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« The impact of plastic pollution in the marine environment»

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Abstract

It is actually a fact that human activities in the oceans have increased significantly in recent decades. The expansion of coastal and marine activities has undoubtedly adversely affected the marine environment while fundamentally affecting ecosystem goods. In addition, coastal and marine human activities have generated significant amounts of waste and marine litter, which may contaminate the marine environment.

The plastics are synthetic polymers and have been used for over a century. It is a material consisting of a wide range of synthetic or semi-synthetic organic compounds that are flexible and can be molded into solid objects. Plastics are produced by converting natural products or by synthesis from primary chemicals, generally from oil, natural gas or coal. The majority of marine microplastics come from rivers and estuaries. The main sources refer to runoff from urban areas, inflows from treatment plants sewage, sewage system overflow and from industrial inputs that contribute to the composition of river water.

One of the most important measures to deal with marine pollution from plastics is to raise the awareness of all involved entities, “players” of the plastic industry and fishing and consumers - citizens, about the consequences of this environmental problem. Public awareness is an integral part of primary prevention strategies and aims on the one hand to reduce plastic waste in aquatic ecosystems, and on the other hand to ecologically awaken and activate the individual. The education of both professionals and citizens is the first component of programs aimed at reducing marine plastic waste. Undoubtedly, however, changing attitudes and behaviors is not an easy task, especially when it conflicts with existing and established social norms, knowledge and habits.

Key Words: Plastic, Marpol, Pollution, EMSA, Framework

1st Chapter – Introduction

It is actually a fact that the plastics and microplastics are now a daily part of people's lives in modern societies. It is estimated that approximately 27 million tons of plastics are produced only in the European Union where approximately 32.4% of them are recycled while the remaining 67.6% remains as waste which ends up in landfills and mainly in the marine environment. Plastic is defined as the synthetic organic polymer that comes from the polymerization of monomers derived from natural gas and oil, while microplastics are defined as the very small pieces of plastic with a size of up to 5 mm that are not visible to the naked eye (UNEP, 2016).

It is also a fact that human activities in the oceans have increased significantly in recent decades. The expansion of coastal and marine activities has undoubtedly adversely affected the marine environment while fundamentally affecting ecosystem goods. In addition, coastal and marine human activities have generated significant amounts of waste and marine litter, which may contaminate the marine environment.

Much of this waste will remain in the sea for years, decades or even centuries. On average, three-quarters of all marine litter is made up of plastics that are known to be highly durable. The occurrence of marine debris has been shown worldwide to exist in gyrating (rotating) ocean currents, on shores, in sediments and in deep water. Waste accumulates in both densely populated areas and remote areas such as Antarctica (Barnes et al., 2009). In particular, every year, very large amounts of plastics end up in the aquatic environment, which results in the challenge, due to of their accumulation, particularly burdensome consequences for the environment and marine life.

As early as 1970, the accumulation of large parts of plastics in the marine environment has been observed internationally, with the result that the research community, especially in the last decade, has been intensely concerned with the way they are transported, their fate and the consequent effects on the marine environment. Plastics enter the aquatic environment in various sizes. For the largest and most frequently used of these, it is not possible to completely remove them, but they are crushed into microplastics. The reasons why this happens are varied and are indicative, the exposure of plastics to ultraviolet (UV) radiation, their mechanical stress due to waves, wind or sand, their exposure to extreme temperatures, as well as the existence of biological action mechanisms.

For example, high density polyethylene (HDPE) which is one of the most commonly used high molecular weight polymers, exhibits excellent resistance to most biotic and industrial chemicals and can resist corrosion and dissolution by strong oxidants, acid salts and organic solvents. This results in it being difficult to degrade except through normal aging, while the actual time required for polyethylene to completely degrade in the marine environment remains unknown.

In the context of this research, the issue of plastics and microplastics in the marine environment will be analyzed and the very big challenges related to this development at the level of protection of the marine environment. As for the research methodology, secondary research was used, specifically literature research. Within its framework, the researcher identified, studied, analyzed, criticized and presented positions and data from published texts concerning the issue under analysis. Secondary sources describe, summarize, or discuss information or details originally presented in other primary sources.

Thus, the researcher uses primary sources to gain an overview of the topic under study and/or to identify primary resources. Examples of secondary sources are, publications such as books, journal articles, book reviews, commentaries, encyclopedias, journals, annual reviews, scholarly review articles, dictionaries, textbooks, etc. (Wade, & Hulland, 2004). The results of the whole investigation showed that the problem of the accumulation of plastics and microplastics in Greece is very big. Marine litter, and especially plastics, which are the most important environmental problem for the world's oceans in the 21st century, are also an important environmental problem in the case of Greece.

2nd Chapter – MARPOL Annexes / Current Regulation

2.1 MARPOL Annex About Plastic Pollution from Ships

Marpol is the combination of the two treaties adopted by the IMO in 1973 and 1978, while modifications and changes have taken place since its adoption until today. The Marpol Convention is an international convention that covers and regulates the prevention of marine pollution due to accidents such as collision, collision, grounding, but also operational procedures on the ship such as loading and unloading of oil, fuel collection, fuel management, The purpose of the contract is to prevent and deal with oil pollution, liquid noxious substances in bulk, harmful substances in packaged form, ship effluent, waste and air pollutants, by establishing specific technical standards (EMSA, 2016).

The convention was first adopted on November 2, 1973 by the IMO and mainly concerned pollution from petroleum, chemicals, packaged substances, waste and sewage. However, due to increased accidents in the period 1976-1977, the International Conference on Tank Safety was closed. The prevention of marine pollution in February 1978. The Marpol Convention had not yet entered into force and thus the 1978 Convention absorbed the first Convention and their combination created the new MARPOL 73/78 Convention which entered into force on 2 October 1983. The Marpol Convention consists of the following parts:

- ✓ 1973 International Convention for the Prevention of Marine Pollution and the
- ✓ 1978 Protocol to the 1973 International Convention for the Prevention of Marine Pollution.
- ✓ Protocol I: Predicting accident reports involving harmful substances.
- ✓ Protocol II: Arbitration.

There are six (6) technical annexes (ANNEXES):

- ✓ Annex I: Regulations for the prevention of oil pollution. It entered into force on 2 October 1983.
- ✓ Annex II: Regulations for the control of pollution by liquid noxious substances in bulk. It entered into force on 6 April 1987.
- ✓ Annex III: Regulations for the prevention of pollution by harmful substances in packaged form. It entered into force on 1 July 1992.

