential sources and coastal and oceanic locations where marine debris aggregates; and develop and implement joint prevention and recovery programmes for marine debris.[649]

Knowing that most of the pollution load of the oceans emanated from land-based activities, States were advised to implement the GPA and to take all appropriate measures to fulfil the commitments of the international community embodied in the Manila Declaration. In order to fulfil this, it is imperative to help the developing States to raise awareness and to implement improved waste management practices, as previously referred.[650]

[646] Para 164.
[647] ibid.
[648] Para 166.
[649] Para 167. In relation to port reception facilities, States were also urged to cooperate in correcting the shortfall in port waste reception facilities in accordance with the action plan to address the inadequacy of port waste reception facilities developed by the IMO (para 173).
[650] Paras 23 and 174.

After this advancement, another consistent step forward was given towards the consolidation of the strategy. During the first session of the UN Environment Assembly of the UNEP, in June 2014, it was adopted the Resolution 1/6.[651] This Resolution was entirely dedicated to marine plastic debris and microplastics, whose presence in the marine environment was characterised as 'a rapidly increasing problem due to their large and still increasing use combined with the inadequate management and disposal of plastic waste'.[652] The significant risks arising from these practices, especially in the case of microplastics,[653] were recognised, as well as the need to take action.[654] Take action at source, by addressing marine plastic debris and microplastics at source, by reducing pollution through improved waste management practices and by cleaning up existing debris and litter.[655]

More than a year later, in September 2015, in the UN Sustainable Development Summit, a new legal text emerged to broaden the scope of action to combat marine pollution. Even without mentioning plastic waste or marine plastic litter, *The 2030 Agenda for Sustainable Development*[656] announced Sustainable Development Goals[657] capable of curb marine plastic pollution from various viewpoints. This universal Agenda of unprecedented extent and significance was designed to be a plan of action for people, planet and prosperity. The non-binding seventeen Sustainable Development Goals and the 169 associated targets,

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651 UN Report A/69/25, of 23-7 June 2014, 35ff.
652 Resolution 1/6, para 4.
653 It was stated that microplastics in the marine environment originate from a wide range of sources, including the breakdown of plastic debris in the oceans, industrial emissions and sewage and run-off from the use of products containing microplastics (para 7). In terms of impacts, it was noted that microplastics might contribute to the transfer in the marine ecosystems of POPs and other persistent, bioaccumulative and toxic substances/contaminants which are in or adhere to the particles (para 6). In addition, it was acknowledged that such particles could be ingested by biota and could be transferred to higher levels in the marine food chain, causing adverse effects (para 5).
654 Para 2.
655 Para 8. In line with all the previous measures, herein governments, intergovernmental organisations, non-governmental organisations, industry, the private sector and other relevant actors were encouraged to take the following actions: cooperate with the GPML in the implementation of the Honolulu Strategy; facilitate information exchange through the online marine litter network (para 3); promote the most resource-efficient use and sound management of plastics and microplastics (para 16); take comprehensive action to address the marine plastic debris and microplastic issue through, were appropriate, legislation, enforcement and international agreements, provision of adequate reception facilities for ship-generated wastes, improvement of waste management practices and support for beach clean-up activities, as well as information, education and public awareness programmes (para 17); and undertake studies on the source and fate of marine plastic debris and microplastics and their impact on biodiversity, marine ecosystems and human health (paras 5 and 14).
656 A/RES/70/1, of 25 September 2015. It came into effect on 1 January 2016 (para 21).
657 Sustainable Development Goals were presented for the first time in *The Future We Want*, in July 2012. These Global Goals were built on the success of the Millennium Development Goals, which in the year 2000 established measurable and universally-agreed objectives for tackling extreme poverty and hunger, preventing deadly diseases and expanding primary education to all children, among other development priorities. Therefore, even though the new goals must not divert focus or effort from the Millennium Development Goals, they must complete what the last ones did not achieve, particularly reaching the most vulnerable, and they must go far beyond them.

which are integrated and indivisible, meant to stimulate action in the entire world, in all countries, for a period of fifteen years in areas of critical importance for humanity and the planet.[658] In fact, these goals are unique in that they call for action by all countries, with different national realities, capacities, levels of development and priorities, to promote prosperity while protecting the planet. The implementation and success of the Global Goals will rely on countries' own sustainable development policies, plans and programmes and will request real strong commitment and dedication at all levels, bringing together governments, civil society, the private sector, the UN system and other actors.

In order to find the way towards a global solution for the marine plastic pollution problem, we have to consider all the goals and targets related to the two resources in question: water and waste. Since the sustainable management of our planet's natural resources is crucial, we will highlight first goals 6 and 14. If one aims to ensure the availability and sustainable management of water and sanitation for all, the other considers that oceans, seas and marine resources should be conserved and sustainably used. Naturally, in both cases the quality of water must be improved and pollution of all kinds must be reduced, by 2030 and 2025, respectively. This implies: eliminating dumping and minimising release of hazardous chemicals and materials by 2030; halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally by 2030; protect and restore water-related ecosystems, and sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience by 2020; implement integrated water resources management at all levels, including through transboundary cooperation as appropriate by 2030; and by 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism.[659]

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[658] In short, UN resolved, between 2015 and 2030, to end poverty and hunger everywhere, to combat inequalities within and among countries, to build peaceful, just and inclusive societies, to protect human rights and promote gender equality and the empowerment of women and girls and to ensure the lasting protection of the planet and its natural resources. Moreover, UN recognised that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection.

[659] See targets 6.3, 6.5, 6.6, 14.1, 14.2, 14.5 and 14.7. With respect to pollution, there is a target demanding a substantially reduction, by 2030, of the number of deaths and illnesses resulting from hazardous chemicals and air, water and soil pollution and contamination (3.9). As goal 3 requires, at all ages, healthy lives must be ensured and well-being must be promoted. Moreover, since water quality can benefit from the protection, restoration and promotion of the sustainable use of terrestrial ecosystems and from the cessation of biodiversity loss (goal 15), it is important to accomplish the following targets by 2020: ensure the conservation, restoration and sustainable use of

Regarding waste, it is possible to identify two moments: before its production and afterwards. The first moment is related to consumption and production of products and services. Ensuring their patterns are sustainable is a major goal, as it is also important to promote sustainable economic growth. It is mandatory, by 2030, to achieve the sustainable management and efficient use of natural resources and to improve progressively global resource efficiency in consumption and production, to commit to decouple economic growth from environmental degradation.[660] With regard to the second moment, the most relevant target is to achieve, by 2020, the environmentally sound management of chemicals and all wastes throughout their life cycle, and significantly reduce their release to air, water and soil in order to minimise their adverse impacts on human health and the environment (12.4). In turn, by 2030, waste generation through prevention, reduction, recycling and reuse must be substantially reduced (12.5).

The second Resolution on marine plastic litter and microplastics adopted by the UN Environment Assembly of the UNEP was the Resolution 2/11 of 27 May 2016,[661] and it marked another milestone in the development of the strategy. This Resolution is more extensive and much more specific and detailed than the Resolution 1/6 because it incorporated knowledge from scientific papers, institutional reports and legal texts, such as *The 2030 Agenda for Sustainable Development*, and because it was recognised the seriousness of the presence of plastic litter and microplastics in the marine environment. It was no more considered merely as 'a rapidly increasing problem' (as stated in paragraph 4 of the Resolution 1/6). Instead, it was acknowledged as 'a rapidly increasing serious issue of global concern that needs an urgent global response', requiring immediate action.[662]

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terrestrial and inland freshwater ecosystems and their services; take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and prevent the extinction of threatened species; and introduce measures to prevent the introduction, and significantly reduce, the impact of invasive alien species on land and water ecosystems. Furthermore, particularly regarding goal 14, there are other aims to consider: increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the IOC Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries (14.a).

[660] See targets 8.4 and 12.2. Secondary, but not less important targets are: encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle (12.6); promote public procurement practices that are sustainable, in accordance with national policies and priorities (12.7); elaborate and implement policies to promote sustainable tourism (8.9); and upgrade infrastructures and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities (9.4).

[661] UNEP/EA.2/Res.11, of 27 May 2016.

[662] Paras 1 and 20.

This new perspective broadened the range of measures presented, but we will only talk about the ones that are absolutely new, in comparison with all the measures exposed above. Based on the keys to long-term success in combating plastic marine pollution – prevention and environmentally sound management of waste –,[663] the measures we emphasise are as follows: more (and more supported) research on marine plastic debris and also microplastic, in particular on associated chemicals, environmental and social impacts (including on human health) pathways, fluxes and fate, fragmentation and degradation rates, in all marine compartments, and especially in water bodies and sediment deposits of the coastal and open ocean, as well as on impacts on fisheries, aquaculture and economy;[664] the establishment of harmonised international definitions and terminology concerning the size of, and compatible standards and methods for the monitoring and assessment of, marine plastic debris and microplastics, likewise the establishment of and cooperation on cost-effective monitoring, building as far as possible on ongoing related monitoring programmes and considering alternative automated and remote sensing technology where possible and relevant;[665] encourage product manufacturers and others to consider the life-cycle environmental impacts of products containing microbeads and compostable polymers, including possible downstream impacts that may compromise the recycling of plastic waste;[666] phase out of the use of primary microplastic particles in products, including, wherever possible, products such as personal care products, industrial abrasives and printing products, and their replacement with organic or mineral non-hazardous compounds;[667] the development of environmentally friendly alternatives to plastic packaging and deposit refund systems;[668] share knowledge and experience on the best available techniques and environmental practices for reducing littering from the fishing industry and aquaculture, and for implementation of pilot projects where appropriate, including in respect of deposit schemes, voluntary agreements and recovery, in particular through prevention and, reduction, reuse and recycling;[669] the need to reduce illegal dumping of litter in the sea, including through the establishment and use of effective port reception facilities, likewise the

[663] Paras 7 and 18.
[664] Para 20. This was the first UN Resolution that expressed concern about the ability of microplastics enter marine food chains and the potential risk it may cause to environment and human health (whereas 4).
[665] Para 19.
[666] Paras 1 and 18.
[667] Para 17.
[668] Para 13.
[669] Para 15.

identification and, as appropriate, recovery of costs related to the disposal of garbage and waste, including through harbour fees, and consideration of other incentives and innovative approaches;[670] the need to identify transport and distribution pathways and hotspots of plastic marine litter, to cooperate regionally and internationally to clean up such hotspots, and to develop environmentally sound systems and methods for removal and sound disposal of marine litter (urgent in areas where it poses an immediate threat to sensitive marine and coastal ecosystems or marine-based livelihoods or local societies).[671] All these measures must be necessarily adapted, as appropriate, to local, national and regional situations, not only because the levels and sources of marine plastic litter and microplastics vary between regions, but also because the resources available to tackle the issue are not the same everywhere.

In February 2017, intentions became reality at the Economist World Ocean Summit in Bali, Indonesia. UNEP launched the Clean Seas campaign with the aim of engaging governments, the general public and the private sector in the fight against marine plastic pollution.[672] To achieve this, UNEP proposed to raise awareness of what plastic waste was doing to our oceans, our wildlife and ourselves, hoping to create aware and engaged citizens, worried in addressing the problem in their daily lives and beyond. Moreover, by addressing the root-cause of marine litter – the production and consumption of non-recoverable and single-use plastic – UNEP aimed to create an unstoppable global momentum towards a truly circular global economy, which included tackling the excessive use of single-use plastics, getting rid of dangerous microplastics in our toiletries and cosmetics, and encouraging recycling. In April 2018, around 90,000 people have taken the pledge to eradicate single-use plastics and microbeads from their lives.[673] By June 2018, this campaign was the largest global compact for combatting marine litter, with commitments from 51 nations covering

[670] Para 16.
[671] Para 12. Removal actions should, as far as possible, be risk-based and cost-effective, following best available techniques and environmental practices and the polluter pays approach. It was also recognised the need for measures to combat the littering of freshwater courses, including measures to adapt to extreme storms, flooding and other relevant effects of climate change. Surface runoff, rivers and sewage outfalls were recognised as important (and rapidly increasing) pathways for plastic and microplastics litter transfer from land to the sea. As a consequence, international cooperation on transboundary watercourses was encouraged. See para 9.
[672] The Clean Seas campaign has a website where everyone can make their pledge: <www.cleanseas.org>.
[673] People are cleaning beaches, cataloguing what they find, and changing their own behaviour by, for example, using cloth bags and carrying steel cups or cutlery with them, refusing plastic straws and demanding the removal of plastic cups or single-use bottles from their offices. See UNEP, 'One Year After the Launch of #CleanSeas, the Tide is Turning' (UNEP, 30 April 2018) <www.unenvironment.org/news-and-stories/story/one-year-after-launch-cleanseas-tide-turning> accessed 6 July 2018.

62% of the world's coastlines.[674] Likewise, businesses have also joined the cause, and European retailers have committed to plastic-free aisles and products while some restaurants have pledged to phase out plastic straws. All these promises will be monitored by the Clean Seas campaign, and at the same time more countries will be engaged in this campaign.

The year 2017 was marked by another novelty. For the first time, marine litter became a major subject both at the G7 and G20 meetings. In 2015, G7 Germany had already acknowledged that marine litter, in particular plastic litter, posed a global challenge and recognised that increased effectiveness and intensity of work was required to initiate a global movement to combat marine litter.[675] The G7 elaborated then the G7 Action Plan to Combat Marine Litter, committing itself to adopt priority actions to address land and sea-based sources, priority removal actions, as well as priority actions on education, research and outreach.[676] The seven largest advanced economies in the world acknowledged marine plastic pollution problem and recognised and supported the work of UNEP, in particular of the GPA, the GPML and the Regional Seas Conventions and Action Plans. In addition, it was

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[674] The 51 countries that have already joined the campaign are: Argentina Bahrain, Barbados, Belgium, Brazil, Canada, Chile, Colombia, Costa Rica, Cote D'Ivoire, Denmark, Dominican Republic, Ecuador, France, Grenada, Guyana, Honduras, Iceland, India, Indonesia, Israel, Italy, Jordan, Kenya, Kiribati, Kuwait, Madagascar, Maldives, Malta, Montenegro, the Netherlands, New Zealand, Norway, Nigeria, Oman, Panama, Peru, Poland, Philippines, Saint Lucia, Seychelles, Sierra Leone, South Africa, Spain, Vanuatu, Sri Lanka, Sudan, Sweden, UK, United Arab Emirates and Uruguay. More governments than ever are implementing some kind of intervention against single-use plastics: bans, restrictions and levies on disposable plastic items, the implementation of better recycling facilities, and the development of viable alternatives to the most common contributors to marine litter. Concrete examples will be given later.

[675] G7 Summit Leaders' Declaration from June 2015, 14. This Declaration and other documents are available at the G7 Information Centre, an information system, provided by the University of Toronto Library and the G7 Research Group at the University of Toronto. Its website is <www.g8.utoronto.ca/>. The G7 is currently composed of Canada, the United Kingdom, Italy, France, Germany, the USA and Japan. The European Union is also represented at the G7 Summits.

[676] Annex to the G7 Summit Leaders' Declaration from June 2015, 8 and 9. It was recognised that prevention was key to long-term success in addressing and combating marine litter and that industries and consumers had an important role to play in reducing waste, and so individual and corporate behaviour should be modified. Moreover, G7 understood that support through international development assistance and investments were important to combat marine litter and encouraged both, especially in relation to developing countries. Regarding priority actions, we highlight only the ones addressing land-based sources, in which are included: improving countries' systems for waste management, reducing waste generation, and encouraging reuse and recycling; incorporating waste management activities into international development assistance and investments and supporting the implementation of pilot projects where appropriate; investigating sustainable and cost-effective solutions to reduce and prevent sewage and storm water related waste, including micro plastics entering the marine environment; promoting relevant instruments and incentives to reduce the use of disposable single-use and other items that impact the marine environment; encouraging industry to develop sustainable packaging and remove ingredients from products to gain environmental benefits, such as by a voluntary phase-out of microbeads; and promoting best practices along the whole plastics manufacturing, and value chain from production to transport, such as aiming for zero pellet loss.

established a G7 Alliance on Resource Efficiency.[677] Although it was not directly linked to waste or marine plastic debris, G7 acknowledged the need to improve resource efficiency, which was considered crucial for the competitiveness of industries, for economic growth and employment, and for the protection of the environment, climate and planet. Differently, in 2016 Summit, the G7 recognised that efforts on resource efficiency contributed to the prevention and reduction of marine litter, particularly plastic, from land-based sources, and reaffirmed the commitment to address marine litter.[678]

In June 2017, Bologna hosted the Environment Ministerial Meeting of the G7, where the Environment Ministers of the seven countries and the Commissioners of the EU for Environment and Climate discussed marine litter, among other themes, and reiterated the concern for the issue, in particular plastic litter and microplastics.[679] G7 reaffirmed that moving towards a more resource efficient and circular economic model, including efficient resource use and sustainable materials and waste management systems, was an effective way to address marine litter. To achieve this, G7 was determined to further implement the G7 Action Plan to Combat Marine Litter, and to call for strengthening the coherence, efficiency and effectiveness of existing international efforts, in particular of the Regional Seas Programmes' activities, allowing this way that the 2030 Agenda is fully and timely implemented.[680]

It was in July 2017 that G20 addressed marine litter for the first time.[681] To contribute to the implementation of the Sustainable Development Goals related to marine litter, G20 launched two initiatives. The first one was the G20 Resource Efficiency Dialogue, designed to exchange views and experiences on policy options and good practice examples to promote

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[677] Annex to the G7 Summit Leaders' Declaration from June 2015, 6 and 7. Being aware that at the global level the consumption of natural resources and production of waste have increased to a greater scale than ever before, this Alliance will allow G7 to promote an exchange of concepts on how to address the challenges of resource efficiency, to share best practices and experience, and to create information networks. Examples of subjects to be addressed in workshops: sustainable products and purchasing, green public procurement, local supply chains and the integration of resource efficiency into decision-making in government agencies; circular economies, eco-design, sharing economies and remanufacturing; the potential of substituting non-renewable resources with sustainable renewable resources; and the importance of life-cycle-based decision-making.

[678] G7 Leaders' Declaration from May 2016, 29.

[679] This meeting was also attended by the Environment Ministers of four outreach countries particularly committed to environmental policies, in representation of developing countries: Chile, Ethiopia, Maldives and Rwanda.

[680] G7 Bologna Environment Ministers' Meeting Communiqué, paras 38, 40 and 41.

[681] G20 Leaders' Declaration from July 2017. This Declaration and other documents can be found in the G20 Information Centre, available on the website <www.g20.utoronto.ca/>. The G20 is currently composed of the representatives of the International Monetary Fund and the World Bank and the finance ministers and central banker of nineteen countries, which are Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, Korea, Turkey, United Kingdom, and USA (plus European Union).

sustainable consumption and production patterns, to stimulate resource efficiency along the entire life-cycle of natural resources, products and infrastructure, and to decouple economic growth from environmental degradation. The second initiative was the G20 Marine Litter Action Plan, that recognised the urgent need for action to prevent and reduce marine litter in order to preserve human health and marine and coastal ecosystems, and mitigate marine litter's economic costs and impacts. Consequently, and affirming the lack of certainty in scientific evidence could no longer be accepted as an excuse for non-action, the G20 committed to promote and initiate measures and actions at local, national, and regional levels to prevent and reduce marine litter of all kinds, to complement existing initiatives, experiences and expertise, and work to incorporate them into the G20 approach. Most measures drawn up in this Action Plan are similar to the ones we have been sharing, except for the ones related to the promotion of the socio-economic benefits of establishing policies to prevent marine litter, in which are included for example: acknowledge and promote the socio-economic benefits of preventing marine litter and reduction measures in terms of employment generation including the informal sector, tourism development, sustainable fisheries, waste and wastewater management, biodiversity and other areas; facilitate communication and cooperation between impacting and impacted municipalities, countries and regions as well as with other stakeholders; and develop highly qualified scientific and technical staff for monitoring and assessing marine litter and alleviating its impacts (ie treatment centres for injured animals).