- ✓ Annex IV: Regulations for the prevention of pollution from ship sewage. It entered into force on 27 September 2003. The revised Annex IV was adopted in 2004.
- ✓ Annex V: Regulations for the Prevention of Pollution from Ship Waste. It entered into force on 31 December 1988.
- ✓ Annex VI: Regulations for the prevention of gaseous pollution from ships. It entered into force on 19 May 2005.

2.1.1 Annex III: Regulations for the prevention of pollution by harmful substances in packaged form

MARPOL Annex III sets out the rules and requirements regarding the packaging of harmful substances, the marking, the labels, the documents that must accompany the consignment, the correct stacking and the correct quantity, the exceptions and the notifications to the competent Authorities, the procedures to be followed in accordance with Annex III to avoid causing marine pollution during the transport of harmful substances in packaged form.

The International Maritime Dangerous Code (IMDG) lists all harmful substances that require care and special handling during transport, taking protective measures. Finally, harmful carrier vessels must bear a Conformity document for their construction and equipment for the safe transport of harmful substances as required by SOLAS Regulation II-2 / 19.4 (EMSA, 2016).

Plastic waste on board comes from supplies spare parts and other work performed on board. The greatest danger to the marine environment is plastic as it remains unchanged for many years. In the past, many people thought that the oceans could absorb any waste and if we did, however, this attitude changed as we as humans revised our views on environmental protection. Also, much of the ocean waste comes not only from ships but also from holidaymakers on the beaches, fishermen and even many villages dump their waste uncontrollably on rivers and shores. Briefly in the table below we see the time it takes to dispose of some waste at sea (MEPC.244(66), 2014).

Table 1: Time required to dissolve at sea. Source: (Helmepa, 2020).

Paper	2 - 4 weeks
Cotton clothes	4 - 5 months

Ropes	3 - 14 months
Woolen clothes	1 year
Painted wood	13 years
Can	100 years
Aluminum paper	200 - 500 years
Plastic bottle	450 years

Marpol Annex V was set up to limit and control ocean waste. Thus, it explicitly states that the disposal of plastics anywhere in the sea is completely prohibited. However, there are two ways to manage these on board. The first most common and safest is to compress them and then deliver them to the PRF. The second is rarer and is limited by Marpol Regulation 16 in which we use a special purpose incinerator under very specific conditions. The incineration of polyvinyl chloride (PVC) on ships is prohibited. The incineration of polyvinyl chloride (PVC) is permitted provided the ship has an IMO-approved incinerator for incineration of this type of waste in accordance with MEPC.244.

Note that the burning of plastics with PCB is always prohibited. Because segregation requires expertise and is implemented under conditions and restrictions, ships choose not to incinerate plastics. However, in the event that plastics beyond the above specifications are incinerated, the ash delivered to the PRF may be subjected to a laboratory analysis before being delivered to the reception facilities, resulting in increased delivery costs. Reverse osmosis desalination is a reliable and effective way to reduce the amount of plastic waste produced from bottled water on ships (EMSA, 2016). Ships such as cruise ships where large quantities of plastic are produced, due to the large number of people, usually use a compressor or crusher in order to minimize the volume of waste as the cost of dumping waste in visiting ports is often calculated based on the volume of waste.

Many times, in smaller boats or ships with a small number of people they crush the plastics themselves by hand to minimize their volume. In many cases we separate the plastics into clean and dirty for their delivery to different ports. Below is a schematic diagram of the plastic waste management flow chart (MEPC.244(66), 2014).

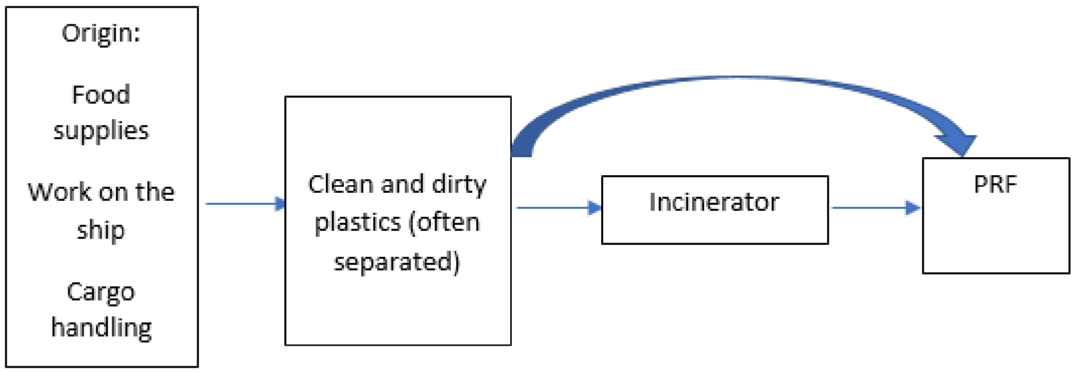


Figure 1: Plastic waste flow chart. Source: (EMSA, 2016)

The amount of plastic waste depends on the quality of hotel services, the number of passengers and crew, the consumption of material and depends to a large extent on people's livelihood (EPA, 2008). It also depends on the policy and specifications of the suppliers regarding the packaging of the products and the profile of the respective shipping company. In summary, most ships according to the international literature produce between 0.001m^3 and 0.008m^3 of plastic per day per and in rare cases quantities of up to 0.025m^3 per person per day have been reported (EMSA, 2016).

Table 2: The quantities of plastics produced on the ships under study

	Cruise	Tanker Oil
Month	Plastics (m^3)	Plastics of a Tanker Oil Disposed Monthly (m^3)
January	211	2,97
February	172	0,336

March	223	0
April	213,5	3,5
May	209,5	4,5
June	246	0
July	224	4
August	209	3
September	183	2
October	188	2,6
November	144,7	0
December	95	2,5
Sum	2319	25,41

From the above case studies of table No.2, we calculated that the daily production of plastic waste per person in the case of the cruise ship is estimated at $0.0018m^3$ and in the case of the oil tanker is $0.0029m^3$. According to the international literature each person produces 1 kg of solid waste on a daily basis and the quantities produced per day of crew member range from $0.001m^3$ to $0.016m^3$.

3rd Chapter – Plastic Accumulation Sources / Plastics and Microplastics

3.1 Plastics and Microplastics in the Seas

The plastics are synthetic polymers and have been used for over a century. It is a material consisting of a wide range of synthetic or semi-synthetic organic compounds that are flexible and can be molded into solid objects. Plastics are produced by converting natural products or by synthesis from primary chemicals, generally from oil, natural gas or coal (Thomson, 2009). Plastics are usually high molecular weight organic polymers, but often contain other substances as well. Most plastics are made from synthetic resins (polymers) through the industrial polymerization process.

In modern society, the plastic has gained a major importance, with extensive commercial, industrial, pharmaceutical and other applications (Wright et al., 2003) while ranking among the most widely used materials in the world (Hammer et al., 2012). Over the past 60 years, plastic has become a useful and versatile material with a wide range of applications. It is typical that more than 300 million tons of new plastics are used every year internationally. Half of them are used only once and usually for less than 12 minutes. Another very important fact, which is indicative of the situation, is that eight (8) million tons of plastic waste end up in the ocean every year (UNEP, 2016).

In fact, the amount of plastic that ends up in the sea is so great that in some places these plastic particles present a ratio of 26:1 to plankton (Plastic Ocean Foundation, 2017). A 2018 UNEP report estimated the large number of plastic fragments entering the environment at 8 million pieces per day. However, it should be noted that none of these estimates have been attributed to any specific source so they should be treated with caution.

The world's oceans are diverse and vast, and therefore drawing safe conclusions about the estimated average level of plastic waste is a very difficult task. About 49% of all plastics produced are of such composition and high durability, which gives them the ability to float and thus travel in ocean currents anywhere on the planet (USEPA, 2017). The annual production of plastic products has increased dramatically from 1.5 million tons in the 1950s to about 280 million tons in 2011 (Koushal et al., 2014). Annual plastic production is estimated to reach 400 million tonnes by 2020 (UNEP, 2018).

The most common plastics are polyethylene (PE), polyethylene terephthalate or polyester (PET), and polypropylene (PP) (Koushal et al., 2014). According to the Plastic Ocean Foundation (2017), the typical characteristics that make plastics useful mainly refer to the fact that they are both flexible and durable. These characteristics make plastics easy to use in everyday life, but at the same time they are a problem when plastics are disposed of in the environment. Due to their almost indestructible morphology and the elements they contain, plastics can seriously affect the ecosystem (UNEP, 2018). The greatest mass of plastics and microplastics occurs in the gyre ocean currents (Moore et al., 2001) For example, the eddy currents, where the largest amount of plastic debris currently accumulates in the North Pacific Ocean, covers an area as large as France and Spain together (Moore et al., 2001).

The deposition of plastics and microplastics in the seas affects ocean life and because we are at the top of the food chain, it also affects humans (Hammer et al., 2012). Several decades have passed since the explosion of plastic use and there is evidence that the current approach to the production, use, transport and disposal of plastic materials has caused and continues to cause severe impacts on wildlife and is not sustainable (Hammer et al., 2012).

3.2 The Plastic as a Material in the Oceans

The environmental problem created by plastic waste stems from the composition of this material. Plastic is characterized by durability in environments such as marine or dry environments. The property of plastic items, considered as one of the major advantages of the material, has become a huge disadvantage given its mismanagement and uncontrolled loss in the environment. Plastics dominate a wide variety of products and have replaced other materials such as wood, metal and glass that were used in the past. The production of plastics requires four main stages:

- ✓ The acquisition of raw material,
- ✓ The synthesis of a basic polymer,
- ✓ The synthesis of the polymer into a useful result
- ✓ The shaping of the plastic.

Therefore, depending on the composition of the plastic material, it can either be recycled, composted or, in the worst case, non-recyclable plastic discarded with unpredictable consequences. The plastic can now be recycled, it can be formed into polyester fibers for use in textiles, for food packaging, for glasses and compact discs, among thousands of other uses. The use of plastic in short-lived applications, such as product and food packaging (which also accounts for the main volume of waste, almost 1/3 of the volume of waste), created nowadays the big problem of environmental pollution and the lack of disposal space.

The common plastics remain in the environment for hundreds of years due to the fact that the micro-organisms in them in soil they cannot generally break down a polymer chain consisting exclusively of carbon atoms and which does not exist in nature. For this reason, there was a need to replace common plastics with new, innovative materials that have the same functionality, while being more environmentally friendly. https://skgecoshop.com.

3.3 The Plastic vs. Ocean Water

The biggest problem with plastic material is created in contact with water, where it not only does not dissolve but breaks down into smaller pieces characterized as microplastic and nanoplastic particles which are difficult to remove or dissolve from the marine ecosystem. Global plastics production doubles approximately every 11 years and reached 359 million tonnes in 2018 (Plastics Europe, 2019). "*Every year, the world produces enough municipal waste to cover 800,000 Olympic-sized swimming pools*" as is characteristically mentioned in a related article (BBC, 2019).

As someone could see, plastic pollution has gained viral attention in recent years, with major anti-plastic campaigns launched by the UN, EU and other international bodies as we will see below. Plastic waste has become the main components of marine debris due to the widespread consumption of plastics and poor plastic waste management. As part of the problem, microplastics and nanoplastics have raised particular concerns because of their unique characteristics that make them easy to transport between oceans in the marine ecosystem, at different trophic levels in the food body, even through infected animals. (Häder et al., (2020), Lusher et al., (2015), Peng et al., (2019), Alimi et al., (2018)).

The plastic is still found in a variety of environments from the deep sea to coral reefs. Most research on marine sediments to date has focused on oceans, the water base, seabeds and wildlife. Relatively little has been focused on the potential of coastal areas as debris sinks as it is swept away by water. (Hall et al., (2015), Taylor et al., (2016), Olivelli, Hardesty and Wilcox, (2020)). From the 1950s to 2018, approximately 6.3 billion tons of plastics have been produced worldwide, of which 9% was recycled and another 12% was incinerated. This large amount of plastic waste enters the environment, with studies showing that the bodies of 90% of seabirds contain plastic debris. In some areas, significant efforts have been made to reduce the visibility of free plastic pollution by reducing plastic consumption, cleaning up litter and promoting plastic recycling. Some researchers even claim that by 2050 there could be more plastic than fish in the oceans by weight.