All things considered, in June 2017 the UN General Assembly decided to call for action. The UN Conference to Support the Implementation of Sustainable Development Goal 14 of the 2030 Agenda for Sustainable Development, held in June 2017 in New York, also known as the Ocean Conference, marked a global breakthrough on the path to sustainable management and conservation of oceans, seas and marine resources. The outcome document, that focused several themes and measures like most of the ones already revealed, is the most complete and comprehensive text produced by UN on marine plastic pollution.[682]

During the third session of UN Environment Assembly of the UNEP, in December 2017, it was adopted the Resolution 3/7 on marine litter and microplastics.[683] Herein, the

[682] A/RES/71/312, of 6 July 2017. The other eight theme mentioned are: coral reefs; implementation of international law as reflected in UNCLOS; mangroves; marine and coastal ecosystems management; ocean acidification; scientific knowledge, research capacity development and transfer of marine technology; sustainable blue economy; and sustainable fisheries.
[683] UNEP/EA.3/Res.7, of 6 December 2017. See paras 2, 3 and 4(c, d and e).

United Nations Environment Assembly, urged all actors to step up actions to by 2025, prevent – through waste minimisation and environmentally sound waste management – and significantly reduce marine pollution of all kinds, in particular from land-based activities (including marine debris and nutrient pollution). Action is of even higher importance in geographical areas with the largest sources of marine plastic litter. To achieve this goal, Member States must be encouraged to do the following, amongst other things: prioritise policies and measures at the appropriate scale to avoid marine litter and microplastics from entering the marine environment; develop and implement action plans for preventing marine litter and the discharge of microplastics, including the land/sea and freshwater/sea interface; encourage resource efficiency, and increase collection and recycling rates of plastic waste and re-design and re-use of products and materials; avoid the unnecessary use of plastic and plastic containing chemicals of particular concern; include marine litter and microplastics in local, national and regional waste management plans and in wastewater treatment; develop integrated and source-to-sea approaches to combat marine litter and microplastics from all sources, taking into account that plastic litter and microplastics are transported to the oceans from land-based sources by rivers and run-off or wind from land.[684]

Of 2018, we have only to mention the Sixth International Marine Debris Conference,[685] and the G7 Summit in Quebec, Canada, in June, where it was designed the Charlevoix Blueprint for Healthy Oceans, Seas and Resilient Coastal Communities, which includes the Ocean Plastics Charter. Recognising the urgency of the threat of ocean plastic waste and marine litter to ecosystems and the lost value of plastics in the waste stream, G7

[684] See paras 2, 3 and 4(c, d and e).

[685] In March 2018, more than 700 participants, representing around 50 countries, gathered in San Diego, California, USA, to celebrate and encourage further innovation, collaboration, and action around this far-reaching topic. The Conference highlighted innovative marine debris solutions, research, and technological advances since the Fifth Sixth International Marine Debris Conference held in 2011, and facilitated discussions around strategies to minimise the impacts and occurrence of marine debris. After being warned about the inability of society to properly manage plastic, participants were advised to stop and think about how many products were designed to be thrown away immediately after use, and encouraged to consider the current problem of design, production, and consumption of single-use products. Nonetheless, the major strength of the conference was the diversity of disciplines and expertise, including science, art, outreach, and education from individuals representing government, academia, private industry, community groups, and many more. For this reason, some examples and some conclusions presented during the Conference are disclosed in this Part II, especially in the chapter on Global Strategy to Combat Marine Plastic Pollution. Technical session tracks included: monitoring and citizen science; research and microplastics/microfibers; prevention; private sector collaboration, technology and innovation; education and communication; implementing effective law, regulations and policy; removal; single-use product policies, regulations and laws; derelict fishing gear; and innovative case studies from around the world.

committed to take a lifecycle approach to plastics stewardship on land and at sea, moving towards a more resource efficient and sustainable management of plastics.[686]

After all that has been said, it is possible to conclude that much progress has been made since 2005. Whether we are going to see results or not, that is something that does not depend only on the Member States. For now, we will see what are their mandatory obligations and if they are sufficient to be a part of the solution of the marine plastic pollution problem.

B. International Conventions

a. UNCLOS

The Third United Nations Convention on the Law of the Sea (UNCLOS), signed in 1982 in Montego Bay, Jamaica, and in force since November 1994, is the most comprehensive of all the international conventions we are going to analyse. Besides being the overarching legal framework that defines all of world's oceans and seas areas and establishes rules governing all uses of oceans and seas and their resources,[687] it is currently ratified by 167 countries and by the European Union, which means UNCLOS cover all regions of the world, all legal and political systems and the spectrum of socio-economic development.

Since we are concerned just with marine litter, we will pay attention especially to UNCLOS Part XII, on the Protection and Preservation of the Marine Environment. The first article presents a general obligation for States to protect and preserve the marine environment.[688] It encompasses not only the parties that ratified the Convention, but also all the other States. The explanation is that some of the provisions of this Convention, such as

[686] The Charter is divided into five themes: sustainable design, production and after-use markets; collection, management and other systems and infrastructure; sustainable lifestyles and education; research, innovation and new technologies; coastal and shoreline action.
[687] As stated in whereas 4 UNCLOS, this Convention aimed to establish 'a legal order for the seas and oceans which will facilitate international communication, and will promote the peaceful uses of the seas and oceans, the equitable and efficient utilization of their resources, the conservation of their living resources, and the study, protection and preservation of the marine environment'. Some of the matters specified are navigational rights, territorial sea limits, economic jurisdiction, guidelines for business, legal status of resources on the seabed beyond the limits of national jurisdiction, passage of ships through narrow straits, conservation and management of living marine resources, technology and scientific research and a binding procedure for settlement of disputes between States, which is one of the most important features of the treaty.
[688] Article 192.

this one, reflect customary international law which is binding also on states that are not parties to the Convention.[689]

In accordance with this obligation, States were granted the sovereign right to exploit their natural resources, but only pursuant to their environmental policies.[690] While doing this, States shall take, individually or jointly, all measures consistent with UNCLOS that are necessary to prevent, reduce and control pollution of the marine environment, even in foreign waters, from any source, activity or incident under their jurisdiction or control.[691] For this purpose, Sates must use the best practicable means at their disposal, plus technology, in accordance with their capabilities, and they shall endeavour to harmonise their policies.[692] These measures concern all sources of marine pollution, including land-based and coastal activities, continental-shelf drilling, potential seabed mining, ocean dumping, vessel-source pollution, and pollution from or through the atmosphere.[693] Moreover, these measures must be designed to minimise to the fullest possible extent the release of toxic, harmful or noxious substances, especially those which are persistent, from land-based sources, from or through the atmosphere or by dumping, and they must include those necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life.[694]

States shall adopt national laws, regulations, and even other measures, to prevent, reduce and control pollution of the marine environment from the sources referred above, and they shall likewise assure their enforcement.[695] States shall also cooperate on a global basis and, as appropriate, on a regional basis, directly or through competent international

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[689] UNEP, *Marine Plastic Debris and Microplastics...*, 8.
[690] Article 193.
[691] Article 194(1) and (2). Sates must also assure that pollution does not spread beyond the areas where they exercise sovereign rights in accordance with UNCLOS (see also Article 195). If that occurs, the State shall immediately notify other States as well as the competent international organisations (Article 198).

Regarding the definition of 'pollution of the marine environment', we must observe Article 1(1(4)) of the Convention that explains it means 'the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities'. Clearly marine litter, among which is plastic, fits well in this definition. Regarding the risks or effects of pollution, States shall observe, measure, evaluate and analyse them, by recognised scientific methods, and then publish reports of the results obtained. See Articles 204 and 205.
[692] Article 194(1) and Article 196.
[693] See Articles 207, 208, 209, 210, 211 and 212.
[694] Article 194(3 and 5). UNCLOS care for conservation and management of the living resources of the high seas, see Articles 116ff.
[695] Herein are include laws and regulations necessary to implement applicable international rules and standards established through competent international organisations or diplomatic conference. See Articles 207 to 222.

organisations, in formulating and elaborating international rules, standards and recommended practices and procedures consistent with UNCLOS, for the protection and preservation of the marine environment, taking into account characteristic regional features. For the formulation of these instruments, States must consider the appropriate scientific criteria resulting from the studies, the programmes of scientific research and the exchanging of information and data gathered in cooperation between them.[696]

b. London Convention and London Protocol

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, known as the London Convention, was adopted on 13 November 1972 and came into force on 30 August 1975. It was one of the first global convention to protect the marine environment from human activities and it became a key pillar of the international regime for marine environmental protection. Actually, the number of Contracting States to the London Convention is 87.[697]

Administered by IMO since 1977, the London Convention requires that Contracting Parties take all practicable steps – individually, according to their scientific, technical and economic capabilities, or collectively – to prevent pollution of the sea by dumping of wastes and other matter liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea.[698] Consequently, the Contracting Parties 'shall prohibit the dumping [in all marine waters other than the internal waters of States][699] of any wastes and other matter in whatever form or condition'[700], meaning *dumping*, for the purposes of this Convention, any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea, including also the deliberate disposal at sea of vessels, aircraft, platforms or other manmade

[696] See Articles 197, 200 and 201. Scientific and technical assistance, as well as the allocation of appropriate funds must be provided in first place to developing States. Se Articles 202 and 203.
[697] This number represents approximately 60% of the gross tonnage of the world's merchant fleet. See IMO, 'Status of Conventions' (*IMO*) <www.imo.org/en/About/Conventions/StatusOfConventions/Pages/Default.aspx> accessed 30 July 2018.
[698] Articles I and II of the London Convention. Article II enlightens that Contracting Parties should likewise harmonise their policies in this regard.
[699] This is the definition of *sea* for the purposes of the London Convention, see Article III(3).
[700] Article IV(1).

structures existent at sea.[701] However, certain *dumping* is excluded from the scope of this Convention, which evidently allows plastic leakage.[702]

Since dumping is prohibited *in whatever form or condition*, we have to understand under what circumstances dumping can be processed from the point of view of the London Convention: the dumping of wastes or other matter listed in Annex I is prohibited; the dumping of wastes or other matter listed in Annex II requires a prior special permit; and the dumping of all other wastes or matter requires a prior general permit.[703] It is thus prohibited to dump persistent plastic and other persistent synthetic materials but only the ones that 'may float or may remain in suspension in the sea in such a manner as to interfere materially with fishing, navigation or other legitimate uses of the sea'.[704] In case industrial waste contains traces of these materials, its dumping is likewise prohibited.[705] In turn, if sewage sludge and dredged materials contain the referred materials, they shall be subject to the provisions of Annexes II and III.[706] This means they might be dumped at sea, unless they contain significant amounts of the matters listed in Annex II, para A.[707] At this time, marine plastic pollution clearly was not an issue. Dumping of dredged material, fish waste or organic materials resulting from industrial fish processing operations and vessels and platforms or other man-made structures at sea shall be subject to the provisions of Annex I, and to the provisions of Annexes II and III.[708]

Nevertheless, there are exceptions to these rules, as stated in Article V. If dumping appears to be the only way of avoiding danger to human life and/or real threats to vessels, aircraft, platforms or other man-made structures at sea, the provisions of Article IV shall not

[701] Article III(1)(a).
[702] See Article III(1)(b): (i) the disposal at sea of wastes or other matter incidental to, or derived from the normal operations of vessels, aircraft, platforms or other man-made structures at sea and their equipment, other than wastes or other matter transported by or to vessels, aircraft, platforms or other man-made structures at sea, operating for the purpose of disposal of such matter or derived from the treatment of such wastes or other matter on such vessels, aircraft, platforms or structures; and (ii) the placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Convention. In the same way, the disposal of wastes or other matter directly arising from, or related to the exploration, exploitation and associated off-shore processing of sea-bed mineral resources is likewise not covered by the provisions of this Convention, Article III(1)(c).
[703] Permits shall be granted in advance and only after careful consideration of all the factors set forth in Annex III, including prior studies of the characteristics and composition of the matter, of the dumping site and method of deposit, the possible effects on amenities, marine life and other uses of the sea, and the practical availability of alternative land-based methods, see Article III(5) and (6) and Article IV(2).
[704] Annex I, para 4.
[705] Annex I, para 9.
[706] Annex I, para 9.
[707] Some of the substances are arsenic, beryllium, chromium, copper, lead, nickel and their compounds.
[708] Annex I, para 11.

apply. Such dumping shall be so conducted as to minimise the likelihood of damage to human or marine life and shall be reported forthwith to the IMO.[709]

Everything considered, we must highlight that each Contracting Party shall apply the measures required to implement the present Convention to all vessels and aircraft registered in its territory or flying its flag, to all vessels and aircraft loading in its territory or territorial seas matter which is to be dumped and to all vessels, aircraft and fixed or floating platforms under its jurisdiction believed to be engaged in dumping.[710] Therefore, the Contracting Parties shall take, individually in its territory or in cooperation particularly regarding the high seas, appropriate measures to prevent and punish conduct in contravention of the provisions of this Convention, and procedures to report non-compliance with the Convention.[711]

At last, we clarify that the Contracting Parties have some freedom to operate since they can not only prohibit the dumping of wastes and other matter not mentioned in Annex I (they just have to communicate it to the IMO), but also adopt other measures to prevent dumping at sea in accordance with the principles of international law.[712]

In 1996 it was though recognised that more stringent measures with respect to prevention and elimination of pollution of the marine environment from dumping at sea should be adopted.[713] As a result, on 7 November 1996 it was adopted the Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972. Known as the London Protocol, it entered into force on 24 March 2006 and currently it is ratified internationally by 50 Contracting Parties.

Contrary to what was expected, the London Protocol did not repeal the London Convention.[714] In fact, the Protocol is a separate treaty, that can be ratified by States without being a party to the Convention and that 'will supersede the Convention as between Contracting Parties to this Protocol which are also Parties to the Convention'.[715]

[709] Regardless of the type of dumping, the Contracting Parties must keep records of the nature and quantities of all matter permitted to be dumped and the location, time and method of dumping. This information must be reported to the IMO and to other Parties if appropriate. See Article VI(1)(c) and (4).
[710] Article VII(1).
[711] Article VII(2) and (3).
[712] See Article IV(3) and Article VII(5), respectively.
[713] See whereas 5 of London Protocol.
[714] In our view, not revoking the London Convention had two purposes: ensure that the Contracting Parties to the Convention would not denounce the Convention after the introduction of more restrictive measures such as the ones of the London Protocol; and attract new Parties, slightly interested in marine pollution prevention, available to comply only with the London Convention. The countries that adhered only to the London Convention after the adoption of the London Protocol are: Benin, Bolivia, Equatorial Guinea, Saint Vincent and the Grenadines, Syrian Arab Republic and United Republic of Tanzania.
[715] London Protocol, Article 23.

Such replacement made a lot of sense. If the aim of the Convention is to regulate pollution, that of the Protocol is to prevent pollution.[716] Necessarily, the Protocol tightened and specified the provisions of the London Convention, and as a consequence some concepts were changed and adapted for the purposes of this Protocol, and objectives and obligations were reset. *Sea* means not only 'all marine waters other than the internal waters of States', but also 'the seabed and the subsoil thereof' (excluding sub-seabed repositories accessed only from land).[717] Similarly, *dumping* has a wider meaning than in the Convention, comprising 'any storage of wastes or other matter in the seabed and the subsoil thereof from vessels, aircraft, platforms or other man-made structures at sea' and 'any abandonment or toppling at site of platforms or other man-made structures at sea, for the sole purpose of deliberate disposal'.[718]

To achieve greater protection of the marine environment, actions beyond prevention, such as reduction and elimination of pollution – caused by dumping or even by incineration at sea of wastes or other matter – became new objectives.[719] Naturally, the general obligations were adjusted, and Contracting Parties are now encouraged to apply a precautionary approach to environmental protection from dumping of wastes or other matter,[720] and to take into account the approach that the polluter should, in principle, bear the cost of pollution.[721] Here, in contrast with the Convention, we can find references to the principles of prevention and polluter pays.

Furthermore, the key difference between the two legal texts is the fact that the Convention allows generically at-sea dumping, unless it was specifically prohibited, while

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[716] Chung-Ling Chen, 'Regulation and Management of Marine Litter' in Bergmann M, Gutow L and Klages M (eds), *Marine Anthropogenic Litter* (Springer International Publishing, 2015) 400, citing Louka E, *International Environmental Law: Fairness, Effectiveness, and World Order* (Cambridge University Press, 2006).

[717] London Protocol, Article 1(7).

[718] Article 1, 4.1.3 and paragraph 4.1.4, respectively. Notwithstanding paragraph 4.1.4, abandonment in the sea of matter (such as cables, pipelines and marine research devices) placed for a purpose other than the mere disposal thereof is not included in *dumping*'s definition, see Article 1(4)(2)(3).

[719] See Article 2. For the purposes of the Protocol, *pollution* was defined as 'the introduction, directly or indirectly, by human activity, of wastes or other matter into the sea which results or is likely to result in such deleterious effects as harm to living resources and marine ecosystems, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities', Article 1(10).

[720] Appropriate preventative measures must be taken when there is reason to believe that wastes or other matter introduced into the marine environment are likely to cause harm even when there is no conclusive evidence to prove a causal relation between inputs and their effects, see Article 3(1).

[721] The Protocol states in Article 3(2) that 'each Contracting Party shall endeavour to promote practices whereby those it has authorized to engage in dumping or incineration at sea bear the cost of meeting the pollution prevention and control requirements for the authorized activities, having due regard to the public interest'.

the Protocol urges Contracting Parties to 'prohibit the dumping of any wastes or other matter with the exception of those listed in Annex 1'.[722] This Annex contains the so-called reverse-list[723] that identifies wastes and other matter that may be considered for dumping. Even though persistent plastic and other synthetic materials were excluded from this list, these materials can be contained in some of the wastes and other materials considered for dumping in Annex I, particularly in dredge materials, sewage sludge, fish waste or material resulting from industrial fish processing operations, and vessels and platforms or other man-made structures at sea.

In any case, in order to assure that no pollution is caused, it was stipulated that the dumping of wastes and other matter listed in Annex 1 requires a permit.[724] The Contracting Parties must therefore guarantee the issuance of permits and ensure that the permits conditions comply with provisions of Annex 2. This annex, which is much more complete and environmentally conscious than any of the annexes of the London Convention, lays down rules on waste prevention audit, waste management options, chemical, physical and biological properties of waste, dump-site selection, potential effects assessment, monitoring and permit conditions.

Before issuing a permit, it is imperative to assess environmentally preferable alternatives to dumping and they must respect the waste hierarchy principle.[725] For a better consideration of alternatives, it is essential to elaborate a detailed description and

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[722] Article 4(1)(1).

[723] According to Annex I, the wastes and other matter that may be considered for dumping are the following: 1) dredged material; 2) sewage sludge; 3) fish waste, or material resulting from industrial fish processing operations; 4) vessels and platforms or other man-made structures at sea; 5) inert, inorganic geological material; 6) organic material of natural origin; 7) bulky items primarily comprising iron, steel, concrete and similar unharmful materials for which the concern is physical impact and limited to those circumstances, where such wastes are generated at locations, such as small islands with isolated communities, having no practicable access to disposal options other than dumping; and 8) carbon dioxide streams from carbon dioxide capture processes for sequestration. IMO developed *Generic Guidelines* and comprehensive *Specific Guidelines* for all wastes on the reverse list. These Guidelines contain step-by-step procedures to evaluate wastes being considered for sea disposal, including waste prevention audits, assessment of alternatives, waste characterisation, assessment of potential adverse environmental effects of dumping, disposal site selection and monitoring and licensing procedures. A technical co-operation and assistance programme had been established too to assist with capacity building for waste assessment and management, and in developing national regulations to comply with and implement the London Protocol. Regarding the paragraphs 1(4) and 1(7) of Annex I, the Protocol itself clarifies that they may only be considered for dumping, 'provided that material capable of creating floating debris or otherwise contributing to pollution of the marine environment has been removed to the maximum extent and provided that the material dumped poses no serious obstacle to fishing or navigation', see para 2.

[724] Article 4(1)(2).

[725] The waste management hierarchy that Annex 2 advises to adopt is the following: re-use; off-site recycling; destruction of hazardous constituents; treatment to reduce or remove the hazardous constituents; and at last disposal on land, into air and in water (para 5).

characterisation of the waste,[726] which implies an evaluation of the types, amounts and relative hazard of wastes generated. During the *waste prevention audit*, it is also important to evaluate the details of the production process and the sources of wastes within that process and the feasibility of the following waste reduction/prevention techniques: product reformulation; clean production technologies; process modification; input substitution and on-site, closed-loop recycling. In addition, if the audit reveals that opportunities exist for waste prevention at source, the Contracting Party must formulate and implement a waste prevention strategy, in collaboration with relevant local and national agencies, focusing specific waste reduction targets, and must provision for further waste prevention audits to ensure that the targets are being met.[727] The principles of qualitative prevention, correction at source, and waste hierarchy were considered in all of the provisions described.