The majority of marine microplastics come from rivers and estuaries. The main sources refer to runoff from urban areas, inflows from treatment plants sewage, sewage system overflow and from industrial inputs that contribute to the composition of river water. It is estimated that more than 2 million tons of plastic are delivered each year from rivers to the ocean. (Hitchcock, (2020), Paula et al., (2020), Mohrig (2020), Hui et al., (2020), Jambeck et al., (2015)). A significant portion of marine plastic debris comes from land-based sources, and rivers act as an important transport pathway for all sizes of plastic debris. In particular, rivers that run through large and populous cities with increased tourism, fishing and trade are vulnerable to attracting plastic waste along their course and ultimately into the sea they discharge.

The countries that are wet by the sea, with increased exploitation of water either by fishing or by tourism, have a more direct deposition of the material in the water due to carelessness, weather phenomena or even intentional disposal of the useless material in the water. (Ludwig et al., (2009)). In order to obtain a complete picture of how plastic eventually manages to reach the seas and oceans, we conclude that we cannot have an accurate understanding.

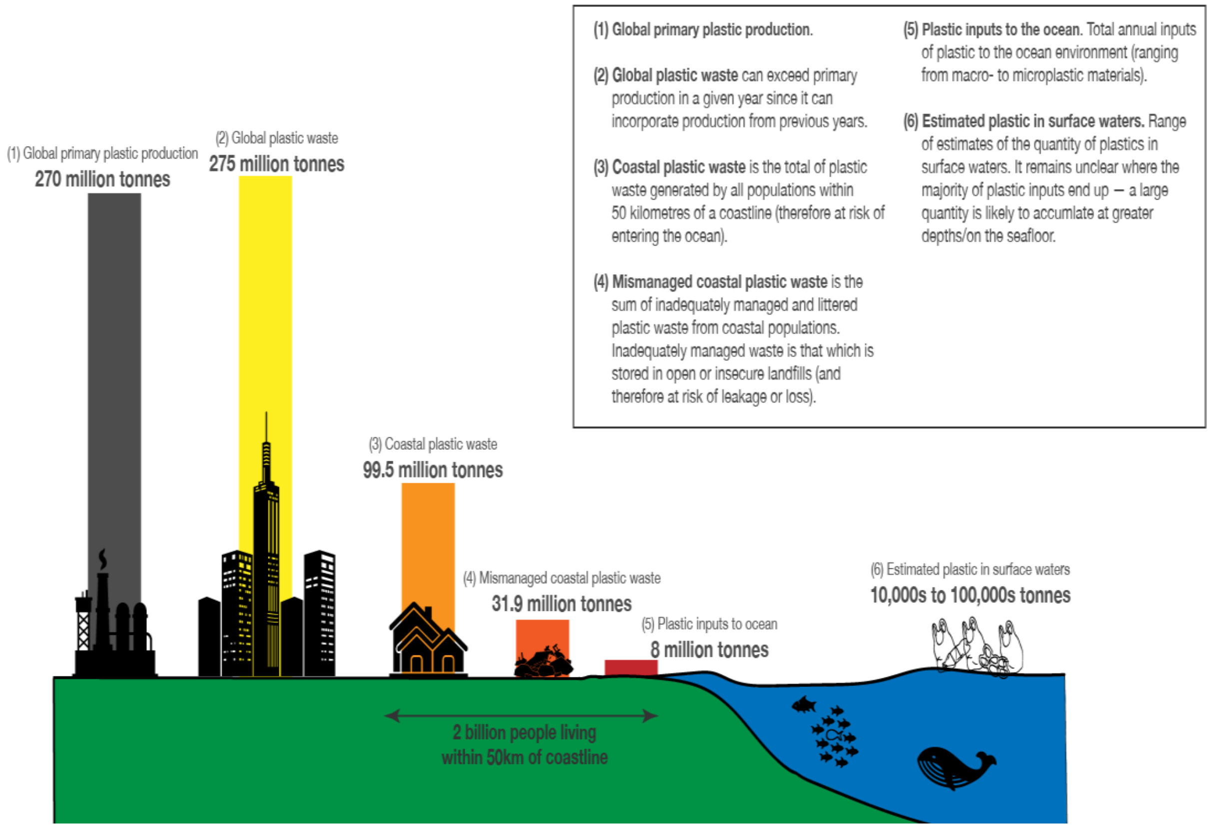
The fate of floating plastic debris 'trapped' in a water current remains largely unknown. Only targeted studies and research in selected areas can provide a more accurate estimate of the residence time and fate of floating plastics that accumulate in these areas. It is important to realize that not all floating plastic objects end up in offshore waters. Coastal environments play a critical role in removing floating plastic debris. (Egger, Sulu-Gambari, and Lebreton, (2020)). It is of course noticeable that concentrations in seas, lakes and rivers can have health, water quality, but also economic and aesthetic effects.

3.4 The Various Sources of Plastics and Microplastics' Appearance

The plastic is defined as synthetic organic, polymer, which comes from the polymerization of monomers derived from natural gas and oil. The first synthetic plastic (Bakelite) was manufactured in 1907 and is said to mark the beginning of the global plastics industry. However, rapid growth in global plastics production did not occur until the 1950s. Over the next 60 years or so, annual plastics production increased almost 200-fold to 381 million tonnes in 2015. For the environment this is almost equivalent to the mass two-thirds of the world's population.

Plastic pollution has negative effects on our oceans and the health of wildlife. They have been Many studies have documented the impact of plastic on marine ecosystems. Revised publications on the effects of plastics date back to the 1980s. An analysis by Rochman et al., (2016) examines the findings of an extensive literature review on the effects of plastic waste on the oceans as well as animals. Despite this and despite the many documented cases, it is widely recognized that the full extent of the impacts on ecosystems is not yet known.

According to Eriksen et al., (2014) and Jambeck et al., (2015) in 2010, the global primary production of plastic was 270 million tons, while global plastic waste amounted to 275 million tons (can exceed annual primary production through plastic waste from previous years). The plastic waste most at risk of entering the oceans is produced in coastal populations (within 50 kilometers of the coastline). Thus, in 2010 coastal plastic waste amounted to 99.5 million tonnes, of which 8 million tonnes - 3% of global annual plastic waste - entered the ocean (via multiple entry points, including rivers). It is also estimated that 10,000 to 100,000 tons of plastics are found in the surface waters of the oceans (a few orders of magnitude smaller than the plastic inputs to the oceans). Figure 1 shows the volume of plastics that entered the oceans in 2010 alone.



Picture 1: Global input of plastics entering the oceans in 2010 - Source: Eriksen et al., (2014), Jambeck et al., (2015).

Regarding the origin of plastic waste, high-income countries tend to produce more plastic waste per person (Li et al., 2016). However, the factor that determines the risk of plastics entering the ocean is how plastic waste is managed. High-income countries have very efficient waste management systems, with the result that useless waste (and consequently its inputs into the oceans) is therefore low. Poor waste management in many middle- and low-income countries means that plastics dominate the sources of global ocean pollution. This makes improving waste management systems around the world critical to tackling plastic pollution.

Overall, about 80% of ocean plastics come from land-based sources and 20% from marine sources. However, in some areas, marine sources predominate. It is also important to note that plastic is a unique material with many advantages: it is cheap, versatile, light and durable. This makes it a valuable material for many functions. It can also provide environmental benefits through certain supply chains: it plays a critical role in maintaining food quality, safety and waste prevention.

Microplastics are defined as plastic particles <5 mm in diameter (UNEP, 2016). Microplastics are not a specific type of plastic, but rather any type of plastic fragment less than 5mm in length, according to the US National Oceanic and Atmospheric Administration (NOAA). (Collignon et al., 2014). Microplastics enter natural ecosystems and especially the seas from a variety of sources, including, among others, cosmetics, clothing and industrial processes. There is growing scientific and social concern about the effects of microplastics. (Hidalgo-Ruz et al., 2012, Yoon et al., 2010, Kako et al., 2014, Isobe et al., 2014).

Microplastics can be classified as primary or secondary, depending on how they are produced. Primary microplastics are small plastic particles that are released directly into the environment through e.g. domestic and industrial waste, leaks and sewage disposal or indirectly (e.g. through runoff). The range of primary types of microplastics includes fragments, fibers (Rummel et al., 2016), pellets (Nobre et al., 2015), films (Lusher et al., 2015) and microspheres (Li et al., 2016). Microspheres are often associated with the pharmaceutical and cosmetic industries (Patel et al., 2009).

Secondary microplastics are formed as a result of the gradual degradation / fragmentation of larger plastic particles that are already present in the environment, due to e.g. of UV radiation (photo-oxidation), mechanical transformation, (eg, wave abrasion) and biological degradation by microorganisms (Cole et al., 2011). Sources of secondary microplastics include water and soda bottles, fishing nets and plastic bags. Another source of microplastics are synthetic fabrics, the microbeads of which enter the drains through the laundry facilities. Also, a source of microplastics (microbeads) are some cosmetics and personal care products, industrial lubricants, "sandblasting" materials, as well as textile application materials (Boucher, and Friot, 2017).

Both types of microplastics are recognized to pollute the environment at high levels, particularly in aquatic and marine ecosystems. In addition, plastics degrade slowly, often over hundreds if not thousands of years. This increases the likelihood that microplastics will be absorbed and incorporated into the bodies and tissues of many organisms (Conkle et al., 2018).

However, it should be noted that the full cycle, movement and consequences of microplastics in the environment are not yet known, but research is ongoing to investigate this issue. Microplastics in the environment can further fragment and produce nanoplastics (1-100nm), which, compared to other forms of plastic waste, have unknown characteristics and toxicological properties (da Costa et al., 2016).

3.5 Time Evolution of the Accumulation of Plastics and Microplastics

The advantages of plastics, including their flexibility, strength and durability in use, have led their evolution over time to their widespread use, with the result that today, almost everything contains this material. Plastics production has increased dramatically worldwide over the past 60 years, rising from 0.5 million tonnes/year in 1960 to almost 300 million tonnes in 2013. Europe ranks second globally with 20% of total production, corresponding to in 57 million tons of plastics produced in 2012. It is typical that the European plastics industry provides direct employment to over 1.45 million people, generating approximately 26.3 billion euros for public finances and welfare (Plastic Europe, 2014 / 2015).

High concentrations of plastic debris were first observed in the North Pacific Ocean (Moore et al., 2001) and the term "marine litter" (Kaiser, 2010) has since emerged. At least 21,290 tons of floating plastic debris was estimated to have accumulated over time in the North Pacific (Law et al., 2010), while today giant marine dumps are the North Pacific, South Pacific, North Atlantic, South Atlantic and Indian Ocean regions. Even a very large accumulation of marine litter from plastics and microplastics is predicted to occur in the Barents Sea (van Sebille et al., 2012).

It appears that primary releases of microplastics into ocean waters even exceed those of secondary microplastics. The average global release of primary microplastics into the ocean was estimated at 1.5 million tonnes per year (Mton / year) (Boucher, Friot, 2017). Obviously, these are huge amounts and this total corresponds to a global equivalent release of 212 grams per capita, or the equivalent of one empty conventional plastic grocery bag dumped into the ocean per person/week worldwide.

The vast majority of primary microplastic discharge (98%) is produced by land-based activities. Only 2% comes from activities at sea. In addition to releases into the oceans, the accumulation of microplastics in the oceans results from the use of products (49%) or the maintenance of products (28%). The main pathways of these plastics into the ocean are through road runoff (66%), sewage treatment systems (25%) and airborne transport (7%) (Boucher and Friot, 2017).

3.6 Life Cycle of the Plastic Waste in the Sea Environment

The plastics production has increased on a global scale in recent years. In 1950 it was about 2 million tons (Geyer et al., 2017), while in 2016 global production reached 335 million tons (Plastics – the Facts, 2017), with a simultaneous emission of 2 billion tons of CO2 (CO2 carbon dioxide), accounting for around 6% of annual global CO2 emissions. Since 2000, global plastic production has been increasing at a rate of 4% per year, with a trend by 2030 to have increased to 40% compared to 2000 (WWF, 2019).