Planning principle is also contemplated. Each Contracting Party shall develop a national Action List to provide a mechanism for screening candidate wastes and their constituents, on the basis of their potential effects on human health and the marine environment.[728] Anyway, it is only after a concise statement of the expected consequences of sea or land disposal that a decision to approve or reject the proposed disposal can be taken.[729] Furthermore, the decisions to issue permits can only be taken if the impact evaluation is

[726] According to the paragraph 8 of Annex 2, the characterisation of the wastes and their constituents shall take into account the: origin, total amount, form and average composition; properties: physical, chemical, biochemical and biological; toxicity; persistence: physical, chemical and biological; and accumulation and biotransformation in biological materials or sediments. If waste is poorly characterised and no proper assessment of its potential impacts can be made, then that waste shall not be dumped (para 7).
[727] Annex 2, para 3.
[728] Annex 2, para 9. In selecting substances for consideration in an Action List, priority shall be given to toxic, persistent and bioaccumulative substances from anthropogenic sources (eg cadmium, mercury, organohalogens, petroleum hydrocarbons, and, whenever relevant, arsenic, lead, copper, zinc, beryllium, chromium, nickel and vanadium, organosilicon compounds, cyanides, fluorides and pesticides or their by-products other than organohalogens). As we have seen in Part I, some of these substances are present in plastics' original structure and other are absorbed after plastic reaches marine environments.

The Action List shall specify an upper level and may also specify a lower level, being the upper level set so as to avoid acute or chronic effects on human health or on sensitive marine organisms representative of the marine ecosystem (para 10). This would be the suitable level for plastic waste.
[729] Annex 2, para 12. Para 13 added that 'the assessment for dumping should integrate information on waste characteristics, conditions at the proposed dump-site(s), fluxes, and proposed disposal techniques and specify the potential effects on human health, living resources, amenities and other legitimate uses of the sea. It should define the nature, temporal and spatial scales and duration of expected impacts based on reasonably conservative assumptions'. An analysis of each disposal option should be considered in the light of a comparative assessment of the following concerns: human health risks, environmental costs, hazards, (including accidents), economics and exclusion of future uses (Annex 2, para 14).

completed, and also if the monitoring requirements are determined.[730] Monitoring is used to verify that permit conditions are met and that the assumptions made during the permit review and site selection process were correct and sufficient to minimise environmental disturbance and detriment and maximise the benefits.[731] Review of monitoring results will indicate whether field programmes need to be continued, revised or terminated and will contribute to informed decisions regarding the continuity, modification or revocation of permits – which provides an important feedback mechanism for the protection of human health and the marine environment.[732] All in all, the acceptance of dumping under certain circumstances shall not remove the obligations under this Annex to make further attempts to reduce the necessity for dumping.[733]

In line with the London Convention, there are also exceptions to the dumping prohibition in the London Protocol. In fact, they are the same,[734] as all the other things not mentioned here particularly regarding the Protocol. New and relevant things need to be noticed though: incineration at sea is regulated and mentioned beside dumping through the entire Protocol, being in fact absolutely prohibited;[735] evoking the self-sufficiency and proximity principles, Contracting Parties shall not allow the export of wastes or other matter to other countries for dumping or incineration at sea;[736] Contracting Parties may now apply the provisions of the Protocol to internal waters;[737] at last, technical cooperation and assistance provisions content were amplified, comprehending waste minimisation, clean production processes, the disposal and treatment of waste and other measures to prevent, reduce and eliminate pollution caused by dumping; and the access to environmentally sound technologies and corresponding know-how, in particular to developing countries.[738]

More recently, a profound concern with marine plastic pollution has emerged. In May 2014, the Scientific Groups of the London Convention and Protocol, having recalled the plan

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730 Any permit issued shall contain data and information specifying the types and sources of materials to be dumped, the location of the dump-site(s), the method of dumping, and the monitoring and reporting requirements (Annex 2, para 17).
731 Annex 2, para 16.
732 Annex 2, para 18.
733 Annex 2, para 1.
734 London Protocol, Article 8.
735 London Protocol, Article 5. The definition of *incineration* can be found in Article 1(5). With respect to the London Convention, we clarify that although incineration at sea of industrial waste is prohibited (Annex 1, para 10(a)), the incineration at sea of any other wastes or other matter requires the issue of a special permit (Annex 1, para 10(b)).
736 London Protocol, Article 6.
737 Article 7.
738 Article 13(1)(3), (4) and (5).

of action to cooperate with UNEP-GPA, which the governing bodies endorsed in 2009, recognised the global attention given to litter and plastics in the marine environment and highlighted the knowledge gaps with respect to the waste streams regulated under the two legal instruments. Therefore, under the GPML (of which IMO is a partner), it was carried a study regarding the waste streams most likely to contain items and fragments of plastic marine litter: dredged material, sewage sludge and industrial discharges. In the end, it was clear that dredged materials and sewage sludge had a high probability of containing marine litter.[739] Therefore, possibilities for reducing plastics in wastes prior to disposal should be considered.

In view of the above, a recommendation to encourage action to combat litter was adopted at the thirty-eighth Consultative Meeting of Contracting Parties to the London Convention and the eleventh Meeting of Contracting Parties to the London Protocol, held in London, in September 2016.[740] It encouraged Member States to make every effort to combat marine litter, including through the identification and control of marine litter at source and to encourage monitoring, additional study and knowledge-sharing on this issue.[741]

c. MARPOL

The International Convention for the Prevention of Pollution from Ships, known as MARPOL 73/78,[742] is the most important international agreement covering marine

[739] IMO, *Review of the Current State of Knowledge Regarding Marine Litter in Wastes Dumped at Sea Under the London Convention and Protocol - Final Report* (Office for the London Convention/Protocol and Ocean Affairs, IMO, 2016) 28, available at <www.imo.org/en/OurWork/Environment/LCLP/newandemergingissues/Pages/default.aspx>.

[740] See Annex 8 of LC 38/16. In this recommendation, the governing bodies of the London Convention and Protocol recalled *The Future We Want*, the UN Environment Assembly Resolution 2/11 on marine plastic litter and microplastics, and the final report of the *Review of the Current State of Knowledge Regarding Marine Litter in Waste Dumped at Sea under the London Convention and Protocol*.

[741] In the report, delegations were encouraged to submit their practices and experiences on the issue to the future sessions of the Scientific Groups and were informed that plastic issue would be revisited in the next revision of the waste assessment guidance. See LC 38/16, 33.

[742] The MARPOL Convention was adopted in November 1973 at IMO, a specialised agency of the UN responsible for regulating shipping. The Protocol of 1978 was adopted in response to a spate of tanker accidents in 1976-7. As the 1973 MARPOL Convention had not yet entered into force, the 1978 MARPOL Protocol absorbed the parent Convention. The combined instrument, MARPOL 73/78 including Annexes I (oil and oily wastes) and II (noxious liquid substances in bulk), entered into force on 2 October 1983. MARPOL 73/78 has been updated by amendments through the years. In 1997, a Protocol was adopted to amend the Convention and a new Annex VI (air pollution from ships) was added which entered into force on 19 May 2005. Annexes III (harmful substances in packaged

environmental pollution by ships. Example of its significance is that MARPOL 73/78 has currently 156 Contracting States, representing approximately 99.15% of the gross tonnage of the world's merchant fleet.[743]

This Convention, which has a smaller scope than the London Convention and the London Protocol, regulates types and quantities of waste that only ships may discharge into the sea, taking into account the ecological sensitivity of different sea areas. It has six annexes, each one dealing with a specific type of potential pollutant from ships, but we will only analyse two: Annex V, on the prevention of pollution by garbage from ships, and very briefly Annex IV, on the prevention of pollution by sewage from ships.[744]

Annex V, whose 2011 updated version entered into force on 1 January 2013, is much more relevant to marine plastic pollution issue than Annex IV, as we will see. Applicable to all ships,[745] Annex V prohibits the discharge of all plastic (since 1988) and of all garbage (since 2013) into the sea.[746] Despite the recent implementation of the general prohibition on discharge of all garbage into the sea, concept in which plastic is necessarily included, the Annex V still has a paragraph exclusively dedicated to the prohibition of plastic discharge into the sea, emphasising thus the importance this subject has for MARPOL 73/78. Applicable only to certain ships engaged in international voyages,[747] Annex IV provisions prescribe a general prohibition of sewage discharge into the sea, while determine a few limited exceptions.[748] However, when the sewage is mixed with wastes or waste water covered by other Annexes of MARPOL, the requirements of those Annexes shall be

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form), IV (sewage) and V (garbage) entered into force in 1 July 1992, 27 September 2003, 31 December 1988, respectively.

[743] See 'Status of Conventions' (*IMO*) <www.imo.org/en/About/Conventions/StatusOfConventions/Pages/Default.aspx> accessed 24 July 2018.

[744] Unlike annexes I and II, the remaining ones are optional (see Article 14 MARPOL 73/78). Currently, the number of Contracting Sates to Annex IV is 142, which constitute approximately 96.54% of the gross tonnage of the world's merchant fleet. In turn, the number of Contracting States to Annex V is 153, which constitute approximately 98.97% of the gross tonnage of the world's merchant flee. See ibid.

[745] Regulation 2.

[746] Regulation 3(1) and (2). For the purposes of Annex V, *all plastic* means 'all garbage that consists of or includes plastic in any form, including synthetic ropes, synthetic fishing nets, plastic garbage bags and incinerator ashes from plastic products', Regulation 1(13). With respect to *garbage*, the Regulation 1(9) defines it as 'all kinds of food wastes, domestic wastes and operational wastes, all plastics, cargo residues, incinerator ashes, cooking oil, fishing gear, and animal carcasses generated during the normal operation of the ship and liable to be disposed of continuously or periodically except those substances which are defined or listed in other Annexes to the present Convention'.

[747] Annex IV, Regulation 2(1).

[748] See Regulation 11 for the prohibition and the exceptions. See Regulation 1(3) for *sewage* meaning: drainage and other wastes from any form of toilets and urinals; drainage from medical premises (dispensary, sick bay) via wash basins, wash tubs and scuppers located in such premises; drainage from spaces containing living animals; and other waste waters when mixed with the drainages defined above.

complied with in addition to the requirements of Annex IV.[749] If that Annex is Annex V, then it means that the sewage mixed with all the garbage and all the plastics whose discharge is prohibited by Annex V provisions, cannot be discharged into the sea under any circumstances. Obviously, there are exceptions to these general prohibitions.[750] Some involve food wastes, cargo residues, cleaning agents and additives, and animal carcasses,[751] but those that are of interest to marine plastic pollution are: the safety of the ship or its crew; the protection of the marine environment, and even accidental loss.[752] In case of emergency and non-routine situations, it may be impossible to avoid plastic leakage. Notwithstanding, all reasonable precautions must be taken before and after the occurrence of the event, to prevent or minimise this or any other damages.

To ensure these regulations are known and enforced, every ship of 12m or more in length overall and every fixed or floating platforms shall display placards notifying the crew and passengers of the general prohibition on discharge of garbage into the sea and its exceptions.[753] While at sea, the garbage that cannot be discharged must be managed properly by all ships. Notwithstanding, only fixed or floating platforms, ships of 100 gross tonnages and above, and ships which are certified to carry fifteen or more persons are obliged to develop garbage management plans.[754] These plans must be incorporated in crew and ship operating manuals and shall provide procedures for ship-specific garbage minimisation and

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[749] Annex IV, Regulation 11(4). Annex IV has no reference to plastic, and so this was the only contribution we could identify in Annex IV to the prevention of marine plastic pollution.

[750] Likewise, neither MARPOL 73/78 nor its Annexes can be applied to any warship, naval auxiliary or other ship owned or operated by a State and used only on government non-commercial service. However, 'each Party shall ensure by the adoption of appropriate measures not impairing the operations or the operational capabilities of such ships owned or operated by it, that such ships act in a manner consistent, so far as is reasonable and practicable, with the present Convention', MARPOL 73, Article 3(3).

[751] These provisions can be found in Regulations 4 to 6. Of all situations, we highlight the discharge of cargo residues, especially solid bulk cargoes. In either case, these discharges are only permitted while the ship is en route, if the cargo residues cannot be recovered using commonly available methods for unloading, and if the residues are not considered to be harmful to the marine environment. The methods for unloading are not specified in Annex V, but the harmfulness criteria are. According to Appendix I, cargo residues are considered to be harmful to the marine environment if they are residues of solid bulk cargoes which are classified according to the criteria of the UN Globally Harmonised System of Classification and Labelling of Chemicals meeting the parameters listed in Appendix I, where is comprised 'solid bulk cargoes containing or consisting of synthetic polymers, rubber, plastics, or plastic feedstock pellets (this includes materials that are shredded, milled, chopped or macerated or similar materials)', among other parameters that are associated to plastics' chemicals consequences, such as mutagenicity and reproductive toxicity. See Regulation 4(1)(3) and (3) for discharge of garbage outside special areas and Regulation 6(1)(2) for discharge of garbage within special areas.

[752] Regulation 7.

[753] Regulation 10(1)(1). Sample placard targeting crew and shipboard operations can be found in the appendix of the *2017 Guidelines for the Implementation of MARPOL Annex V* (Resolution MEPC.295(71) from 7 July 2017).

[754] Regulation 10(2). A generalised garbage management plan for handling and storing ship-generated garbage is presented in table 2 of Guidelines, para 2.3.4.

for collecting, storing, processing and disposing of garbage, including the use of the equipment on board. Recalling the principles of prevention and of correction at source, we emphasise the importance of ship owners and operators to carry on-board less materials that can become garbage.[755] The *2017 Guidelines for the Implementation of MARPOL Annex V* present options that should be considered to decrease the amount of such garbage. Some of them are: using supplies that come in reusable or recyclable packaging and containers; avoiding the use of disposable cups, utensils, dishes, towels and rags and other convenience items whenever possible; and avoiding supplies that are packaged in plastic, unless a reusable or recyclable plastic is used.[756] Once garbage is generated on board, it has to be placed in distinctively marked garbage receptacles – securely fixed and covered – to reduce or avoid the need for sorting after collection and to facilitate recycling.[757] Afterwards, all processed and unprocessed garbage stored for any length of time should be in tight, securely covered containers in order to prevent the unintentional discharge of stored garbage.[758] If there are clear grounds for believing that the master or crew are not familiar with the referred essential shipboard procedures and with the ones relating to the prevention of pollution by garbage, the ship – when in a port or an offshore terminal of another Party – is subject to inspection by officers duly authorised by such Party concerning operational requirements under the Annex V.[759] The ship will not sail until the situation is rectified in accordance with the requirements of the Annex V.

If, in fact, garbage is discharged into the sea, regardless of the reason, that event may have to be registered in the Garbage Record Book. The registry is only mandatory for ships of 400 gross tonnages and above, for ships which are certified to carry fifteen or more persons

[755] Guidelines, para 2.1.1. When making supply and provisioning arrangements, and when considering selection of materials for stowage and securing of cargo or protection of cargo from the weather, ship owners and operators, where possible with the ships' suppliers, should consider the products being procured in terms of the garbage they will generate (paras 2.1.2 and 2.1.3). The action of limiting the amount of material that may become garbage from being brought on board the ship is not only environmentally advantageous but it is also economically advantageous (para 2.3.3).
[756] Guidelines, para 2.1.2.
[757] The recommended garbage types that should be separated are: non-recyclable plastics and plastics mixed with non-plastic garbage; rags; recyclable material (cooking oil, glass, aluminium cans, paper, cardboard, corrugated board, wood, metal and plastics, including styrofoam or other similar plastic material); e-waste generated on board (eg electronic cards, gadgets, instruments, equipment, computers, printer cartridges); and garbage that might present a hazard to the ship or crew (eg oily rags, light bulbs, acids, chemicals, batteries) (para 2.4.3). When plastic is mixed with other garbage, the mixture must be treated as if it were all plastic (para 2.4.6).
[758] Guidelines, para 2.6.1. Proper management of containers and packaging coming on board and proper handling and storage can minimise shipboard storage space requirements and enable efficient transfer of retained garbage to port reception facilities for proper handling (recycling, reuse) or land-based disposal (para 2.3.3).
[759] Regulation 9.

engaged in voyages to ports or offshore terminals under the jurisdiction of another Party to the Convention, and for fixed or floating platforms.[760] Each discharge into the sea (even in case of accidental loss), and each discharge to a reception facility, must be promptly recorded in the Garbage Record Book. Whatever the situation may be, the registry must include date and time, the position of the ship (latitude and longitude, and water depth if known) or port/facility/ship name, category of the garbage and the estimated amount for each category. In the event of any discharge or accidental loss covered by the Regulation 7, it has to be mentioned likewise the reason for the discharge or loss and the precautions taken to prevent or minimise such discharge or accidental loss. Knowing that it poses a significant threat to the marine environment and to navigation, the discharge or loss of fishing gear at sea has to be reported not only to the State whose flag the ship is entitled to fly, but also to the coastal State if the discharge or loss occurred within waters subject to its jurisdiction.[761] In any case, it is important to try to recover the garbage improperly discharged or lost at sea, as well it is advisable to recover persistent garbage from the sea during routine operations as opportunities arise and prudent practice permits, and to retain the material for discharge to port reception facilities.[762]

At last, we note that the general prohibition on discharge of garbage into the sea, and the entire Annex V, cannot be effectively implemented without the existence of adequate facilities at ports and terminals for the reception of garbage.[763] Although Each Party is free to decide how to provide the waste reception service, the Parties must make sure that they respect the needs of the ships using their facilities and that no undue delay is caused to the ships. In case reception facilities are located within special areas, the Parties must meet the requirements mentioned above as soon as possible in all ports and terminals.[764] Because of their unique circumstances, Small Island Developing States may satisfy the same

[760] Regulation 10(3). The form of Garbage Record Book is described in the appendix II to Annex V.
[761] Regulation 10(3)(6). The Guidelines reveal that the Governments are encouraged to develop communication frameworks to enable the recording and sharing of information on fishing gear loss in order to reduce loss and facilitate recovery (para 2.2.2.3).
[762] Guidelines, para 2.4.9.
[763] Regulation 8(1). The Parties need to know and follow the *Consolidated Guidance for Port Reception Facility Providers and Users* (MEPC.1/Circ.834/Rev.1 adopted on 1 March 2018).
[764] Regulation 8(2)(1). For the purposes of this Regulation and of Annex V, *special areas* mean 'a sea area where for recognized technical reasons in relation to its oceanographic and ecological condition [such as low water exchange, extreme ice states, endangered marine species] and to the particular character of its traffic the adoption of special mandatory methods for the prevention of sea pollution by garbage is required', Regulation 1(14). The Annex V defined the following eight special areas: the Mediterranean Sea area; the Baltic Sea area; the Black Sea area; the Red Sea area; the Persian Gulf and Gulf of Aden area; the North Sea area; the Antarctic area; and the wider Caribbean Region.

requirements through regional arrangements – and develop a Regional Reception Facilities Plan – when such arrangements are the only practical means to satisfy the referred requirements.[765]

The adequacy of facilities is though very difficult to determine, especially because most ship waste handling is provided by private waste operators.[766] Nevertheless, any alleged inadequacy of the reception facilities must be notified to IMO, which in turn must report the violation to the concerned Contracting Parties and contact the defaulting Party to ensure compliance.[767]

There is, since 2014, a Chapter named Verification of Compliance with the Provisions of Annex V. This Chapter provides that Parties must use the provisions of the Code for Implementation in execution of their obligations and responsibilities,[768] and be subject to the IMO Member State Audit Scheme in accordance with the audit standard to verify compliance with and implementation of the Annex.[769] In case of noncompliance, neither MARPOL 73/78 nor IMO Conventions in general impose sanctions. Instead, they must be established under the law of the Administration of the ship concerned wherever the violation occurs, meaning *Administration* the Government of the State under whose authority the ship is operating.[770] These sanctions must be adequate in severity to discourage violations and shall be equally severe irrespective of where the violations occur.[771]

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[765] Regulation 8(3). Particulars of the identified Regional Ships Waste Reception Centres and particulars of the ports with only limited facilities must be shared by IMO to the Parties of the present Convention.

[766] Jens Peter Øhlenschlæger, Stephanie Newman and Andrew Farmer, *Reducing Ship Generated Marine Litter - Recommendations to Improve the EU Port Reception Facilities Directive* (Institute for European Environmental Policy, London, 2013) 10. According to the Guidelines, 'the methodology for determining the adequacy of a reception facility should be based on the number and type of ships that will call at the port, the waste management requirements of each type of ship as well as the size and location of a port'. Emphasis should also be placed on calculating the quantities of garbage – that must be separated on board –, including recyclable material. While assessing the adequacy of reception facilities, Governments should also consider the technological challenges associated with recycling, treatment and discharge of garbage received from ships (para 5.1).