According to the United Nations global environmental map, China is the largest producer of plastics, followed by North America and Western Europe with 28%, 19% and 19% respectively. Regarding the consumption of plastics, the corresponding percentages are 20%, 21% and 18%, with North America being the largest consumer (Ryber et al., 2018). The life cycle of plastic waste consists of three axes as shown in Diagram No.1 below:

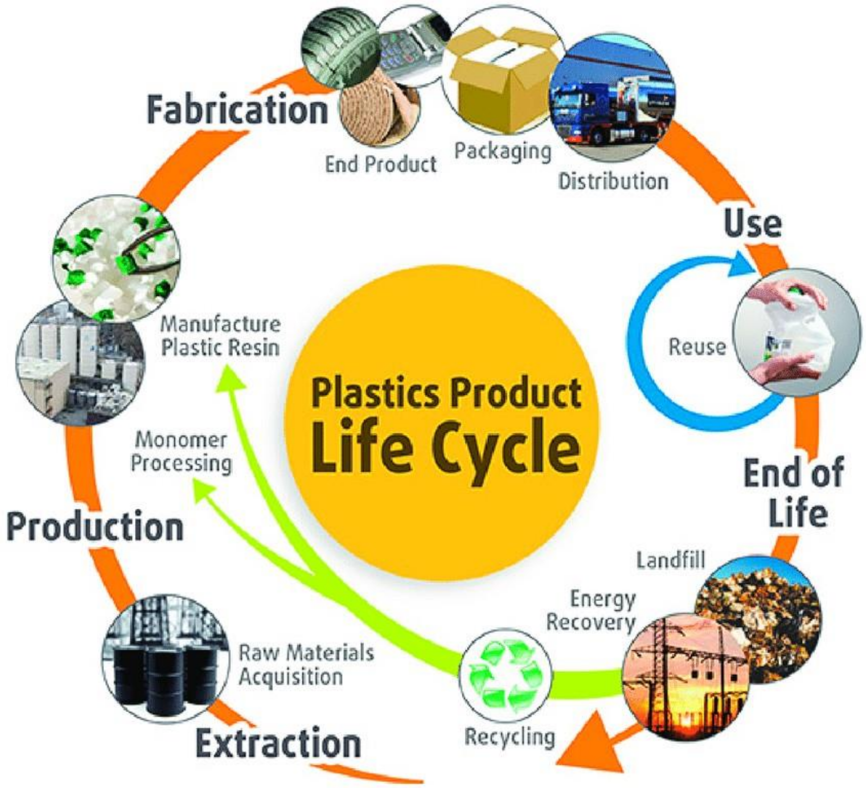


Diagram 1: Life cycle of plastics (Source: Devasahayam et al., 2019)

Production

The plastics consist of synthetic or semi-synthetic organic polymers, consisting of repeating chemical building blocks. These chemical units, in most cases, are composed of hydrocarbons derived from oil and natural gas (Napper & Thompson, 2020). In this way, the production of plastics is largely linked to petrochemicals and mineral raw materials. Fossil fuels make up 99% of the raw material for plastics production, which accounts for 8-9% of global oil and gas consumption, with 4-5% used as feedstock and the remaining 3-4% as energy (Andrady, 2015). Polymers come in a huge variety with the most commonly used being polypropylene, low density polyethylene, polyvinyl chloride, high density polyethylene, polyethylene terephthalate (polyester) and polystyrene at 21%, 20%, 11.8%, 16.3%, 10.2% and 7.6% respectively (Geyer et al., 2017).

Application

The plastics are used in a variety of ways, including food packaging, the construction industry, plastic bags, plastic bottles, disposable cups, fishing gear, and microbeads in cosmetics (Nielsen et al., 2020). The most common application of plastics is food packaging at 36%, followed by the construction industry at 16% respectively (Geyer et al., 2017).

Disposal

At the end of their use, plastics follow three main routes for their management as waste. Recycling, which delays their final disposal, incineration, which thermally destroys them with or without energy recovery and landfill, disposed of in landfills. However, due to poor management, plastic waste ends up in open dumps and in the natural environment as final disposal options (Bhattacharya et al., 2018). In the environment and specifically in the marine environment, pollution caused by plastic waste is a global problem, with 60-80% of waste in the sea consisting of plastics (Derraik, 2002). Plastic waste has negative effects on both the marine environment and its food chain, including humans, as plastics are consumed by fish and then by humans, directly and negatively affecting their health (Laskar & Kumar, 2019).

3.6.1 Polymers

The availability of plastic materials for use in various applications is vast. There are several ways to categorize or classify plastics, making it easier to understand the similarities and differences between materials. The two main classifications of plastics are thermoplastics and thermosets (Peters, 2003). In this work we will deal with thermoplastic materials.

Thermoplastics

Thermoplastics belong to the family of plastics that have the ability to melt when heated and solidify when cooled. These characteristics, which give the material its name, are reversible. Therefore, they can be reheated, reshaped and cooled repeatedly (Plastics – the Facts, 2019). This category includes, among others:

Poly (ethylene terephthalate) (PET) - Chemical formula: (C10H8O4)n

PET is made by polymerizing dimethyl terephthalate (dimethyl terephthalate) or terephthalic acid with ethylene lycol (Roers, 1997). It is a semi-crystalline polymer with high strength, high melting point, good electrical propertiesproperties and moisture and solvent resistance (Peters, 2014). It is used, among other things, for the manufacture of fibers, such as carpets or fabrics, sheets, films and in particular it is used in beverage packaging, such as soft drinks, electronic goods, car parts, sports goods, plastic bottles, plastic food wrappers, etc. (Niaounakis, 2017).

Polyethylene -Polyethylene (PE)- Chemical formula: $(C_2H_4)_n$

The PE plastics are lightweight, semi-crystalline thermoplastics made by the catalytic polymerization of ethylene (Peacock, 2000). Depending on temperature, pressure, catalyst and the use of a common monomer, three basic types of polyethylene can be produced: high-density polyethylene (Hi h-density Polyethylene - HDPE), low-density polyethylene (Low-density Polyethylene - LDPE) and linear low lensity polyethylene (LLDPE) (Peters, 2014). The HDPE: Used in products and packaging, such as milk containers, butter containers, detergent bottles, garbage containers, water pipes, toys, plastic bottle caps, plastic bags, fishing lines, etc. The LDPE is used for rigid containers and in film applications such as carrier bags, garbage bags, wrapping films, etc. The LLDPE is mainly used in packaging, as well as in the manufacture of lids, containers, toys, plastic bags, plastic food wrappers, etc. (Niaounakis, 2017).

Polyvinyl chloride - Polyvinyl chloride (PVC) - Chemical formula: $(C_2H_3Cl)_n$

PVC is a semi-crystalline polymer with a relatively high tensile modulus at room temperature, which can be reduced to produce semi-rigid and flexible objects (Wilkes et al., 2005). This plastic is used in two basic forms: rigid and flexible (Niaounakis, 2017). The rigid form is used in the manufacture of pipes, in containers such as bottles, which do not contain food, in doors, windows, etc. The flexible form is used in flooring materials, wallpapers, decorative sheets, wrapping and packaging films, flexible pipes, cable insulation, fishing lines, etc. (Niaounakis, 2017).

Polypropylene - Polypropylene (PP)- Chemical formula: $(C_3H_6)_n$

The Polypropylene is a semi-crystalline thermoplastic, with a balance of properties that are higher than HDPE. It is prepared by the catalyzed polymerization of propylene (Karian, 1999). PP is used in packaging, containers, tubes, disposable medical devices such as syringes, furniture, ropes, plastic bottle caps, straws, stirrers, etc. (Niaounakis, 2017).

Polystyrene - Polystyrene (PS)- Chemical formula: (C8H8)n

PS is an amorphous polymer, with a disordered geometric structure, that exhibits high stiffness, moderately high heat dissipation temperature, and excellent electrical insulation properties (Peters, 2014). It is used in various forms, such as General-Purpose Polystyrene (GPPS), High Impact Polystyrene (HIPS), Oriented Polystyrene (OPS) and Foamed Polystyrene (EPS) (Niaounakis, 2017). It is used for the manufacture of CD and DVD cases, cutlery, drink cups, etc. (Niaounakis, 2017). It is used in displays, toys, medical supplies, household supplies, electronics, office equipment, etc. (Peters, 2014). The OPS is used in packaging and the confectionery industry (Niaounakis, 2017). The EPS is used as thermal insulation material for buildings and refrigerators, drink glasses and lids, as protective packaging for household appliances, plastic cups, plates, forks, knives, spoons, plastic food wrappers, etc. (Niaounakis, 2017).

Polyamides - Polyamides (Nylon) - Chemical formula: (C12H22N2O2) n

The Polyamides, commonly called nylons, are produced by the polymerization of dicarboxylic acids and diamines or the catalytic polymerization of a lactam monomer (a cyclic amide) (Aharoni, 1997). They are a class of resins characterized by broad chemical resistance, high strength and hardness (Peters, 2014). Nylon is used in the manufacture of nets due to its low cost and high strength, in general-purpose towing straps, fishing lines, etc. (Niaounakis, 2017).

<u>Thermosets</u>

Thermosetting plastics belong to the family of plastics that undergo a chemical change when heated, creating a three-dimensional network. After being heated and shaped, these plastics cannot be re-melted and reshaped (Plastics – the Facts, 2019). Typical thermosetting polymers are epoxy resins, phenolic resins, amine-formaldehyde, polyurethanes and silicones (Guo, 2012).

3.7 Effects of the Plastics and Microplastics in the Sea Environments

As mentioned above, microplastics are plastic particles that have a diameter of less than 5mm and that may be fragments of larger plastic objects, such as packages or bottles, or may be particles that have been manufactured to this size, such as the microspheres, used in face and body care cosmetic creams or toothpastes. Microplastics are found today in the sea and on beaches and are able to damage the marine ecosystem to a very large extent (Jambeck et al, 2015).

According to research, it is known that the accumulated amount of microplastics in the marine environment today is clearly greater compared to the corresponding amounts of produced plastics. It is a fact that larger plastics can become absolutely dangerous for the marine environment and the organisms living in it, as marine organisms can become entangled and trapped in them, as a result of which they drown or develop malnutrition problems, as their digestive system is blocked by their ingestion (Pham et al., 2014).

However, as also results from relevant studies, microplastics are those that, compared to plastics, are consumed by a greater number of marine living organisms, as their small size obviously facilitates this. Also, microplastics have the property of attracting, absorbing and then releasing toxic pollutants as well as the chemicals that have been added to them, during their manufacturing process (ten Brink et al., 2016).

There is no doubt that the more plastic we throw away, the more plastic waste will end up in the world's water systems and then into the sea. Furthermore, as large plastic fragments can then be broken down into smaller pieces, this will inevitably lead to thousands of microplastics being created from each plastic that floats in the sea. Research has shown that marine life drowns by consuming microplastics in a number of ways. For example, mussels and oysters absorb microplastics by filtering their food. Fish, respectively, absorb microplastics through their gills or also swallow them through the mouth directly.

3.8 Plastic Types Polluting the Sea Environment

The plastic is a relatively recent material, which first appeared at the beginning of the 20th century (Geyer et al., 2017). The first synthetic plastic created was Bakelite, the use of which was limited and mainly related to household items (Napper & Tompson, 2020). The now mass production of plastics was marked with the end of the Second World War producing in 1950, annual 5 million tons (Andready, 2017).

A century later, plastics are an integral part of modern society, utilizing them in clothing, nutrition, and transportation, mainly because of their durability, which is at the same time the most important cause of their harmful effect on the environment (Ivar do Sul & Costa, 2014). The light and flexible composition of plastics, as well as their low production costs, are some of the reasons that led to their rapid increase, whose production from 30 million tons in 1980 (Napper &

Tompson, 2020), reached 359 million tons in 2018 (Plastics – the Facts, 2020).

Today, the accumulation of plastic waste in marine and coastal areas is one of the most important global environmental and economic problems of the 21st century (Botterell et al., 2019). The UN General Assembly recognized the problem of marine pollution only in 2005, with resolution A/60/L.22, where it was imperative to implement national, regional and global actions to deal with marine waste (Isensee & Valdes, 2015). At the 2012 United Nations Conference on Sustainable Development (Rio +20), there was an explicit reference to marine plastic waste, its risks, negative consequences and actions to be taken, while the United Nations committed to a significant reduction of plastic waste by 2025 (Assembly, 2012).