[767] Regulation 8(4). According to the IMO Global Integrated Shipping Information System, between February 2005 and December 2017, were reported 571 cases of alleged inadequacy of reception facilities. Information available at <https://gisis.imo.org/Public/Default.aspx>.

[768] Regulation 11. *Code for Implementation* is the IMO Instruments Implementation Code (III Code) adopted by the IMO by Resolution A.1070(28), from 4 December 2013.

[769] Regulation 12.

[770] MARPOL 73, Article 4(1). Governments are encouraged to consider not only restrictive and punitive measures consistent with international law, but also the removal of disincentives and the creation of positive incentives and initiatives to facilitate more effective compliance, Guidelines, para 6.1.

[771] MARPOL 73, Article 4(4).

d. Other Relevant International Conventions

i. Hazardous Substances Release

Over the years, several International Conventions have been produced to control the release of hazardous substances into the environment. It is the case of the Basel, Rotterdam and Stockholm Conventions. They are relevant for the purpose of this study insofar as plastics are produced containing compounds known to have toxic properties, and still have a tendency to absorb organic pollutants. In any case, the repercussions – already illustrated in Part I – are significant, are felt through different ecosystems and can reach the human food chain.

'Aware of the risk of damage to human health and the environment caused by hazardous wastes and other wastes and the transboundary movement thereof',[772] the UNEP adopted in 1989 the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal.[773] Currently binding for 186 countries,[774] this Convention was designed to: minimise the generation of hazardous wastes and other wastes (in terms of quantity and/or hazard potential); ensure the availability of adequate disposal facilities to manage that waste in an environmentally sound manner, respecting the principle of self-sufficiency; prevent pollution arising from such management and if such pollution occurs, minimise the consequences thereof for human health and the environment; reduce the transboundary movements of the referred wastes to the minimum; and not allow their export, especially to developing countries, if there is reason to believe that the wastes in question will not be managed in an environmentally sound manner.[775]

Considering this, it is possible to conclude that the Basel Convention covers many of the issues which are at the heart of reducing marine pollution from plastics. There is considerable international trade both in plastics and plastic waste, and some are indeed

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[772] See Whereas 1.
[773] This Convention was adopted on 22 March 1989 and entered into force on 5 May 1992. For the purposes of this Convention, *transboundary movement* means 'any movement of hazardous wastes or other wastes from an area under the national jurisdiction of one State to or through an area under the national jurisdiction of another State or to or through an area not under the national jurisdiction of any State, provided at least two States are involved in the movement' see Article 1(3).
[774] Information is available at the official website of the Basel Convention: <www.basel.int>.
[775] See Whereas 3, 4, 17, 18, 20 and 21 and Article 4(2). According to Article 1(8), *environmentally sound management of hazardous wastes or other wastes* implies taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner that will protect human health and the environment against the adverse effects which may result from such wastes.

hazardous.[776] Even if the broad range of plastic waste is unlikely to be considered hazardous, it may fall on the *other wastes* category, which comprehends wastes collected from households that are subject to transboundary movement.[777]

These and other measures and obligations have been further developed over the years by the Convention of the Parties (COP),[778] and lately plastic waste has been taken into account more often. In May 2017, at its thirteenth meeting,[779] the COP included in the work programme of the Open-ended Working Group for the biennium 2018-2019 the mandate to: a) consider relevant options available under the Convention to further address marine plastic litter and microplastics; and b) develop a proposal for possible further action, within the scope of the Convention and avoiding duplication with activities relating to the matter in other

[776] For the Basel Convention, *wastes* are 'substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law', see Article 2(1). In turn, *hazardous wastes* are those that: belong to any of the categories listed in Annex I of the Basel Convention, as further elaborated in Annexes VIII and IX, unless they do not possess any of the hazardous characteristics in Annex III; are considered hazardous wastes by the domestic legislation of the Party of export, import or transit. See Article 1(1)(b) and Article 3. The hazardous characteristics contained in Annex III are: explosive; flammable liquids; flammable solids; substances or wastes liable to spontaneous combustion; substances or wastes which, in contact with water emit flammable gases; oxidising; organic peroxides; poisonous (acute); infectious substances; corrosives; liberation of toxic gases in contact with air or water; and toxic (delayed or chronic). Toxicity has more to do with plastic waste. It refers to substances or wastes that, if inhaled, ingested or penetrate the skin, may involve delayed or chronic effects, including carcinogenicity. Despite this, the Basel Convention does not cover all plastic debris that may enter the sea. For example, plastics from industrial or commercial packaging, unless hazardous or until they become household waste, are not currently within the scope of the Convention. Plastic particles that arise from the abrasion of tyres or garments while in use are also not considered.

[777] Article 1(2). Annex II includes also residues arising from the incineration of household wastes.

[778] In 2002, COP-6 adopted the Technical Guidelines for the Identification and Environmentally Sound Management (ESM) of Plastic Waste and for Their Disposal (see Decision VI/21 and UNEP/CHW.6/21). It focused mainly on the technical aspects of the management of plastic wastes, with particular emphasis on their recycling. Moreover, the document advised that waste prevention or reduction should involve both upstream alterations in product design and in consumer habits, but did not offer suggestions on this, neither on environmental and health impacts of plastic waste, nor on the reduction of hazard potential of plastic products and waste. In 2012, at COP-10, Parties committed themselves to promote and implement more efficient strategies to prevent and minimise the generation of hazardous and other wastes, particularly through measures to prevent and minimise wastes generated at source (see the Cartagena Declaration on the Prevention, Minimisation and Recovery of Hazardous Wastes and Other Wastes). In 2013, COP-11 adopted the Framework for the ESM of Hazardous Wastes and Other Wastes (see Decision BC-11/1 and UNEP/CHW.11/3/Add.1/Rev.1). This framework is a practical guide to establish a common understanding of what ESM encompasses, to identify strategies and tools to support and promote its implementation at the national level.

[779] See Decision BC-13/17. Furthermore, COP-13: adopted a set of Practical Manuals for the Promotion of the Environmentally Sound Management of Wastes and extended the mandate of the working group to develop further the guidance and advice (see Decision BC-13/2 and UNEP/CHW.13/4/Add.1); welcomed Draft Practical Manuals on Extended Producer Responsibility and Financing Systems for ESM (see Decision BC-13/2 and UNEP/CHW.13/INF/8); adopted Guidance to Assist Parties in Developing Efficient Strategies for Achieving the Prevention and Minimisation of the Generation of Hazardous and Other Wastes and Their Disposal (see Decision BC-13/3 and UNEP/CHW.13/INF/11/Rev.1), in which plastic waste was highlighted as a key waste stream; established the Partnership on Household Waste (see Decision BC-13/14), through which the ESM of household wastes including plastics will be further explored; and adopted also Guidance Manual on How to Improve the Sea-land Interface (see Decision BC-13/15 and UNEP/CHW.13/18), to ensure that wastes falling within the scope of MARPOL, once offloaded from a ship, are managed in an environmentally sound manner.

forums, for consideration by the COP at its fourteenth meeting.[780] As a result, the following ideas, among others, were set forth as possible elements to consider by COP-14: reconfirm that marine plastic litter and microplastics are an issue of serious global concern, and emphasise that the Basel Convention can and will play a central and significant role in addressing this problem; tackle pollution by marine plastic litter and microplastics at source; give high priority and toughen preventive action through waste minimisation and environmentally sound waste management (particularly through the application of lifecycle approach and waste management hierarchy); invite Governments, industry and consumers to make efforts to prevent and minimise the generation of plastic waste, in particular that which arises from the use of single use plastics; consider whether any additional constituents or characteristics should be added to Annex I or Annex III respectively to the Convention (for example, plasticizers which have endocrine disrupting properties) and consider whether any new categories of waste should be listed in Annex II of the Convention (for example, industrial, construction, commercial, agricultural, packaging waste and microplastic beads); invite Parties to the Stockholm Convention to address in particular substances which may pose a risk through their presence as additives or contaminants in marine plastic litter and microplastics, with a view to eliminating or minimising their use; consider whether the framework and practical guidance on prevention and minimisation of hazardous and other waste and on ESM, as well as the technical guidelines adopted in 2002 on the sound management of plastic wastes, deal sufficiently with the challenge of marine plastic litter and microplastics reflecting current technical and other considerations; consider establishing a mechanism to monitor the implementation of the technical guidelines on plastic wastes; and consider developing voluntary indicators, targets, timelines and reporting mechanisms on reductions in plastic waste generation, so as to enable the monitoring of progress towards plastic waste minimisation at the national and global levels.

A key part of the work of the Basel Convention is building international, regional and national capacity, supporting national action, and sharing information especially with the COP of Stockholm and Rotterdam conventions. The three share a technical assistance plan for the implementation of the conventions for the period 2018–2021,[781] that can help address the issues of marine plastics and microplastics. In fact, the three conventions together provide

[780] This proposal can be found in UNEP/CHW/OEWG.11/7 and UNEP/CHW/OEWG.11/INF/22.
[781] See UNEP/CHW.13/INF/43, UNEP/FAO/RC/COP.8/INF/29 and UNEP/POPS/COP.8/INF/46.

the international legally binding framework governing the ESM of hazardous substances (including wastes) throughout their life cycles. The Stockholm Convention on Persistent Organic Pollutants was adopted in May 2001 in response to the urgent need for global action to protect human health and the environment from chemicals that, as seen in Part I, remain intact in the environment for long periods, become widely distributed geographically, bioaccumulate in tissues of living organisms, increase in concentration along the food chain, and are highly toxic to both humans and wildlife. Given their long range transport, no one government acting alone can protect its citizens or its environment from POPs. The same happens with plastic waste, which has become a carrier of POPs in the oceans and seas.[782] Therefore, the provisions of this Convention require each party to prohibit, eliminate or restrict the production and use, as well as the import and export, of some intentionally produced POPs (listed in Annexes A and B), reduce or eliminate releases from unintentionally produced POPs listed in Annex C to the Convention, and ensure that stockpiles and wastes consisting of, containing or contaminated with POPs are managed safely and in an environmentally sound manner.[783] This Convention and the Basel Convention have in common regional and coordinating centres, where it is mandatory to work on the impact of plastic waste, marine plastic litter, microplastic, and measures for prevention and environmentally sound management.[784]

Lastly, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, was adopted in September 1998, to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm, and to contribute to the environmentally sound use of those hazardous chemicals, by facilitating information exchange about their characteristics, potential dangers, and safe handling, by providing for a national decision-making process on

[782] Clearly there is a potential synergy between POPs monitoring under the Stockholm Convention and monitoring the occurrence of plastic particles. For this purpose, the Global Monitoring Plan for POPs under the Stockholm Convention provides a harmonised organisational framework for the collection of globally comparable POPs monitoring data to illustrate concentration trends over time, as well as regional and global environmental transport. Regarding exclusively plastic, we recall that the worldwide plastic pellets' distribution and its POPs are registered by the International Pellet Watch.

[783] See Articles 3, 5 and 6. As of 2018, the Convention controlled 28 POPs, including those which have been used as additives, flame retardants or plasticisers in plastics such as: brominated diphenyl ethers; hexabromocyclododecane; perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride; and short-chain chlorinated paraffins.

[784] See Decisions BC-13/11 and SC-8/15.

their import and export and by disseminating these decisions to Parties. The Convention covers pesticides and a very broad range of industrial chemicals that have been banned or severely restricted for health or environmental reasons by Parties and which have been notified by Parties for inclusion in the Prior Informed Consent procedure. Plastics leaked into the water may contain substances listed within the Convention Annexes.

ii. Conservation of Biodiversity

Since the impacts caused to nature and animals are increasing more and more and becoming truly alarming, it is also important to analyse if and how international law is protecting biodiversity from the plastic waste menace, which is nowadays listed among the major perceived threats to marine biodiversity. All animals are sentient beings, and they deserve respect and protection, specifically because their welfare, physical safety and life is threatened by humans and/or human activities. We will now contemplate some of the legal changes achieved as a consequence of marine plastic pollution.

The Convention on Biological Diversity (CBD) came into force in December 1993 and since then obliges 196 Parties.[785] Among other purposes, we point out the conservation of biological diversity, the sustainable use of its components, the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources and the creation of a system of protected areas. Evidently, Contracting Parties shall implement this Convention with respect to the marine environment consistently with the rights and obligations of States under the law of the sea.

The first reference, albeit an indirect on, to marine plastic pollution was made during the tenth meeting of the COP of the CBD, in October 2010. Parties, other governments and relevant organisations were urged to adopt, in accordance with international law, complementary measures to prevent significant adverse effects by unsustainable human activities to marine and coastal areas, especially those identified as ecologically or biologically significant.[786] This Decision was followed by the publication of the report

[785] Information obtained on the official website of the CBD: <www.cbd.int>.
[786] UNEP/CBD/COP/DEC/X/29 (29 October 2010), para 73.

Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions,[787] and by the Decision XI/18 on marine and coastal biodiversity, that invited Parties to submit information on the impacts of marine debris on marine and coastal biodiversity and habitats.[788] Only in 2016, after the report *Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity*,[789] the issue was taken up again, and this time in a very comprehensive manner. The Decision XIII/10, from December 2016, addressed the impacts of marine debris and anthropogenic underwater noise on marine and coastal biodiversity,[790] and Parties and other governments, relevant organisations, industries, other relevant stakeholders and local communities, were encouraged and urged to: develop and implement measures, policies and instruments to prevent the discard, disposal, loss or abandonment of any persistent, manufactured or processed solid material in the marine and coastal environment; take appropriate measures, in accordance with national and international law and within their competencies, to prevent and mitigate the potential adverse impacts of marine debris on marine and coastal biodiversity and habitats, taking into account the voluntary practical guidance contained in the annex; incorporate issues related to marine debris in the mainstreaming of biodiversity into different sectors; and facilitate collaboration between all public and private players to prevent and mitigate the impact of marine debris on marine and coastal biodiversity and habitats, by facilitating the sharing of experiences, information, toolkits and best practices.[791] All in all, this Decision represents the incorporation of all the knowledge available into the CBD framework, providing them with more tools to conserve biodiversity.

The Convention on the Conservation of Migratory Species of Wild Animals (CMS), which is an environmental treaty under the aegis of UNEP, such as the CBD, provides since November 1983 a global platform for the conservation and sustainable use of migratory species as well as their habitat. Among these species and populations that cross national jurisdictional boundaries there are a lot of fishes, marine mammals and birds (some

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787 Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel - GEF, *Impacts of Marine Debris...*

788 UNEP/CBD/COP/DEC/XI/18 (5 December 2012), para 26. It was also requested to the Executive Secretary, subject to availability of financial resources, to include the issue of marine debris in regional capacity building workshops in order to discuss ways to prevent and reduce the impact of marine debris on biodiversity and strengthen research on the reduction and management of marine debris, with a focus on addressing sources (para 27).

789 Secretariat of the Convention on Biological Diversity, *Marine Debris: Understanding...*

790 CBD/COP/DEC/XIII/10 (10 December 2016). Two of its influences were the UN Environment Assembly Resolution 2/11 and the G7 Action Plan to Combat Marine Litter.

791 Paras 6, 8 and 10(a).

threatened with extinction), that ingest marine plastic waste and/or that are injured or killed by it. In order to fulfil the obligation of taking action to avoid any migratory species becoming endangered, the CMS and its 126 Parties[792] have to be aware of the plastic pollution phenomenon and develop measures to that effect.

The first CMS initiative on marine debris dates from 2011.[793] Aware of the impacts that debris was causing to animals, the COP encouraged Parties to identify coastal and oceanic locations where marine debris aggregate, to communicate that data, to develop and implement their own national plans of action and to help Parties with limited resources developing their plans of action. In 2014, a Resolution on management of marine debris, based on three important reports,[794] called upon Parties to incorporate marine debris targets when developing marine debris management strategies, including targets relating directly to impacts on migratory species (para 8). Furthermore, the Resolution encouraged the Scientific Council to promote the prioritisation of research into the effects of microplastics on the species ingesting them, and support research on the significance of colour, shape or plastic type on the likelihood of causing harm, in order to be able to focus management strategies in future (para 9). Moreover, the Secretariat was invited to work with the UNEP Regional Seas Programme to support standardisation and implementation of methods for studies monitoring impacts in order to produce comparable data across species and regions that will allow robust ranking of debris types for risk of harm across different species groups (para 10). In addition, Parties were strongly encouraged to address the issue of abandoned, lost or otherwise discarded fishing gear by following the strategies set out under the FAO Code of Conduct for Responsible Fisheries (para 14),[795] and to develop marine debris campaigns of specific

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[792] Information obtained on the official website of the Convention: <www.cms.int>.

[793] The Resolution 10.4 on Marine Debris was adopted by the COP at its tenth meeting in Bergen, Norway, in 20-25 November 2011. The Resolution recalled the UN Resolution A/60/30, the Honolulu Commitment and the Honolulu Strategy.

[794] The Resolution 11.30 on Management of Marine Debris was adopted by the COP at its eleventh meeting in Quito, Ecuador, in 4-9 November 2014. The comprehensive reports published by the CMS were the following: Migratory Species, Marine Debris and its Management (giving an overview of the issue and identifying knowledge gaps relevant to species conservation) (UNEP/CMS/COP11/Inf.27); Marine Debris and Commercial Marine Vessel Best Practice (UNEP/CMS/COP11/Inf.28); and Marine Debris: Public Awareness and Education Campaigns (UNEP/CMS/COP11/Inf.29).

[795] The FAO Code of Conduct for Responsible Fisheries contains some provisions and standards relevant to marine litter. The Code is voluntary and global in scope, and is directed at both members and non-members of FAO, and at all levels of governance. Provisions concerning marine litter include the provision of port-reception facilities, storage of garbage on board and the reduction in abandoned, lost or otherwise discarded fishing gear. For instance, it was suggested not only the development of technologies, materials and operational methods that minimise the loss of fishing gear and the ghost fishing effects of lost or abandoned fishing gear, but also the research on the environmental and social impacts of fishing gear and, in particular, on the impact of such gear on biodiversity and

relevance to migratory species (para 21). These two resolutions were repealed, but their measures were included in a new Resolution with a wider scope than the previous ones, far beyond biodiversity.[796] It put forward measures such as: develop marine debris campaigns specific relevant to migratory species; progressive elimination of single-use plastics; re-design of products and packaging; prevent loss of pre-production plastics; establish measures consistent with the waste hierarchy and the circular economy concept to achieve prevention and environmentally sound management of waste, and develop incentives for the private sector to consider the circular economy concept in their approach; implement market-based instruments (levies or bans on single-use carrier bags and other single-use plastics, extended producer responsibility, subjecting fishing gear to mandatory deposit-and-refund schemes, and more); and clean-up actions of hotspots of marine debris, with particular attention given to areas where migratory species are at higher risk.

The International Whaling Commission (IWC) has been paying attention to marine debris for many years. They can entangle and trap whales, causing them severe harm, which runs counter to the objectives of preserving and managing whale stocks to be pursued by the International Convention for the Regulation of Whaling.[797]

Since 2010, the IWC has been working in a number of programmes to understand and mitigate potential threats caused by a range of different types of debris. The most relevant are: two expert workshops on marine debris;[798] three workshops on large whale entanglement in all fishing gear, including lost and abandoned gear; and the establishment of a Global Whale Entanglement Response Network in 2011, to build safe and effective entanglement response capability around the world and to increase the efforts to strengthen international

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coastal fishing communities. Regarding the protection of the aquatic environment, owners, charterers and managers of fishing vessels should: minimise the taking aboard of potential garbage; ensure that their vessels are fitted with appropriate equipment as, required by MARPOL 73/78; and consider fitting a shipboard compactor or incinerator to relevant classes of vessels in order to treat garbage and other shipboard wastes generated during the vessel's normal service. At last, during the design and construction of harbours and landing places States should introduce waste disposal systems, including for the disposal of oil, oily water and fishing gear.

796 The Resolution 12.20 on Management of Marine Debris was adopted by the COP at its twelfth meeting in Manila, the Philippines, in October 2017.

797 The IWC was set up in 1946 under the auspices of the International Convention for the Regulation of Whaling and has currently 88 Contracting Governments. This information and everything that has to do with IWC is available on the official website of the Commission: <https://iwc.int/home>.

798 IWC/SC/65a/Rep06 and IWC/65a/Rep04. The first, in 2013, was scientifically focused, analysing the different threats, knowledge gaps and further research requirements. The second workshop, in 2014, was policy-led, agreeing practical, management actions that the IWC could take in order to contribute its expertise most effectively to the each of the range of global initiatives on marine debris.

collaboration.[799] After all, the IWC recognises that this Programme has shown the importance and potential impact of international and intergovernmental collaboration, but it is aware that much is left to be done, especially achieving the long-term goal of preventing entanglements from happening.

C. Regional Seas Programme

In 1974, the UNEP established the Regional Seas Programme (RSP). It addresses the accelerating degradation of the world's oceans, coastal and marine areas by engaging neighbouring countries to cooperate in comprehensive and specific actions for the protection of their common marine environment. The Programme also reaffirms that sustainable development of the oceans requires effective coordination and cooperation at global and regional levels and between relevant bodies. So, currently, more than 143 countries have joined eighteen Regional Seas Programmes for the conservation and sustainable management of marine and coastal environments.[800-801]

Most of the Regional Seas Programmes function through Action Plans, which are adopted by member governments in order to establish comprehensive strategies and frameworks for protecting the environment and promote sustainable development. They have to be tailored to suit the particular environmental challenges, as well as the socio-economic

[799] A Technical Advisor and an Expert Panel developed global Best Practice Guidelines and devised a two-day training package, contemplating classroom work on data collection, law and relevant species in each region, and practical use of disentanglement tools on the water. Since 2012, training has been delivered on five continents, reaching over 1000 scientists, conservationists and government representatives from more than 30 countries.

[800] There are 18 Regional Seas Programmes in the following regions: Wider Caribbean Region (Cartagena Convention), East Asian Seas (COBSEA), Eastern Africa Region (Nairobi Convention), Mediterranean Region (Barcelona Convention), North-West Pacific Region (NOWPAP), Western Africa Region (Abidjan Convention) and Caspian Sea (Tehran Convention) (UN Environment-administered); Black Sea (Bucharest Convention), North-East Pacific Region (Antigua Convention), Red Sea and Gulf of Aden (Jeddah Convention), ROPME Sea Area (Kuwait Convention), South Asian Seas (SACEP Convention), South-East Pacific Region (Lima Convention) and South Pacific Region (Noumea Convention) (Non-UN Environment-administered); and Antarctic Region (CCMLAR Convention), Arctic Region (PAME), Baltic Sea (Helsinki Convention or HELCOM), and North-East Atlantic Region (OSPAR Convention) (Independent Regional Seas programmes). The UNEP coordinates the Regional Seas Programme, which is based at the Nairobi headquarters.

[801] Most of these Programmes evolved around a common axis and identified shared priorities, including: land-based sources of pollution; ship-generated marine pollution (oil, chemicals, litter); increased urbanisation and coastal development causing destruction of ecosystems and habitats; conservation and management of marine and coastal ecosystems; integrated coastal and river basin management; over-exploitation and depletion of living marine resources, including fisheries; and monitoring, reporting and assessment of marine environment. Other emerging issues included the impacts of climate change, conservation of deep sea biodiversity, and increasing incidences of marine invasive species. See UNEP, *Marine Litter: A Global Challenge...*, 16.

and political conditions of each regional sea. Fourteen of these programmes have also adopted legally-binding Conventions that express the commitment and political will of governments to tackle their common environmental issues through joint coordinated activities, which is essential to tackle successfully the problem of marine plastic pollution. Most Conventions have added Protocols, legally-binding agreements addressing specific issues such as land-based sources and activities, pollution by dumping, protection of the marine and coastal environment, marine protected areas, biodiversity and landscape conservation.

Even though there are some protocols concerning pollution from land based sources and activities in force, they are not sufficient to tackle effectively and widely marine plastic pollution.[802] Therefore, in 2005, the UNEP Regional Seas Programme took an active lead on the marine litter issue, through the organisation and implementation of regional activities on marine litter in twelve Regional Seas.[803] The activities and the respective adherence were as follows: the preparation of a document to review the status of marine litter, which everyone concluded; the elaboration of a Regional Action Plan (RAP) on the Sustainable Management of Marine Litter, which only seven of the participating Regional Seas prepared; the organisation of a regional meeting of national authorities and experts on marine litter, accomplished by nine regions; and at last, the participation in a Regional Cleanup Day, within the framework of the International Coastal Cleanup campaign, fulfilled by eleven regions.[804] Of all these activities, the most noteworthy is the RAP on the Sustainable Management of Marine Litter. Above all, it represents a way to consolidate, harmonise and implement necessary environmental policies, and regional and national strategies to achieve, in the respective regions, a significant quantitative reduction of marine litter and of its potential impacts on marine biota, habitats, public health and safety and of its socioeconomic costs.

Currently, there are only in force seven RAPs on the Sustainable Management of Marine Litter. They were developed by the following Regional Seas Programmes: South-East Pacific (2007); North-East Atlantic (2014); Mediterranean (2013); Wider Caribbean

[802] In the opinion of Mark Gold and others, in 'Stemming the Tide of Plastic Marine Litter: A Global Action Agenda' (2013) 5 Pritzker Brief 10, some of the most promising regionally-focused agreements include the Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR), the Helsinki Convention, and particularly the Barcelona Convention and the Cartagena Convention, which have always been extremely active, visible and effective.
[803] Baltic Sea, Black Sea, Caspian Sea, East Asian Seas, Eastern Africa Region, Mediterranean Region, North-West Pacific Region, North-East Atlantic Region, Red Sea and Gulf of Aden, South Asian Seas, South-East Pacific Region and Wider Caribbean Region.
[804] UNEP, *Marine Litter: A Global Challenge*..., 17.

(2008; 2014); Baltic Sea (2015); North-West Pacific (2008); and East Asians Seas (2008). However, only the action plan adopted by the Mediterranean Sea RSP is legally binding.

Although they work independently, they pursue the same goals and have in common a number of similarities in their approaches to marine litter management. For this reason, and to guide the Contracting Parties in implementing them, they are built upon the same key principles and approaches – the integration principle, the prevention principle, the precautionary principle, the polluter-pays principle, the waste hierarchy principle, as well as the ecosystem-based approach, the public participation and stakeholder involvement, the sustainable consumption and production, and the best available knowledge and socio-economic effectiveness. Regarding the content of the RAPs, their main structure comprehends both regional and voluntary national actions divided into four themes: actions to combat land-based sources; actions to combat sea-based sources; removal actions; and education and outreach.[805] Concerning land-based sources, combat actions comprise: improved waste prevention and management; measures to tackle top items (micro particles, expanded polystyrene, plastic bags, bottles and containers); zero pellet loss; reduction of sewage and storm water related waste (including micro particles); assess relevant instruments and incentives to reduce the use of single-use and other items, which impact the marine environment; and elimination, change or adaptation of the products for environmental benefits, which comprehends the development of sustainable packaging, the establishment of deposit, return and restoration systems, and of procedures and manufacturing methodologies together with plastic industry, in order to minimise the decomposition characteristics of

[805] The regional actions have a large-scale, widespread and transboundary character and require thus a joint approach by Contracting Parties and possibly also by other organisations and institutions having the specific competence to act (such as the EU, the IMO). In turn, the voluntary national actions are primarily of national concern and responsibility of the Contracting Parties. They are presented in the format of a pick list for the Contracting Parties to voluntarily select for their implementation according to national relevancy. See HELCOM, *Regional Action Plan for Marine Litter in the Baltic Sea* (2015), 6. To date, only HELCOM and OSPAR have proposed a list of voluntary actions. Some of the measures included are: promoting extended producer responsibility strategies requiring producers, manufacturers, brand owners and first importers to be responsible for the entire life-cycle of the product with a focus on items frequently found in the marine environment; improvement of storm water management in order to prevent litter, including micro litter, from heavy weather events and to enter the marine environment; seeking cooperation in the river and river basin authorities in order to include impacts of litter on the marine environment in river and river basin management plans; bring in certification schemes, such as Blue Angel, EU Ecolabel, Nordic Ecolabel; encourage refill systems and recycling, e.g. bulk and refill/reusable container for dry food and cleaning products, when applicable; encourage fishing vessels to be involved in passive fishing for litter schemes; raising public awareness, including for children and youths and consumer campaigns, on the occurrence, and prevention of marine litter; and promoting or adopting environmental awareness courses for fishermen and the fishery sector.

plastic, and to phase out the use of micro plastics as a component in personal care and cosmetic products.

With respect to actions to combat sea-based sources of marine litter, we point out the following: actions addressing shipping related waste, involving the development of best practice in relation to inspections for MARPOL Annex V; develop best practice in relation to fishing industry and aquaculture, considering waste management on board, at harbours and in relation to abandoned, lost and otherwise discarded fishing gear and derelict fishing gear and their removal; harmonise and improve the port reception facility system, audit the adequacy of garbage collection, and apply fair waste burden sharing between ports or when applicable, apply no-special-fee system; and impose fines for littering at sea.

In turn, removal actions demand in first place the elaboration of regional-wide maps of landfills and dumpsites that may eventually pose a risk to the marine environment, of hotspots of floating litter, based on mapping of circulation of floating masses of marine litter, and of hotspots of accumulation on coastal areas based on the role of prevailing currents and winds. Moreover, marine environmental compartments (beach, seafloor, water column) must be cleaned and kept cleaned.[806] For this purpose, it is important to implement regional and national marine litter clean-up campaigns on a regular basis and to elaborate national programmes on their regular removal and sound disposal. Both can benefit from the establishment of an exchange platform for spreading experiences on environmental friendly technologies and on good cleaning practices, including fishing for litter initiatives, which implies the collection of litter caught in fishing nets during normal fishing activities.

The last theme – education and outreach on marine litter – it the least developed. It requires the establishment of a communication strategy, education programs and a database on good practice examples of marine litter measures and initiatives, that must be shared in order to make action more visible to the public.

All these actions, for which were defined implementation years and their main leaders, are linked to general measures such as: the enforcement of international legislation,

[806] Since 1998, OSPAR has monitored levels of beach litter. The OSPAR Pilot Project on Monitoring Marine Beach Litter (2000-2006) has been the first region-wide attempt in Europe to develop a method for monitoring marine litter on beaches and to assess presence of marine litter on the beaches in the OSPAR region, using this standardised method. This standardised methodology was complimented with information derived from UNEP's own realisation of a worldwide guideline, allowing therefore a uniform way of monitoring and interpreting the litter situation in the OSPAR area and comparisons between regions. See OSPAR Commission, *Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area* (London, 2010).

and of national/regional legal and administrative instruments; the enhancement of knowledge on marine litter composition, sources, quantities, distribution, pathway and impacts; the development of common indicators and associated targets; the harmonisation of monitoring and assessment programmes; and information exchange and coordination of national implementation activities. For determining the success of the RAPs, Contracting Parties must promote coordination, cross-sectorial cooperation and partnerships with civil society (private sector, NGOs and the scientific community), with industry and other organisations, such as UNEP, other Regional Seas Conventions,[807] the IMO, the Convention on Biological Diversity, the EU Fisheries Regional Advisory Councils, and the North East Atlantic Fisheries Commission and River and River Basin Commissions.[808] RAPs from RSPs farther from Europe and specially from the southern hemisphere, often refer to the need to find funding. In fact, despite being paramount, their needs are more basic, and so are their RAPs, that still require that marine litter is recognised as a problem and set as a priority in the countries of each region.[809] Therefore, marine litter must be integrated into the national legislation on solid waste management, national plans on coastal areas and river basin

[807] At the UN Conference to Support the Implementation of Sustainable Development Goal 14, held in New York in June 2017, OSPAR Commission and the Cartagena Convention registered a voluntary commitment to collaborate across the Atlantic. Since marine litter spreads across the Wider Caribbean Region and North-East Atlantic, joint measures to reduce the pollution through assessment and improved management will benefit the inter-regional cooperation. See OSPAR Commission, 'Cartagena Convention' (*OSPAR Commission*) <www.ospar.org/about/international-cooperation/cartagena-convention> accessed 25 July 2018.

[808] A good example of coordination and cooperation is the Marine Litter-MED 2016-2019 project. With the ultimate objective of achieving the GES of the Mediterranean Sea, it aims to specifically support the Contracting Parties from Southern Mediterranean and EU Neighbourhood to implement the Marine Litter Regional Plan through the implementation of a number of measures contributing to achieve the marine litter reduction targets. This project also works towards the promotion of enhanced regional governance on marine litter management among all stakeholders. For that purpose, a Regional Cooperation Platform was established, as an instrumental tool to provide coordinated support and guidance to the implementation of the Regional Plan on Marine Litter Management in the Mediterranean. It also envisages direct support to the Black Sea Commission in their efforts to finalise their Marine Litter Regional Plan and Marine Litter Monitoring Programme. See UNEP/MAP, 'Projects' (*UNEP/MAP*) <http://web.unep.org/unepmap/what-we-do/projects> accessed 25 July 2018.

[809] Marine litter was as well recognised as a priority area in the Pacific Regional Waste and Pollution Management Strategy, for the period 2016-2025. Even though the South Pacific Region does not have a RAP on the Sustainable Management of Marine Litter, nor even a protocol addressing land-based sources of pollution, the Secretariat of the Pacific Regional Environment Programme has been working, since 2010, to achieve a cleaner and healthier Pacific. Strategic goals include the prevention or minimisation of waste production and their associated impacts, recovery of wastes and pollution, improvement of the life-cycle management of residuals and improved monitoring of the receiving environment. Notably, this strategy has provided for performance indicators, baseline information, and targets for 2020 and 2025. In addition, it put forward strategic actions such as strengthening institutional capacity, promoting public-private partnerships, implementing sustainable best practices for waste, chemicals and pollutants, developing human capacity and promoting cooperation at the national and regional levels. See SPREP, *Cleaner Pacific 2025: Pacific Regional Waste and Pollution Management Strategy 2016-2025* (SPREP, Samoa, 2016).

management must be developed, the waste collection systems must be expanded, especially in coastal municipalities, and the waste management infrastructures must be improved.

In comparison to broader international agreements, the RSPs tend to address plastic pollution issues with less ambiguity by taking into account at least the ecological and economic dimensions of the region at issue. Notwithstanding some gaps and hurdles,[810] work must continue in order to achieve better results.[811]

D. The Final Analysis

Considering everything, it is now appropriate to analyse to what extent is international law in fact contributing to solve the plastic marine litter crisis. First of all, there can be no doubts about the progress that has been made since 2005. Since it was recognised as a real problem, this issue has been handled in a more serious way, always considering the most recent

[810] The RSPs potential to stem the tide of marine plastic waste might be limited, mainly because there are some regions of the ocean that are not covered by any RSP, such as South-East Atlantic, and because there are in fact very few binding conventions and action plans.

[811] Regarding the Baltic Sea, to date, of the 30 joint actions agreed in the RAP referred, two actions related to land-based sources (RL11 and RL14) have been achieved, six have been initiated, while for seven there is yet no identified lead country or process to implement the action. As regards joint actions related to sea-based sources, seven have been initiated, including to identify best practices to remove and reduce input of abandoned, lost or otherwise discarded fishing gear, while for five actions there is no lead country or process to implement the action. In the field of education and outreach, none of the three joint actions have been initiated. See HELCOM, *Implementation of the Baltic Sea Action Plan 2018,* 31.

In relation to East Asian Seas, most of the RAP activities were already implemented at the national level, in cooperation with local governments and authorities, and non-government organisations such as Our Sea of East Asia Network (OSEAN). They include: encouraging the active involvement of local residents, providing key information for cost-efficient removal; enabling the use of floating receptacles in Korea to collect derelict fishing gear; an initiative in Korea, led by OSEAN, to address the problem of EPS floats used for bivalve aquaculture, one of the most serious sources of beach debris and microplastics; the promotion of regional monitoring using a harmonised protocol; the assessment of the impacts of marine debris on wildlife in the coastal areas of Korea, to identify harmful debris items and vulnerable species; and the implementation of various education and public relations programmes have in the four member states. See Secretariat of the Convention on Biological Diversity, *Marine Debris: Understanding...*, 41-2.

At last, in the Mediterranean Sea, the RAP accomplishments and findings were the following: data on marine litter is inconsistent and geographically restricted mainly to the North Mediterranean; derelict fishing gear and ghost nets are considered to be a serious problem; Mediterranean countries have not yet drawn up their marine litter monitoring programmes in a coherent manner (if at all) via the use of harmonised monitoring methods across the region; there is no monitoring of marine litter impacts on biota in the Mediterranean, but there is a good scientific and technical basis to start, which is adopt the loggerhead turtle, classified worldwide as endangered, as a bio indicator species of environmental pollution; a better definition of baselines and targets is required in order to facilitate the implementation of the management measures agreed and identified in the RAP; the role of NGOs in tackling marine litter in the Mediterranean is prominent, and apart from gathering thousands of volunteers in support of a litter-free Mediterranean and running awareness-raising and education activities, their initiatives are significant in terms of data collection and clean-up operations. See UNEP/MAP, *Marine Litter Assessment in the Mediterranean...*, 10-1.

scientific findings in the newest guidelines and regulations. Today, it is possible to observe a complete picture of the situation in the set of all regional and international legal texts, particularly in soft law instruments, that most abundant in international environmental law. In truth, the last ones are more updated in what concerns marine plastic problematic because non-binding agreements are more flexible and easier to reach, amend or replace than treaties. These instruments mainly serve as global guiding instruments motivating regional bodies and countries to follow the actions and initiatives proposed therein, or as a platform for the States interested in engaging in coordination and cooperation in marine litter issues. Nevertheless, very positive results have been achieved by the binding regulations, and the older the better. It was recognised by the UN that international shipping rules and standards adopted by the IMO in respect of maritime safety, efficiency of navigation and the prevention and control of marine pollution, complemented by best practices of the shipping industry, have led to a significant reduction in maritime accidents and pollution incidents.[812]

Undoubtedly, each of the regional and international instruments analysed above is potentially helpful. However, there are some significant gaps and faults, particularly in conventions, that must be revised. In effect, no agreement covers all of the main sources of marine plastic pollution – not even clean-up operations –, and many agreements make express exemptions for major sources.[813] Nonetheless, we must not forget that at the time they were

[812] UN Resolution A/68/70 of 9 December 2013, para 147. Nonetheless, if we take into account the elevated number of Contracting Parties of MARPOL Annex V, its impact may be considered quite limited. See Eduard Interwies and others, *Issue Paper to the 'International Conference on Prevention and Management of Marine Litter in European Seas'* (European Commission and German Federal Environment Agency, 2013) 35 <https://marine-litter-conference-berlin.info/userfiles /file/Issue%20Paper_Final%20Version.pdf> accessed 14 May 2018 citing Dworak T and others, *Methodische Grundlagen für sozio-ökonomische Analysen sowie Folgenabschatzungen von Maßnahmen einschließlich Kosten-Nutzen Analysen nach EG-Meeresstrategie-Rahmenrichtlinie (MSRL)* (Project Report, 2011). Sharing the same opinion, see European Commission, 'Plastic Waste: Ecological and Human Health Impacts'..., 30 citing Mouat J, Lozano RL and Bateson H, *Economic Impacts of Marine Litter* (KIMO International, 2010) and Kershaw P and others, *Plastic Debris in the Ocean in UNEP Year Book 2011: Emerging Issues in Our Global Environment* (UNEP, Nairobi, 2011). Scientific research to prove these limitations can be found in Michelle Allsopp and others, *Plastic Debris in the World's Oceans...*, 33-4: 'Henderson (2001) made an inventory of beach debris in the Northwestern Hawaiian Islands between 1987 and 1996 and concluded that the accumulation of debris had not decreased since the introduction of Annex V in 1989. Furthermore, at the same time and in the same area, the number of entanglements of the Hawaiian monk seal (Monachus schauinslandi) did not change (Henderson 2001). In South Australia, a study of entanglement of Australian sea lions and the New Zealand fur seals found that by 2002, there was no evidence of a reduction in the number of entanglements (Page et al. 2004). In Brazil, research showed that ships continued to dump trash into the ocean (Santos et al. 2005)'. Hopefully, after the 2011 revision, the control of illegal disposals and the enforcement of MARPOL regulations at sea will be easier and more important for the reduction of pollution.

[813] For instance, UNCLOS does not penalise ships for the incidental loss of otherwise prohibited waste. The London Dumping Convention does not regulate ship generated waste and expressly permits disposal 'incidental to or derived from the normal operation of vessels'. Annex V of MARPOL, which broadly prohibits the 'discharge into

elaborated, the impacts of plastic debris were unknown, and pollution was only considered a problem if it created obstacles to ocean navigation and exploration. With respect to land-based sources, the instruments that address them are largely non-binding or limited in scope. Only UNCLOS regulates them, but it simply requests that countries address the problem in their waters through domestic means. No minimum standard nor timeframe is suggested for the implementation of such laws. And this brings us to the question of the lack of enforceable standards of the existing agreements.[814] Indeed, the greatest problem with legislation is the lack of effective enforcement, and the difficulties are not only legal but also technical. This causes policing legislation in seas and oceans to be extremely challenging.

Technical challenges mainly concern the difficulty in identifying the concrete ocean-based source of illegal disposal. For instance, to enforce obligations under UNCLOS, a state must witness a violator in the overt act of illegally disposing waste or must acquire sufficient evidence to warrant investigation of the suspect vessel. The ocean is so vast that without tracking systems, it is immensely difficult to link waste disposal to a particular ship. In addition, even if all the boats and vessels were obliged to have record keeping systems, they are unlikely to be reliable.[815]

Moreover, in any event, the authorities have limited power to intercept vessels suspected of illegal activity, which leads us to the legal challenges. First and foremost, the agreements we presented above are only as strong as the laws of the Contracting Parties. It is up to them to regulate, prosecute and sanction illegal activities within their waters, or in some instances, to prosecute acts done by vessels sailing under their flags. They define compliance in whatever way best serves their national interest. Sometimes, conventions authorise coastal states to penalise foreign-flagged vessels traveling in the State's territorial waters or EEZ, but even those powers are limited.[816]Apart from this, it is also hard to determine which particular

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the sea of all plastics', nonetheless exempts accidental loss or disposal of plastic resulting from damage to the ship or its equipment. See Mark Gold and others, 'Stemming the Tide..., 9.

[814] It is reflected in the texts of the Conventions: 'UNCLOS, for example, requires only that nations "shall endeavour" to use the "best practical means" to reduce marine pollution "in accordance with their capabilities". Similarly, the Helsinki Convention asks contracting parties to take "all appropriate" measures to prevent and eliminate pollution. OSPAR and the Cartagena Convention go further, instructing parties to take "all possible measures" to prevent and control pollution – a much stronger mandate, but one that obviously is still difficult to define and enforce. Indeed, it is hard to know what the phrases "best practical means", "all appropriate measures", or even "all possible measures" require of countries with differing legal systems, environmental circumstances, and capacities'. See ibid 10-1.

[815] See Mark Gold and others, 'Stemming the Tide..., 11.

[816] See ibid 9, where it is explained that under MARPOL, 'coastal states responding to alleged violations in their territorial waters or EEZ have few avenues of recourse other than demanding information from the suspect vessel.

State has jurisdiction to investigate and prosecute pollution violations. Since there are several laws (national, regional and international) potentially applicable and at least three potential parties involved – the Flag State, under whose flag the ship in question is registered, the Port State, the State in which the ship in question has made a port-of-call, and the Coastal State, in whose territorial waters the ship may be passing –, it is not always easy to ascertain the responsible.[817] Moreover, no RSP currently provides for sanctions against violating parties.

Overall, it can be concluded that legislation will have limited effectiveness if there is significant non-compliance, combined with low rates of detection and enforcement. At the same time, 'as there is very little enforcement there is little deterrent to breaking the law'.[818] This is a vicious circle that must be broken, and sooner the better, since international environmental law plays an essential role in the achievement of important solutions to the problematic of marine plastic pollution. Fortunately, international environmental law is a permanent work in progress and it has access to all the necessary knowledge to prove it has much more potential than it shows and to stem the tide.[819] In the first place, it is recommended to extend the reach of existing international law: binding instruments should be further explored to address plastic pollution in all its forms; abandoned, lost or otherwise discarded fishing gear should be considered more seriously; and clean-up actions should also be added to the scope of the conventions, such as the training of several sea professionals. Additionally, the same legal texts must be amended to narrow exceptions, among which are: the parties to MARPOL should eliminate the current vessel size and tonnage limitations in Annex V for requirements respecting placards, garbage management plans, and garbage record-keeping, so that no vessel is exempted; the parties to MARPOL should clarify the circumstances in

If the suspect vessel does not supply the requested information, the coastal state may physically inspect and prosecute a vessel only if it anticipates an imminent threat to the state's coastline, which is a very high burden'.

[817] Grant A Harse, 'Plastic, the Great Pacific Garbage Patch, and International Misfires at a Cure' (2011) 29(2) UCLA Journal of Environmental Law and Policy 349. It is also worth noting that 'enforcement is further hindered by disparity among nations' ability and willingness to enforce the requirements of MARPOL 73/78. In spite of, or perhaps because of, overlapping jurisdiction, most countries report violations to the flag state. This is because the country that prosecutes a case under MARPOL is responsible for the resulting legal expenses. Between 1983 and 1990, 1,335 violations were reported by port states; in only 238 of these instances did the port state prosecute, as opposed to simply report the violation to the flag state. Of those so reported, only 77 resulted in fines, while eight resulted in warnings, and ten in unspecified actions'. See ibid 350.

[818] OSPAR, *Marine litter in the North-East Atlantic Region: Assessment and Priorities for Response* (UK, 2009) 79.

[819] Nowadays, it is commonly embraced the Daniel Bodansky's idea of international environmental law as a 30% solution to international environmental problems, particularly in the context of: 1) norm proliferation and continuing environmental decline, and 2) the concept of sustainable development as an obstacle to environmental improvement. See Arie Trouwborst, 'Managing Marine Litter..., 9 citing Bodansky D, The Art and Craft of International Environmental Law (Harvard University Press, 2009).

which loss of fishing gear is prohibited by defining in Annex V when an *accidental loss* will be deemed to have occurred despite *all reasonable precautions*; stiffer penalty schedules under MARPOL and all other agreements with enforceable standards should be imposed.[820] With regard to land-based sources, it must be regulated by law urgently, as approximately 80% of marine litter is land-based. It is imperative to elaborate a new multilateral agreement covering all main sources of marine plastic litter, including microplastics, or at least the land-based ones, and solid waste management and wastewater treatment must be given higher priority as it happens in RAPs. [821] New legislation for areas beyond national jurisdiction could likewise be elaborated. It would be also a positive sign if more States ratified the existing conventions and actually respected them. Furthermore, international law and institutions could contribute to: harmonisation of national legislation; encouragement of countries that are lagging behind with their national legislation; agreements on liability and compensation for countries affected by pollution and damage caused by other countries; better implementation and monitoring of plastic debris levels and its impacts on nature, human health and economy.[822] At last, it is also essential to improve enforcement of existing obligations, for instance by guaranteeing that there is no overlapping jurisdictions and by installing cameras aboard ships to prevent waste disposals.

Concerning regional seas, we have to clarify that not all participate in the UNEP Global Initiative, such as West Central and Southern Africa, North-East Pacific, Pacific and the ROPME Sea Area. RAPs on the Sustainable Management of Marine Litter should be created by each RSP, either within the framework of their regional convention or protocol or as an independent instrument and document. These RAPs should be sustainable and long term in nature, incorporating basic principles of preventive actions and strategies, and they should be routinely updated according to changing circumstances or conditions.[823] Anyhow,

[820] See Mark Gold and others, 'Stemming the Tide..., 13-4.
[821] Mark Gold and others suggested the development of a new multilateral agreement on the scale and scope of the Montreal Protocol on Substances that Deplete the Ozone Layer. This new agreement should incorporate enforceable marine litter standards, as well as strong tracking, monitoring, reporting, and enforcement mechanisms, including, for once, adequate penalties and the establishment of jurisdiction for party dispute resolution at an international tribunal. It should be based in the recognition that ill-managed plastic litter is harmful to people, economies, and the environment. As regards its scope, it should address all of the main sources of plastic pollution, strictly regulate disposal of plastic litter from both ocean- and land-based sources, ban altogether the most common or damaging types of plastic marine litter (ie microbeads and fish-egg-sized nurdles), and support the development of and transition to product substitutes. For example, the new agreement could call for a phase-out of all plastics that are not recycled at a rate of 75% or higher by a certain date. See ibid 12-3.
[822] Wurpel G and others, *Plastics do not Belong...,* 25.
[823] See UNEP, *Marine Litter: A Global Challenge...*, 11.

existing and new RSPs could be strengthened in the following ways: marine litter should be included explicitly; the scope of application should include activities that generate plastic marine litter (eg river discharge, outfalls, and watercourses) as well as its sources; agreements should cover inland activities throughout the entire watershed of the protected waterbody, not just specific areas such as coastlines or territorial seas; agreements should, to the extent possible, contain narrowly drafted language with timelines, enforcement, third-party assessment, and a funding mechanism; a regional third-party organisation should be established and funded to ensure compliance.[824]

Regardless of the binding nature of the legal instruments, participation and cooperation should be enhanced and strengthened both in terms of the number of participating states and the substantiality of cooperation.[825] This would promote a dialogue among States on good practices in marine litter management and allow for substantial coordination and cooperation in research and developing and implementing more effective and practical management measures, such as the standardisation of litter monitoring methods, the technologies for solid waste management, the waste notification system and the fee system for ship-generated waste. Moreover, this would help less wealthy countries to advance solid waste and sewage management through technical and financial assistance and training provided by more experienced countries and international organisations.

In view of the above, there are no reasons to conclude that international environmental law is failing. It is well known that there is no universal legislator, no international tribunals and authorities, and no legal guarantee to enforce international provisions. Therefore, for some countries, the rules that organise international society are only political, and they only consent to be bound by the agreements as the result of calculating the advantages arising from their compliance.[826] However, besides the value and contributions of each guideline and convention, only international environmental law is capable of gathering at the same time, in the same place, almost every country to discuss problems that are affecting the ocean, a shared resource of mankind. All that has been said explains and justifies why international environmental law is undoubtedly part of the solution and why it must be promoted and strengthened. We just wished that all the countries that are trying to own the North Pole, were as prompt and resourceful to help tackling this serious pollution issue.

[824] See Mark Gold and others, 'Stemming the Tide..., 14.
[825] Chung-Ling Chen, 'Regulation and Management..., 421.
[826] António Pedro Barbas Homem, *História das Relações Internacionais* (Almedina, Coimbra, 2009) 296.

IX. European Union Responses to Marine Plastic Pollution

Over the years, the European Union has developed the largest and the most complete and harmonised acquis of the world, and EU law became a worldwide reference in relation to many matters. Environment is definitely one of them and it is one of the main EU areas of intervention.[827] Environment is as vast as the need to standardise environmental policies in the most comprehensive way, so it makes all the sense that the EU environmental policy represents one of the EU policy sectors where the process of *europeanisation* of national legislation is most apparent.[828-829]

Environment is a shared competence between the EU and its Member States.[830] However, the environment is a field in which the principle of subsidiarity plays an important role.[831] This means that the Member States have primary responsibility for the protection of the environment, but by reasons of scale or effects of the proposed actions, that protection cannot be sufficiently achieved by the Member States themselves, either at central level or at regional and local level. Instead, it can be better achieved at European Union level, as Whereas 49 Waste Framework Directive (WFD) specifically says regarding waste. Anyhow, Member States may maintain or introduce more stringent protective measures, as long as these measures are compatible with the EU treaties and are notified to the Commission.[832]

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827 Emanuela Orlando, 'The Evolution of EU Legislation and Policy in the Environmental Field: Achievements and Current Challenges' in Bakker C and Francioni F (eds), *The EU, the US and global climate governance* (Ashgate, 2014) 61.
828 ibid.
829 In Portugal, the influence of the European Environmental Law is an undeniable fact. The 1990s, which corresponds to the immediately post-accession of Portugal to EEC in 1986, are the awakening of Portuguese environmental regulations. Since then, the Portuguese Environmental Law is fundamentally EU Environmental Law materialised. See Carla Amado Gomes, *Introdução ao...,* 64.
830 See Article 4(2)(e) of the Treaty on the Functioning of the European Union (TFEU).
831 See Article 5(3) of the Treaty on European Union (TEU).
832 See Article 193 TFEU.

Regarding legislation, the scattered and uncoordinated group of measures inflicted by the ecological events and disasters of the late 1960s and 1970s,[833-834] steadily gave place to a sophisticated and consolidated system of environmental regulation and multilayer governance, looking for synergies between business and environmental goals.[835] If *environmental regulation* means also *environmental protection* is something that we do question. At least, *environmental protection requirements* – whatever they may be; treaties do not define them – must be 'integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development'.[836] Preserving, protecting and improving the quality of the environment, protecting human health, utilise natural resources in a prudent and rational way, and promoting measures at international level to deal with regional or worldwide environmental problems (in particular, combating climate change) are the objectives that the EU shall

[833] During these years, several meaningful environmental events have occurred. Carla Amado Gomes, citing Alexandre Kiss, highlighted the following: the publication of *Silent Spring* (1962) and *Environmental Revolution* (1969), two ecological books appealing to containment in the exploitation of natural resources; the mercury contamination in the bay of Minamata (Japan), with various reflexes for public health; and the shipwreck of the oil tanker Torrey Canyon, in 1967, off the coasts of England, France and Belgium, with devastating effects on marine pollution. See Carla Amado Gomes, 'Direito Administrativo do Ambiente' in Otero P and Gonçalves PC, *Tratado de Direito Administrativo Especial* (vol 1, Almedina, 2009) 160-1.

[834] Carla Amado Gomes mentioned that legal scholars identify the UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage, organised in Paris in 1972, as the beginning of the European Environment Policy. This Convention gave sequence to the United Nations Conference on the Human Environment (Stockholm Conference), also organised in 1972, which was the UN's first major conference on international environmental issues and which was able to mark a turning point in the development of international environmental politics. See Carla Amado Gomes, *Introdução ao...*, 57. Alexandra Aragão has even identified *The Limits to Growth* – a 1972 report on the computer simulation of exponential economic and population growth with a finite supply of resources, commissioned by the of Club of Roma – as another international initiative that alerted European public opinion to ecological problems. See Alexandra Aragão, *Direito Comunitário...,*9.

[835] For an analysis of the evolution of EU policy and legislation in the environmental field, seeking to combine an examination of the historical evolution of EU Environmental Policy, from an institutional and constitutional perspective, focusing key aspects and main trends of EU environmental governance and law-making, see Emanuela Orlando, 'The Evolution of EU Legislation... Providing a short outline of EU environmental policy history, and especially providing a comparative analysis of 60 pieces of EU environment and nature protection legislation, see Stefan Scheuer (ed), *EU Environmental Policy Handbook: A Critical Analysis of EU Environmental Legislation: Making it Accessible to Environmentalists and Decision Makers* (European Environmental Bureau, Brussels, 2005).

[836] See Article 11 TFEU. The Article 37 of the Charter of Fundamental Rights of the European Union is also dedicated to environmental protection: 'a high level of environmental protection and the improvement of the quality of the environment must be integrated into the policies of the Union and ensured in accordance with the principle of sustainable development'.

pursuit.[837] These objectives are anchored to the environmental principles of precautionary, prevention, correction at source and polluter-pays.[838]

Waste became a legal concern in the First Programme of Action of the European Communities on the Environment.[839] Subsequently, in 1975, the first Directive on waste was published, and since then a lot has been achieved.[840] However, new problems are constantly arising and new measures and politics must be held all the time.

As a global leader in the production of plastics, the generation of plastic waste, and the export of plastic waste, the EU has a responsibility to lead action on marine plastic pollution. In addition, 23 out of the 28 Member States have a coastline, which means that there are 378 European coastal regions (covering 40.0% of the EU-27 territory) – where nearly 205 million people (which correspond to 40.8% of the EU-27 population) live –,[841] that very likely contribute to marine plastic pollution and that at the same time are more prone to suffer the effects of marine pollution. Moreover, we recall that there is enough evidence indicating large debris accumulation in European seas, being the Mediterranean Sea the most polluted one. Everything considered, there are no doubts that the EU has major responsibilities in ensuring and improving safety and quality in all the ways possible, especially in preventing all the consequences deriving from plastic waste referred above.

Since there is not a specific law on marine plastic debris nor simply on plastic waste, we will analyse all the legal instruments produced by the EU that can help in some way to curb plastic pollution and ocean littering. In first place we will present the ones that

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[837] See Article 191(1) TFEU. Additionally, in preparing its policy on the environment, the EU shall take account of: available scientific and technical data; environmental conditions in the various regions of the Union; the potential benefits and costs of action or lack of action; the economic and social development of the Union as a whole and the balanced development of its regions. See Article 191(3) TFEU.

[838] See Article 191(2) TFEU.

[839] Declaration of the Council of the European Communities and of the Representatives of the Governments of the Member States Meeting in the Council of 22 November 1973 on the Programme of Action of the European Communities on the Environment [1973] OJ C112/1. In Chapter 7, dedicated to Action Concerning Wastes and Residues, plastic was already listed as a substance that created problems regarding collection, transport, storage, recycling or final treatment, and that should be studied (see Section 1, B, (b)). Marine pollution was addressed in Section 1 of Chapter 6 (Action Specific to Certain Areas of Common Interest). Of all the different forms of pollution, marine pollution – whose sources were sea transport and navigation, deliberate dumping of waste at sea, exploitation of marine and submarine resources and discharge of effluents from land – was then considered one of the most dangerous, because it could affect the whole Community: 'both because of the essential role played by the sea in the preservation and development of species and on account of the importance of sea transport for the harmonious economic development of the Community'.

[840] A resume of the legal texts implemented until 2006 can be seen in Stefan Scheuer (ed), *EU Environmental Policy Handbook...*, 86ff.

[841] Data of the year 2011. Eurostat, 'Archive: Coastal Regions - Population Statistics: Statistics Explained' (*Eurostat*, 16 June 2015) <http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Coastal_regions_-_populationstatistics&oldid=239987> accessed 5 May 2017.

recognised the problem of plastic marine pollution and that at the same time define some goals and targets. Subsequently, we will present legal texts that contain specific measures for EU and Member States to follow in order to achieve the proposed goals on plastic waste and oceans' sustainability. After that we will check if any of the existing pieces of EU legislation should be amended or better enforced and if new regulation is required to fill any gap.

A. Setting Goals and Establishing Commitments

Marine pollution is recognised by the EU as one of the most dangerous form of pollution since 1973.[842] Some of its sources were already identified back then,[843] and plastic was evidently amongst the items lost to the sea. However, it took a while to recognise that marine plastic pollution was an increasing pressure on Europe's marine environment. The first time it was considered a critical issue requiring the adoption of targeted measures was in the Marine Strategy Framework Directive.[844] In fact, this Directive constitutes currently the strongest and potentially the most effective legal tool to tackle marine litter problem.

Knowing it was imperative to reduce the impacts of the highly demand for marine ecological services on marine waters, regardless of where their effects occur,[845] the MSFD established a framework within which EU Member States shall take action to achieve or maintain good environmental status (GES) of their marine waters by 2020. This means that marine waters must provide ecologically diverse and dynamic oceans and seas which are at the same time clean, healthy and productive within their intrinsic conditions, and that the use of the marine environment must be sustainable, thus safeguarding the potential for uses and activities by current and future generations.[846] Consequently, human activities introducing

[842] See the First Programme of Action of the European Communities on the Environment, Chapter 6, Section 1, 23.
[843] In 1973, marine pollution had four main sources: sea transport and navigation; deliberate dumping of waste at sea; exploitation of marine and submarine resources, especially exploitation of the sea bed; and discharge of effluents from land.
[844] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy [2008] OJ L164/19 (Marine Strategy Framework Directive; MSFD), amended by the Commission Directive (EU) 2017/845 of 17 May 2017 [2017] OJ L125/27. The MSFD is the environmental pillar of the Integrated Maritime Policy (COM(2007) 575 final of 15 October 2009) which aims to maximise the sustainable use of the oceans and seas while enabling growth of the maritime economy and coastal regions. As a consequence, it suggests steps against discharges into the sea and planning to reduce the negative environmental impact of economic activities carried out in the marine and coastal areas.
[845] Whereas 2 MSFD.
[846] Article 3(5) MSFD. Detailed criteria in the subparagraphs. See para 1 for *marine waters* definition and para 4 for *environmental status* definition.

substances and energy into the marine environment cannot cause pollution effects.[847] In contrast, all relevant human activities must be carried out in coherence with the following requirements: to protect and preserve the marine environment; to prevent its deterioration; to restore marine ecosystems where practicable; and to prevent and reduce inputs in the marine environment, with a view to phasing out pollution.[848]

GES must be determined according to the eleven qualitative descriptors listed in Annex I of the MSFD. In what concerns plastic waste, GES will be achieved when 'biological diversity is maintained' (descriptor 1), when 'non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems' (descriptor 2), when 'all elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity' (descriptor 4), when 'concentrations of contaminants are at levels not giving rise to pollution effects' (descriptor 8) and when 'properties and quantities of marine litter do not cause harm to the coastal and marine environment' (descriptor 10).[849] Of all these descriptors, we will focus our attention on the last one, and to better understand it we have to know the corresponding criteria and its elements.[850] In summary, by 2020: the composition, amount and spatial distribution of litter – or micro-litter – on the coastline, in the surface layer of the water column, and on the seabed, must be at levels that do not cause harm to the coastal and marine environment;[851] the amount of litter and micro-litter ingested by marine animals must be at a level that does not adversely

[847] The predominant pressures and impacts, including human activity, on the environmental status of marine waters is based on the indicative lists of elements set out in Table 2 of Annex III, and covers the qualitative and quantitative mix of the various pressures (Article 8(1)(b) MSFD). Input of litter (solid waste matter, including micro-sized litter) is particularly mentioned in Table 2a as one of the anthropogenic pressures on the marine environment.

[848] Article 1(2) MSFD.

[849] In this regard, *harm* is divided into three general categories: social (reduction in aesthetic value and public safety), economic (cost to tourism, damage to vessels, fishing gear and facilities, losses to fishery operations, cleaning costs) and ecological (as we saw above in Part I). See Francois Galgani and others, *Marine Strategy Framework Directive - Task Group 10...*, 4.

[850] These elements were published in the Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU [2017] OJ L125/43. This new Decision provides clearer, simpler, more concise, more coherent and comparable set of good environmental status criteria and methodological standards. In truth, the conceptualisation of GES is not a one-off matter, but it will continue to evolve and adapt due to dynamic factors such as ecosystem changes, new scientific knowledge and the development of new technological capabilities.

[851] These are the two primary criteria. The element of D10C1 is litter (excluding micro-litter), classified in the following categories: artificial polymer materials, rubber, cloth/textile, paper/ cardboard, processed/worked wood, metal, glass/ceramics, chemicals, undefined, and food waste. The element of D10C2 is micro-litter (particles <5mm), classified in the categories 'artificial polymer materials' and 'other'.

affect the health of the species concerned;[852] and the number of individuals of each species (birds, mammals, reptiles, fish or invertebrates) which are adversely affected due to litter, such as by entanglement, other types of injury or mortality, or health effects must be catalogued. Threshold values for these levels[853] must be established by Member States through cooperation at Union level, taking into account regional or subregional specificities.

In order to fulfil the purposes specified hereinabove, the MSFD requires Member States to set environmental targets, to develop strategies and to prepare programmes of measures for their marine regions, explaining how they intend to achieve GES.[854] It is thus imperative that Member States establish monitoring programmes for assessment, enabling the state of the marine waters to be evaluated on a regular basis, every six years.[855] Naturally, these programmes must be developed in a coherent and coordinated manner to allow an harmonious implementation of the MSFD, and to fulfil the requirement of regional cooperation. For this reason, it was established a Technical Subgroup on Marine Litter under the Working Group on GES that provide Member States with specifications and standardised methods for monitoring and assessment, plus strong scientific and technical and procedural recommendations to prevent further inputs of litter to, and reducing its total amount in, the marine environment. The reports published by Technical Subgroup on Marine Litter are very complete and useful, whether they provide guidance on monitoring of marine litter,[856] or present the latest figures on marine beach litter items in Europe.[857]

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[852] For secondary criterion D10C3, litter and micro-litter are classified in the categories 'artificial polymer materials' and 'other', assessed in any species from the following groups: birds, mammals, reptiles, fish or invertebrates. We further note that while primary criteria should be used to ensure consistency across the EU, flexibility should be granted with regard to secondary criteria. The use of a secondary criterion should be decided by Member States, where necessary, to complement a primary criterion or when, for a particular criterion, the marine environment is at risk of not achieving or not maintaining good environmental status.

[853] The units of measurement for each criterion are defined in the Commission Decision (EU) 2017/848. Moreover, the use of each criterion in the overall assessment of GES for Descriptor 10 shall be agreed at Union level.

[854] Articles 11, 13 and 17 MSFD. Programmes of measures shall include spatial protection measures, contributing to coherent and representative networks of marine protected areas, adequately covering the diversity of the constituent ecosystems. This way, the MSFD contributes to the realise the objectives of Descriptor 1 and to one of the key objectives of the Convention on Biological Diversity. See Article 13(4) MSFD.

[855] Articles 5 and 13 MSFD.

[856] See Georg Hanke and others, *Guidance on Monitoring of Marine Litter in European Seas* (Publications Office of the European Union, Luxembourg, 2013). This report describes specific protocols and considerations to collect, report and assess data on marine litter, in particular beach litter, floating litter, seafloor litter, litter in biota and micro-litter. Moreover, among other things, it was suggested that: monitoring of marine litter should occur at appropriate spatial and temporal scales; composition of litter in categories indicative of sources should be recorded; more species should be used as a monitor for plastics in the environment; at least four surveys per year in spring, summer, autumn and winter should be organised regarding beach litter; for that purpose, a minimum number of sites that may be representative for a certain length of coast must be considered; shallow sea floor should be sampled annually.

[857] See Anna Maria Addamo, Perrine Laroche, and Georg Hanke, *Top Marine Beach Litter Items in Europe* (Publications Office of the European Union, Luxembourg, 2017). This report provides a pan-European compilation

Furthermore, the MSFD success lays on regional cooperation between Member States and, whenever possible, third countries sharing the same marine region or sub region.[858] The measures required to achieve the objectives of MSFD must be coherent and coordinated.[859] Where practical and appropriate, Member States shall use existing regional institutional cooperation structures, and relevant international forums, including mechanisms and structures of the Regional Sea Conventions, to coordinate actions with third countries having sovereignty or jurisdiction over waters in the same marine region or subregion.[860] In addition, Member States shall consider the implications of their programmes of measures on waters beyond their marine waters in order to minimise the risk of damage to, and if possible have a positive impact on, those waters.[861] At last, the MSFD shall promote the integration of environmental considerations into all relevant policy areas and deliver the environmental

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of information on the most frequent beach litter items, based on existing reports (in particular from Regional Sea Conventions) and an ad hoc analysis of a beach litter data set from the year 2016, in order to support policy actions. In 2016, a total of 355 671 marine litter items were recorded during 679 surveys on 276 European beaches. Harmonised beach litter data set allowed the identification of the most abundant items on EU beaches: 1) plastic/polystyrene pieces 2.5cm > < 50 cm; 2) plastic/polystyrene pieces 0-2.5cm; 3) string and cord (diameter <1cm); 4) cigarette butts and filters; 5) plastic caps and lids (drinks, chemicals, detergents (non-food), unidentified)/plastic rings from bottle caps/lids; 6) cotton bud sticks; 7) paraffin/wax (category: chemicals); 8) crisp packets/sweet wrappers; 9); other plastic/polystyrene items (identifiable); 10) plastic bag (Shopping bags, small plastic bags, e.g. freezer bags, plastic bag collective role; what remains from rip-off plastic bags); 11) other medical items (swabs, bandaging, adhesive plaster etc.) (category: unidentified); 12) other (eg diapers, toilet paper, tissue paper, shaving razors); 13) foam sponge; 14) plastic/polystyrene pieces > 50 cm; 15) bottles incl. pieces (category: glass/ceramic); 16) beverage bottles plastic; 17) knives, forks, spoons, straws, stirrers, (cutlery); 18) nets and pieces of net > 50 cm; 19) sanitary towels/panty liners/backing strips; 20) rope (diameter more than 1cm); and 21) balloons and balloon sticks. The items whose category is not identified, are plastic.

[858] Articles 3(9) and 5(2) MSFD.

[859] Article 5(2) MSFD.

[860] Article 6 MSFD. Action under regional sea agreements would help Member States to implement better their obligations under the MSFD to achieve or maintain GES in the marine environment by 2020. Regional Sea Conventions can support the implementation of the MSFD in at least three main ways: by improving regional and cross-regional coherence of national implementation; by making the Regional Sea Conventions long-standing experience and established structures for cooperation available to increase the efficiency and effectiveness of national implementation; and by offering practical opportunities for the mobilisation and coordination of relevant third countries' activities. Apart from that, the EU is a party to three Regional Sea Conventions and that has officially expressed its wish to become a full Party to the Bucharest Convention. As a result, he EU has been working closely with its neighbours in the four conventions, and in 2017, the first macro-regional Strategy in Europe was designed: the European Union Strategy for the Baltic Sea Region (SWD(2017) 118 final) from 20 March 2017. This Strategy is an agreement between the Member States of the EU and the European Commission to strengthen cooperation between the countries bordering the Baltic Sea in order to meet the common challenges and to benefit from common opportunities facing the region. This Strategy is also welcoming cooperation with EU neighbouring countries (Russia, Iceland, Norway and Belarus).

[861] Articles 2(1) and 13(8) MSFD. Over and above these, if a Member State considers that the management of a human activity at Community or international level is likely to have a significant impact on the marine environment, the Member State shall, individually or jointly, accordingly with Article 13(5), 'address the competent authority or international organisation concerned with a view to the consideration and possible adoption of measures that may be necessary in order to achieve the objectives of this Directive, so as to enable the integrity, structure and functioning of ecosystems to be maintained or, where appropriate, restored'.

pillar of the future maritime policy for the EU, thus fulfilling the environmental principle of integration.[862]

Finally, in 2013, it was developed a regulatory framework strengthening the position of EU and pointing the way ahead in relation to marine litter and other decisive matters. Of the nine priority objectives defined by the Seventh Environment Action Programme (7th EAP)[863] to be attained over the period up to 2020, the first three are the most effective in tackling marine plastic pollution: 1) to protect, conserve and enhance the Union's natural capital; 2) to turn the Union into a resource-efficient, green and competitive low-carbon economy; and 3) safeguarding the Union's citizens from environment-related pressures and risks to health and well-being.[864] Regarding the first objective, the EU assumed greater responsibilities for ensuring marine environment protection given that it has the world's largest maritime territory. As a consequence, by 2020, the impact of pressures on marine and freshwaters must be significantly reduced to achieve or maintain GES and coastal zones should be managed sustainably.[865] This requires, in particular: 'combating pollution and establishing a Union-wide quantitative reduction headline target for marine litter supported by source-based measures and taking into account the marine strategies established by Member States'; and 'enhancing Union public information provision, awareness and education on environment policy'.[866]

The second priority objective was particularly built upon the Roadmap to a Resource Efficient Europe,[867] and so it supports the shift towards an economy that is efficient in the

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862 Whereas 6 and Article 1(4) MSFD.
863 The 7th EAP is annexed to Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' [2013] OJ L354/171.
864 These objectives are inter-related and should be pursued in parallel. Their effective implementation will depend on the success of the horizontal measures that were also defined as priority objectives in the 7th EAP. They are: 4) to maximise the benefits of Union environment legislation by improving implementation; 5) to improve the knowledge and evidence base for Union environment policy; 6) to secure investment for environment and climate policy and address environmental externalities; and 7) to improve environmental integration and policy coherence.
865 Points 21 and 28(b) and (c) 7th EAP.
866 Points 28(iii) and (ix) 7th EAP.
867 The Roadmap to a Resource Efficient Europe (COM(2011) 571) resulted from the Europe 2020 Strategy and its flagship initiative on 'A Resource Efficient Europe' (COM(2011) 21). It was developed taking into consideration the following vision for the year 2050: EU's economy has grown in a way that respects resource constraints and planetary boundaries; a competitive and inclusive economy provides a high standard of living with much lower environmental impacts, since all resources are sustainably managed, from raw materials to energy, water, air, land and soil; climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored. Necessarily, the roadmap proposed ways to increase resource productivity and decouple economic growth from resource use and its environmental impacts: give higher priority to prevention, then to re-use and recycling; product design integrating a life-cycle approach; better cooperation along all market actors along the value chain; better collection processes; incentives for waste prevention and recycling,

way it uses all resources, that decouples economic growth from resource and energy use and its environmental impacts, that reduces dependence on imports of raw materials, and that at the same time, enhances competitiveness through efficiency and innovation and promotes greater energy and resource security, including through reduced overall resource use.[868] Implementing this requires, in first place, the establishment of a more coherent policy framework for sustainable production and consumption. Particularly, it requires the application of structural changes in production, technology and innovation (lifecycle approach, eco-design and eco-labelling), as well as the transformation of consumption patterns and lifestyles, through policies that foster not only the availability, affordability, functionality and attractiveness of environmentally sustainable products and services, but also the product durability, reparability, re-usability, recyclability, recycled content and product lifespan.[869]

In second place, it requires the full implementation of EU waste legislation, especially of the waste hierarchy and the effective use of market-based instruments. This and other measures must ensure that: prevention is privileged, likewise extended producer responsibility; landfilling is limited to non-recyclable and non-recoverable waste; energy recovery is limited to non-recyclable materials; recycled waste is used as a major, reliable source of raw material for the EU; only non-toxic material cycles are developed; hazardous waste is safely managed and its generation is reduced; illegal waste shipments are eradicated, with the support of stringent monitoring; and high quality recycling is ensured.[870]

At last, the third priority objective is referred herein because one of its main aims is to ensure, by 2020, the minimisation of exposure to endocrine disruptors, as the ones contained in thermosetting or thermoplastic polymers, in products, substances and mixtures. Other important measures to ensure by 2020 are that: REACH continues to be implemented;[871] REACH candidate list includes all relevant substances of very high concern,

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as well as public investments in modern facilities for waste treatment and high quality recycling. Concerning marine litter, the Roadmap assured that the Commission should contribute to marine litter strategies in all four EU marine regions in close collaboration with coastal Member States or in the respective Regional Seas Convention, and concluded that Member States should implement the MSFD and designate marine protected areas.

868 Point 29 7th EAP. Point 35 adds that consumers should receive accurate, easy to understand and reliable information about the products they purchase (through clear and coherent labelling, including in relation to environmental claims), that packaging should be optimised to minimise environmental impacts, and that resource efficient business models such as product service systems, including leasing of products, should also be supported.

869 Points 36 and 43(c) and (v) 7th EAP.

870 Points 39, 40 and 43(viii) 7th EAP.

871 Regulation (EC) 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) [2006] OJ L396/1.

including substances with endocrine-disrupting properties; the combination effects of chemicals and safety concerns related to endocrine disruptors are effectively addressed in all relevant EU legislation, and risks for the environment and health, in particular in relation to children, associated with the use of hazardous substances, including chemicals in products, are assessed and minimised; sustainable substitutes including non-chemical solutions are developed; chemicals in products, including, inter alia, imported products, with a view to promoting non-toxic material cycles are reduced, likewise indoor exposure to harmful substances.[872] This way, the reduction of hazardous substances in plastics will protect human health and animals' integrity, and promote more recycling and with greater quality.

Besides the implementation of the existing legal mechanisms, the 7th EAP requires also its review, whether it concerns product, waste or chemicals in substances. Similarly, up to date, realistic and achievable targets must be developed, as well public information campaigns to build awareness and understanding of waste policy and to stimulate a change in behaviour.

Overall, the 7th EAP shall contribute in the long-term to a high level of environmental protection and to an improved quality of life and well-being for citizens, at the same time that economic and social progress is achieved within the carrying capacity of the Earth, by increasing understanding of planetary boundaries.[873] Along the way, the principles of prevention, correction at source and polluter-pays must be always fully considered.[874]

As we could see, marine litter is currently listed as a priority in the EU environmental policy and most of all strong guidelines to tackle the problem were already designed. We will now look at specific measures, actions and targets that can fulfil all the aims and objectives outlined.

[872] Points 50 and 54(d) and (iv) 7th EAP.
[873] Article 2(3) Decision No 1386/2013/EU and Point 106(viii) 7th EAP.
[874] Article 2(2) Decision No 1386/2013/EU.

B. Levels of Solutions

a. Plastic Waste, a Resource

Earth's resources are not endless, but for a while humanity acted like they were. Knowing that the demand for finite and sometimes scarce resources will not slow down, it is necessary to change what has been the traditional approach to growth and prosperity – the linear economy based on pattern of growth *take-make-consume and dispose*. Currently, we are not only using more resources than our planet can produce in a given time. Significant losses of materials and massive environmental pollution, causing degradation and fragility, are also costs of choice that the industry has made for many years.

Valuable materials are leaking from our economies. So, besides losing material, we are losing money too. Today, 95% of the value of plastic packaging material, ie between 70 and 105 billion euros annually, is lost to the economy after a very short first-use cycle.[875] With respect to the impacts of resource use, they can arise at all stages in the life-cycle of the product, including extraction and initial processing, transformation and manufacturing, consumption or use and, finally, waste management. If we focus on waste management, we have necessarily to highlight methane emissions from landfills, energy-related GHG emissions from collection and transport of waste, and emissions from waste incineration and recycling plants. Another aspect to underline is that the benefit from the energy recovery in landfills is much smaller than the corresponding benefit from material recovery: the avoided emissions from recycling constitute almost 75% of the total avoided emissions.[876] It is no coincidence that recycling is the main cause of the rapid decrease in net life-cycle GHG emissions from municipal waste management after the year 2000. The shift of municipal waste management up the waste hierarchy will not only reduce dependence on the extraction of fossil fuels for plastics production, as it will also cut net emissions, as it has been happening: from 67 Mt CO2-equivalent in 2001 to 29 Mt CO2-equivalent in 2010 – a reduction of over 56%.[877]

[875] World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, *The New Plastics Economy...,* 17.
[876] EEA, *Managing Municipal Solid Waste...,* 28.
[877] Ibid.

In essence, we need to reduce the amount of materials we extract – or import –[878] and the amount of waste we generate. How do we do that? We create a resource-efficiency and recycling society, anchored in a circular economy, which means closing the loop between our *endless* resource frontier, which is now increasingly under strain and showing its limits, and our growing needs for human welfare. In other words, it is imperative to decouple economic growth from resource use and environmental impacts.

i. Action Plan for the Circular Economy

In December 2015, the European Commission adopted an EU Action Plan for a Circular Economy.[879] There, plastics were identified as a key priority and the European Commission committed itself to 'prepare a strategy addressing the challenges posed by plastics throughout the value chain and taking into account their entire life-cycle'.

The plan includes comprehensive commitments on eco-design, the development of strategic approaches on plastics and chemicals, a major initiative to fund innovative projects under the umbrella of the EU's Horizon 2020 research programme,[880] and targeted action in key areas, where plastics is considered. To achieve these commitments, 54 actions at EU level, supporting the circular economy in each step of the value chain – from production to consumption, repair and remanufacturing, waste management, and secondary raw materials that must fed back into the economy – were outlined. It was even noted that reaching a circular economy will require long-term involvement at all levels, from Member States, regions and cities, to businesses and citizens and that it will have to be developed globally. Our analysis of the Action Plan will only contemplate, and not exhaustively, the actions

[878] This is a particular problem for the EU which is highly dependent on imported raw materials and fossil fuels. See European Commission, 'Being Wise with Waste: the EU's Approach to Waste Management' (Luxembourg, 2010) 2.
[879] COM(2015) 614 final.
[880] Horizon 2020 is the financial instrument implementing the Innovation Union More than that, is the biggest EU Research and Innovation programme ever with nearly 80 billion euros of funding available over seven years (2014 to 2020). The Innovation Union is one of the seven flagship initiatives of the Europe 2020 strategy for smart, sustainable and inclusive growth, that was implemented in 2010, for the period of ten years, as a way to overcome the structural weaknesses in Europe's economy, improve its competitiveness and productivity and underpin a sustainable social market economy. Specifically, the Innovation Union plan contained over 30 action points and aimed to do three things: make Europe into a world-class science performer; remove obstacles to innovation like expensive patenting, market fragmentation, slow standard-setting and skills shortages; and revolutionise the way public and private sectors work together, notably through Innovation Partnerships between the European institutions, national and regional authorities and business.

proposed that have more to do with plastic pollution and the necessity to avoid plastic leakage into the ocean.

Production was logically the first topic addressed. Indeed, a circular economy starts at the very beginning of a product's life. Both the design phase and production processes have an impact on sourcing, resource use and waste generation throughout a product's life.[881] On design, the European Commission must: promote the reparability, upgradability, durability, and recyclability of products by developing product requirements relevant to the circular economy in its future work under the Ecodesign Directive, as appropriate and taking into account the specificities of different product groups;[882] and include economic incentives for better product design through provisions on extended producer responsibility in the revised legislative proposals on waste – which actually happened, as we will see in the chapter on plastic waste management.

Consumption assumes greater relevance, since the choices made by millions of consumers can support or hamper the circular economy. Their choices are shaped among others by the information to which consumers have access, but the European Commission is aware that not all green claims meet legal requirements for reliability, accuracy and clarity. Therefore, it will work towards better enforcement of the guarantees on tangible products, examine possible options for improvement, and tackle false green claims.[883] If it succeeds, then consumers will actually believe in labels stating that a certain product is made with recycled plastic or that is does not contain micro beads. During consumption, consumers face many challenges, and these days, it is almost impossible to anticipate if a product's lifetime can be extended through reuse and repair, hence avoiding wastage. Currently, certain

[881] On production processes, is pointed out that even for products or materials designed in a smart way, inefficient use of resources in production processes can lead to lost business opportunities and significant waste generation. Loss of raw materials, as happens with industrial pellets, is not an issue. Herein, the concerns are the promotion of sustainable sourcing of raw material globally (for example through policy dialogues, partnerships and its trade and development policy), the application of best practices in a range of industrial sectors through the 'best available technique reference documents' that Member States have to reflect when issuing permit requirements for industrial installations, and the implementation of best practices on mining waste.

[882] Electrical and electronic products are particularly significant in this context. Their reparability can be important to consumers, and they can contain valuable materials that should be made easier to recycle (eg rare earth elements in electronic devices).

[883] At least, there is, since 1992, an EU Ecolabel Initiative. Recognised across Europe and worldwide, it is a label of environmental excellence that is awarded to products and services meeting high environmental standards throughout their life-cycle: from raw material extraction, to production, distribution and disposal. The EU Ecolabel promotes the circular economy by encouraging producers to generate less waste and CO2 during the manufacturing process. The EU Ecolabel criteria also encourages companies to develop products that are durable, easy to repair and recycle, as is the case of the computers whose durability is increased through upgrades. See European Commission, 'Plastic Waste: Ecological and Human Health Impacts'..., 29.

products cannot be repaired because of their design, or because spare parts or repair information are not available. Besides the actions referred above on eco-design of products, the Commission will prepare an independent testing programme under Horizon 2020 to help the identification of issues related to possible planned obsolescence. Achieve this, will help to reduce a lot of electrical and electronic waste, which have a lot of plastic in their composition. Another measures that can support the development of the circular economy, and at the same time contribute to prevent the generation of waste, particularly plastic, are the introduction of innovative forms of consumption (eg sharing products or infrastructure (collaborative economy), consuming services rather than products, or using IT or digital platforms) and Green Public Procurement (Europe's public authorities must use their purchasing power to choose environmentally friendly goods, services and works, making this way an important contribution to sustainable consumption and production). The European Commission will support these new business and consumption models through Horizon 2020 and through Cohesion Policy funding, and will take action on Green Public Procurement, by emphasising circular economy aspects in new or revised criteria, supporting higher uptake of GPP, and leading by example in its own procurement and in EU funding.

Waste management plays a central role in the circular economy, but it will be analysed in its own chapter, mostly because the revised legislative proposals on waste are already in force and deserve to be analysed separately.

Plastic was identified in this Action Plan as a sector facing specific challenges in the context of the circular economy, in particular because of the specificities of its products or value-chains, and its environmental footprint. It was recognised that it needed to be addressed in a targeted way, to ensure that the interactions between the various phases of the cycle were fully taken into account along the whole value chain. Therefore, the European Commission committed itself to adopt a strategy on plastics in the circular economy, addressing issues such as recyclability, biodegradability, the presence of hazardous substances of concern in certain plastics, and marine litter.

In short, transition to a more circular economy requires changes throughout value chains, from product design to new business and market models, from new ways of turning waste into a resource to new modes of consumer behaviour. This implies full systemic change, and innovation not only in technologies, but also in organisation, society, finance methods and policies.

ii. European Strategy for Plastics

Finally, in January 2018, the European Commission published A European Strategy for Plastics in a Circular Economy,[884] where the EU was recognised as the best place to lead the transition to plastics of the future. Thus, the aim of this strategy – whose motto is turning challenges into opportunities – is to lay the foundations to a new plastics economy, where the design and production of plastics and plastic products fully respect reuse, repair and recycling needs, and more sustainable materials are developed and promoted.

The strategic vision presented in this document set out what a circular' plastics economy could look like in the decades ahead, and provided as well the elements to turn the vision into reality. That will require not only actions from the EU, but also from all players in the plastic value chain (from plastic producers and designers, through brands and retailers, to recyclers), and from the civil society, the scientific community, governments, and national and regional authorities. The vision is therefore divided in two parts: the first dedicated to a smart, innovative and sustainable plastics industry; and the second, focused on more sustainable and safer consumption and production patterns for plastics.

In the first part, the following key commitments were defined: design plastics and products containing plastics in a way that allows greater durability, reuse and high-quality recycling, allowing in particular that by 2030 all plastics packaging placed on the EU market is either reusable or can be recycled in a cost-effective manner; achieve higher plastic recycling rates for all key applications, ensuring that by 2030 more than half of plastics waste generated in Europe is recycled; achieve very high levels in separate collection of plastic waste; extend and modernise considerably the EU plastics recycling capacity, guaranteeing that by 2030, sorting and recycling capacity has increased fourfold since 2015, leading to the creation of 200,000 new jobs, spread all across Europe; phase out the exportation of poorly sorted plastics waste and transform recycled plastics in an increasingly valuable feedstock for industries, both at home and abroad; phase out or replace substances hampering recycling processes; establish successfully a market for recycled and innovative plastics, assuring that demand for recycled plastics in Europe will grow four-fold, and provide a stable flow of revenues for the recycling sector and job security for its growing workforce; reduce Europe's dependence on imported fossil fuel and cut CO_2 emissions; and develop and used innovative

[884] COM(2018) 28 final.

materials and alternative feedstocks for plastic production whenever there is clear evidence that they are more sustainable compared to the non-renewable alternatives.

In turn, in the second part it is foreseen that in a near future the following ideas and facts become real: citizens are aware of the need to avoid waste, and make choices accordingly; consumers, as key players, are incentivised, made aware of key benefits and thus enabled to contribute actively to the transition, especially because better designed and innovative products have emerged to offer more sustainable consumption patterns; many entrepreneurs see the need for more resolute action on plastics waste prevention as a business opportunity, and increasingly new companies emerge to provide circular solutions, such as reverse logistics for packaging or alternatives to disposable plastics; the leakage of plastics into the environment decreases drastically, and marine litter from sea-based sources are significantly reduced; cleaner beaches and seas foster activities such as tourism and fisheries, and preserve fragile ecosystems; innovative solutions are developed to prevent microplastics from reaching the seas, and public authorities are working together to prevent them from ending up in our oceans and our air, drinking water or on our plates; best practices are disseminated widely, scientific knowledge improves, citizens mobilise, and innovators and scientists develop solutions that can be applied worldwide.

To help achieve any and all of these commitments, it was created an ambitious set of measures regarding four different themes: improving the economics and quality of plastics recycling; curbing plastic waste and littering; driving investment and innovation towards circular solutions; and harnessing global action.[885] In summary, in relation to the first theme, key players must improve design and support innovation to make plastics and plastic products easier to recycle, expand and improve the separate collection of plastic waste to ensure quality inputs to the recycling industry, expand and modernise the EU's sorting and recycling capacity, and create viable markets for recycled and renewable plastics. Particular importance must be given to plastic packaging when it comes to design for recyclability.[886] It has even been calculated that design improvements could halve the cost of recycling plastic packaging

[885] See Annexes I and II of the European Strategy for Plastics in a Circular Economy. Annex I includes a list of future EU measures to implement the Strategy and their timeline, and since common efforts are required of all the key players, Annex II presents a list of measures recommended to national authorities and industry.

[886] There are also another significant sources of plastics waste that could be recycled: construction, automotive, furniture and electronics. However, only in very few cases it is possible to know about the presence of chemicals of concern that create major obstacles to achieving higher recycling rates. The European Commission is proposing to accelerate work in order to identify possible ways to make chemicals easier to trace in recycled streams, and to make it simpler to process or remove during recycling, thus ensuring a high level of health and environmental protection.

waste.[887] It is imperative that design issues are addressed far more systematically, and that at the same time the internal market is preserved. Therefore, the European Commission will work on a revision of the essential requirements for placing packaging on the market, look into ways of maximising the impact of new rules on extended producer responsibility, support the development of economic incentives to reward the most sustainable design choices, and develop product requirements under the Ecodesign Directive[888] that take account of circular economy aspects, including recyclability.[889] In addition, the European Commission will have to boost the demand for recycled plastics. That is essential not only because the EU aims to became resource efficient, but also because of recent developments in international trade, restricting key export routes for plastics waste collected for recycling.[890] Currently, in the EU, uptake of recycled plastics in new products is low and often remains limited to low-value or niche applications. In fact, there are a lot of uncertainties concerning market outlets and profitability, which causes plastics to be recycled only by small and predominately regional facilities. More scale and standardisation would support smoother market operation. It is definitely time to promote a greater integration of recycling activities into the plastics value chain and ask plastics producers in the chemical sector for advice on how to reach higher quality standards (eg for food grade applications) and aggregate offer for recycled feedstock. Due to the resistance to change among product manufacturers and due to the lack of knowledge of the additional benefits of closed-loop recycled plastics, the European Commission decided to: contribute directly to increased uptake of recycled plastics; finance research and innovation projects on better identification of contaminants and on decontamination of plastic waste through Horizon 2020; and launch an EU-wide pledging campaign,[891] addressed to both private and public actors, to ensure that by 2025, ten million tonnes of recycled plastics find their way into new products on the EU market.

The best manner to curb plastic waste and littering – the second theme – is to apply extended producer responsibility schemes. They have been proven effective in several

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[887] See World Economic Forum, Ellen MacArthur Foundation, and SYSTEMIQ, *The New Plastics Economy: Catalysing Action* (2017), available at <www.ellenmacarthurfoundation.org/publications>.
[888] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 Establishing a Framework for the Setting of Ecodesign Requirements for Energy-related Product [2009] OJ L285/10.
[889] The Commission has already proposed mandatory product design and marking requirements to make it easier and safer to dismantle, reuse and recycle electronic displays (eg flat computer or television screens). It has also developed criteria to improve recyclability of plastics in its Ecolabel and Green Public Procurement criteria (eg marking large plastic parts to facilitate sorting, designing plastic packaging for recyclability, and designing items for easy disassembly in furniture and computers).
[890] We recall China's recent announcements of its decision to ban import of certain types of plastic waste.
[891] The details are presented in Annex III of the European Strategy for Plastics in a Circular Economy.

countries, specifically targeted deposit schemes have helped them to achieve high collection rates for beverage containers.[892] Unfortunately, as it is stated, there is no clear incentive for consumers and producers to switch to solutions that would generate less waste or litter. On the other hand, the EU has made some positive efforts and will continue.[893] The European Commission will, among others, explore the feasibility of introducing measures of a fiscal nature at the EU level, look into the issue of over-packaging as part of the future review of the essential requirements for packaging. To reduce discharges of waste by ships, the Commission presented a legislative proposal on port reception facilities,[894] and in the future it will also develop targeted measures for reducing the loss or abandonment of fishing gear at sea,[895] and study the contribution of aquaculture to marine litter and examine a range of measures to minimise plastic loss from aquaculture. Finally, it will continue its work to improve understanding and measurement of marine litter, an essential but often neglected way to support effective prevention and recovery measures. As a complement to these preventive measures, action to retrieve some of the plastics floating in the oceans and innovative technologies for retrieval are supported by EU funds. Another way to curb plastic waste is to establish a clear regulatory framework for plastics with biodegradable properties, assuring this way that consumers are provided with clear and correct information, and that biodegradable plastics are not put forward as a solution to littering.[896] As regards to microplastics, the Member States are further ahead than the EU. While the first have already taken action to restrict their use, the Commission has only started the process to restrict the use of intentionally added microplastics, by: requesting the European Chemicals Agency to

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[892] According to the Strategy, the five best performing Member States with deposit schemes for PET bottles (Germany, Denmark, Finland, the Netherlands and Estonia) reached an average collection rate for PET of 94% in 2014.

[893] The EU has already elaborated the MSFD, cut the consumption of plastic bags, revised legislative proposals on waste, and initiated the revision of the Drinking Water Directive (Council Directive 98/83/EC of 3 November 1998 on the Quality of Water Intended for Human Consumption [1998] OJ L330/32), to promote access to tap water for EU citizens, therefore reducing packaging needs for bottled water. The criteria for the Ecolabel and Green Public Procurement also promote reusable items and packaging.

[894] This proposal contains measures to ensure that waste generated on ships or gathered at sea is delivered on land and adequately managed.

[895] Possible options to be examined include deposit schemes, extended producer responsibility schemes and recycling targets.

[896] It happens that most currently available plastics labelled as biodegradable generally degrade under specific conditions that are not always easy to find in the natural environment, and can thus still cause harm to ecosystems. Therefore, in addition to clarifying which plastics can be labelled *compostable* or *biodegradable* and how they should be handled after use, the European Commission will also develop lifecycle assessment to identify the conditions under which the use of biodegradable or compostable plastics is beneficial, and the criteria for such applications.

review the scientific basis for taking regulatory action at EU level; promoting research to develop innovative solutions to prevent their dissemination, through for instance improve the capture of microplastics in waste water treatment plants, as well as design targeted measures for each source; and monitoring microplastics in drinking water, where their impact on human health is still unknown.

The third and the fourth themes stand for supportive measures that are central and essential to achieve the previous two. They concern investments both in innovation and infrastructures, and international cooperation. Therefore, the EU must create an enabling framework for investment and innovation,[897] and the European businesses need to invest in the future and affirm their leadership in the modernisation of the plastics value chain. Moreover, the EU will continue to support international action, promote best practices worldwide, and use its external funding instruments to support improved waste prevention and management around the world.[898] International engagement will be necessary to drive change outside Europe's borders, which is of great significance since the EU is highly committed to reaffirming its leadership in global solutions and helping make the transition towards a low-carbon and circular economy, while providing citizens with a cleaner and safer environment.

In view of the exposed, there can be no doubt that this Strategy has huge potential and must therefore be taken seriously. The benefits are several, even also for those who are profit oriented: curb plastic pollution and its adverse impact on our lives and the environment; provide a fertile ground for social innovation and entrepreneurship, creating a wealth of

[897] In fact, Deloitte enlightened in the *Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment*, from 2015, that to meet the goals on plastics recycling alone will require an estimated additional investment of between 8.4 and 16.6 billion euros. So far, Horizon 2020 has provided over 250 million euros to finance research and development in areas of direct relevance to the strategy. About half has been used to help develop alternative feedstocks. In the run-up to 2020, an additional 100 million euros will be devoted to financing priority measures, including developing smarter and more recyclable plastics materials, making recycling processes more efficient, and tracing and removing hazardous substances and contaminants from recycled plastics. Finally, the Commission will develop a Strategic Research and Innovation Agenda on plastics to provide guidance for future research and innovation funding after 2020.

[898] In particular, the Commission will continue to make use of policy dialogues on environment and industry and dialogues under free trade agreements, and to actively cooperate in Regional Sea Conventions. It will also take an active part in the working group established by the United Nations Environment Assembly in December 2017 to work on international responses for combating plastic marine litter and microplastics. In 2018, the Commission will launch a dedicated project to reduce plastic waste and marine litter in East and South East Asia, where the problem is growing fast. It will also examine possible ways to take action to reduce plastic pollution in the Mediterranean, in support of the Barcelona Convention, and in major world river basins, as a vast proportion of waste plastic is carried by rivers before it reaches the seas. Finally, the Commission will facilitate the cooperation of the outermost regions of the EU with their neighbours along the Caribbean Sea, the Indian, Pacific and Atlantic Oceans across different fields, including in waste management and recycling.

opportunities for all Europeans; transform EU in a modern, low-carbon, resource and energy-efficient economy society; and make a tangible contribution to reaching the 2030 Sustainable Development Goals and the Paris Agreement. It is not a complete vision or document, but due to the extension of the problem, no unique instrument will ever be enough. Even though, it comprises the most comprehensive, solid and promising approach ever made with the purpose to reach the solutions. The EU is taking a leading role in a global dynamic, with countries engaging and cooperating to halt the flow of plastics into the oceans, and assuredly with decisive and concerted efforts, the EU can turn challenges into opportunities and set the example for resolute action at global level.

Final Note

We are totally aware that we failed to present the analysis of important and crucial issues, such as waste management and the immense potential contained in several waste directives after the amendments introduced in July 2018. Other EU initiatives and directives are missing too. However, the study we conducted allowed us to design a Global Strategy to Combat Marine Plastic Pollution, divided in two parts: before plastic waste leakage; and sea restoration. The first included, the following logic steps: prevention; behavioural change; knowledge and technology; law enforcement, update and monitoring; sustainable production; economic (market-based) instruments; and environmentally sound waste management.

The investigation on marine plastic pollution will continue, because for us this is not *just* a master thesis. It is a choice we assumed as a personal and professional project, and will go on for many years.

Abbreviations

AFR	Africa Region
ARPH	Annual Review of Public Health
ARS	Annual Review of Sociology
BC	Biological Conservation
CBD	Convention on Biological Diversity
CJEU	Court of Justice of the European Union
COP	Convention of the Parties
DEHP	Bis(2-ethylhexyl) Phthalate
DMP	Dess–Martin Periodinane
EAP	EU Environment Action Programme
EAPR	East Asia and Pacific Region
ECA	Europe and Central Asia Region
EEA	European Environment Agency
EEC	European Economic Community
EEE	Electrical and Electronic Equipment
EEZ	Exclusive Economic Zone
ELV	End of Life Vehicles
EoW	End-of-waste
EPA	USA Environmental Protection Agency
EPR	Extended Producer Responsibility
ESP	Environmental Science & Policy
EST	Environmental Science & Technology
FAO	Food and Agriculture Organisation of the United Nations
FhG-IBP	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.
GES	Good Environmental Status
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Env. Protection
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
GPML	Global Partnership on Marine Litter
HDI	Human Development Index

HDPE	High-Density Polyethylene
IAEA	International Atomic Energy Agency
ICT	Information and Communications Technology
IGR	Intergovernmental Review Meetings
IMF	International Monetary Fund
IMO	International Maritime Organisation
IOC	Intergovernmental Oceanographic Commission of UNESCO
IPCC	Intergovernmental Panel on Climate Change
ISA	International Seabed Authority
IUCN	International Union for the Conservation of Nature
JPE	Journal of Political Economy
LAC	Latin America and the Caribbean Region
LDPE	Low-Density Polyethylene
LoW	European List of Waste
MAP	Mediterranean Action Plan
MARPOL	International Convention for the Prevention of Pollution from Ships
MENA	Middle East and North Africa Region
METAP	Mediterranean Environmental Technical Assistance Programme
MPB	Marine Pollution Bulletin
MSFD	Marine Strategy Framework Directive
MSW	Municipal Solid Waste
NOAA	National Oceanic and Atmospheric Administration
OECD	Organisation for Economic Cooperation and Development
OED	Oxford English Dictionaries
OJ	Official Journal of the European Communities
OUP	Oxford University Press
PAHO	Pan-American Health Organisation
PCB	Polychlorinated Biphenyls
PE	Polyethylene
PET	Polyethylene Terephthalate
PFC	Polyfluorinated Compounds
PMMA	Polymethyl Methacrylate
POPs	Persistent Organic Pollutants
PP	Polypropylene
PPWD	Packaging and Packaging Waste Directive
PTRSB	Philosophical Transactions of the Royal Society B: Biological Sciences
QJE	Quarterly Journal of Economics

RAP	Regional Action Plan
REVEH	Reviews on Environmental Health
RSP	Regional Seas Programme
SAR	South Asia Region
TFEU	Treaty on the Functioning of the European Union
TEU	Treaty on European Union
UMP	University of Minneapolis Press
UNCLOS	United Nations Convention on the Law of the Sea
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNIDO	United Nations Industrial Development Organisation
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive
WHO	World Health Organisation
WMO	World Meteorological Organisation
WTE	Waste-to-energy
WWF	World Wild Fund for Nature
WWTPs	Wastewater Treatment Plants

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