Plastic waste is transported by ocean currents, resulting in it being found in all parts of the planet - from the most remote shores to the depths of the oceans - affecting marine organisms (UNEP, 2016). The impact of marine pollution is also felt in the industrial sector (e.g. fishing, shipping, tourism), while food safety and the human health (Barboza et al., 2018). Marine plastic waste can be found throughout the water column, from the sea surface to the seabed (Amuthu et al., 2020), where a variety of plastic waste is found, such as fishing gear, bottles, bags, straws, as well as remnants of the above (Gallo et al., 2018).

The rapid increase in marine and coastal pollution has caused the global concern of governments, industries, and consumers (Nielsen et al., 2020). According to the UN sustainable development program, the transition to more sustainable ways of production and consumption seems to be the most ideal solution for dealing with this global ecological crisis (Löhr et al., 2017). It is now clear that immediate action and cooperation between the parties involved is required to address the current situation, but also to take preventive measures - at global, national and individual levels - in order to prevent the further spread of marine pollution from plastic waste and of their adverse consequences (UNEP, 2016).Land-based sources of waste

Plastic waste from terrestrial sources includes almost all types of items, from single-use packaging to industrial pre-production pellets (Gold et al., 2013). The main sources of waste from land-based sources include but are not limited to:

✓ Landfills for waste

- ✓ Rivers
- ✓ Industrial effluents
- ✓ Illegal disposals
- ✓ Discharges from storm water drains
- ✓ Raw municipal sewage
- ✓ Waste from beaches, coastal areas (e.g. tourist activities)
- ✓ Cosmetics
- ✓ Synthetic (polyester or acrylic) fibers from the washing process clothes (Niaounakis, 2017).

Despite the fact that marine litter is considered to be 80% from land-based sources, this percentage is not fully documented as there are no global estimates for other sources of plastics in the sea, such as inputs from natural disasters (Niaounakis, 2017).

According to a model presented by Jambeck et al. in 2015, they estimated that 275 million tons of plastic waste were produced in 192 coastal countries, including China, Indonesia, the Philippines (93% of the world's population) in 2010, of which 4.8 to 12.7 million tons entered the ocean, equivalent to 1.7%–4.6% of the total plastic waste produced in these countries (Jambeck et al., 2015). Population size and the quality of waste management systems largely determine which countries contribute the largest mass of unbound waste available to end up as plastic waste in the marine environment (Jambeck et al., 2015). However, the sources of marine plastic waste include but are not limited to:

- ✓ Fishing equipment
- ✓ Commercial shipping
- ✓ Ships and cruise ships
- ✓ Military vessels

- ✓ Pleasure boats
- ✓ Aquaculture facilities
- ✓ Offshore mining platforms (Niaounakis, 2017).

Eriksen et al. estimated, based on their analysis of 4291 visual observations at 891 sampling sites in the North and South Pacific, North and South Atlantic, Indian Ocean, Bay of Bengal, Mediterranean Sea and in Australian coastal waters, that 20% by number and 70% by weight of floating debris was related to fishing gear, mainly buoys (Eriksen et al., 2014) .

Studies have shown that there is a significant relationship between the number of items from marine sources found on beaches and the level of commercial fishing activity. Furthermore, in 2010, the amount of fishing gear "lost" to the environment was estimated at approximately 640,000 tons per year (Napper & Thompson, 2019).

3.8.1 Distribution and Appearance of Plastic Waste

Floating waste

Floating waste is the fraction of waste in the marine environment that is transported by wind and currents to the surface of the sea and is directly related to the routes that waste takes towards the sea. This waste is carried by currents until it sinks to the bottom of the sea, is deposited on the coast or degrades over time (Andrady, 2015). Despite the observation of anthropogenic floating debris already in the past decades, only recently has the existence of accumulation zones in all oceans gained global attention (Bermann et al., 2015).

The main part of floating marine litter consists of plastic synthetic polymers, the course of which depends on their physicochemical properties and environmental conditions. Polymers produced in large quantities, such as polyethylene and polypropylene, have lower densities than seawater and float until they reach land or sink due to biodeposition and leaching of their additives (Bermann et al., 2015).

In the central-western Mediterranean Sea floating debris was observed with an average density of 25 objects/km2, of which the Adriatic Sea had the highest density of 52-55 objects/km2, followed by the Algerian sea section, 53 objects/km2, the central Tyrrhenian Sea , 5 objects/km2 and the Sea of Sicily, 6.3 objects/km2. Plastics made up 82% of the observed floating litter and mainly consisted of bottles, food and packaging wrappers and shopping bags (Takada & Karapanaioti, 2019).

Waste on the seabed

The presence or absence of man-made litter on the seabed has been much less investigated than litter on the sea surface. Difficulty in sampling, access and high costs hamper research in the deepest waters, which represent almost half of the planet's surface. However, these investigations are important as 50% of plastic waste ends up sinking to the bottom of the seas (Enler, 2012).

The plastic debris has been found on the seabeds of all seas, with large accumulations noted (Barnes et al., 2009), with large spatial variations and an average density ranging from 0 to more than 7,700 objects/km2 (Bermann et al., 2015). However, their presence remains unusual in remote areas such as Antarctica and specifically at great depths (Barnes et al., 2009). Large navigable rivers have a large contribution to the plastic waste of the seabed due to the high flow rate and strong currents driving the waste long distances from the coasts. In addition, smaller rivers also contribute to the deposition of waste on the seabed, however at shallower depths and at close distances from the coasts (Gal ani et al., 2000). Studies show that litter on the seabed tends to accumulate in low-traffic areas such as bays and coral reef lagoons where we see large amounts of derelict fishing gear and less in the open sea (Bermann et al., 2015).

In the Mediterranean Sea, the survey of marine debris with bottom observation tools was carried out in 1995 in the Marseille-Nicae sea gorge with a density of 1,623 objects/km2 and plastics being found in a high percentage of 86% (Galani et al., 1996). Recent data show for the western Mediterranean Sea percentages of plastics ranging from 12% to 86% and in the central Mediterranean (Tyrrhenian Sea) percentages of plastics range from 82% to 93% (Fabri et al., 2014).

Coastal waste

The majority of studies on marine plastic waste have focused on their occurrence in coastal waters and the open sea. However, it is now clear that plastic waste is present on all beaches worldwide (Napper & Thompson, 2019). On the beach the waste may come from both land-based sources, local land-based activities, and marine sources, passing ships. Also, coastal tourism is a significant source of plastics whether it occurs intentionally or after an accident (Niaounakis, 2017).

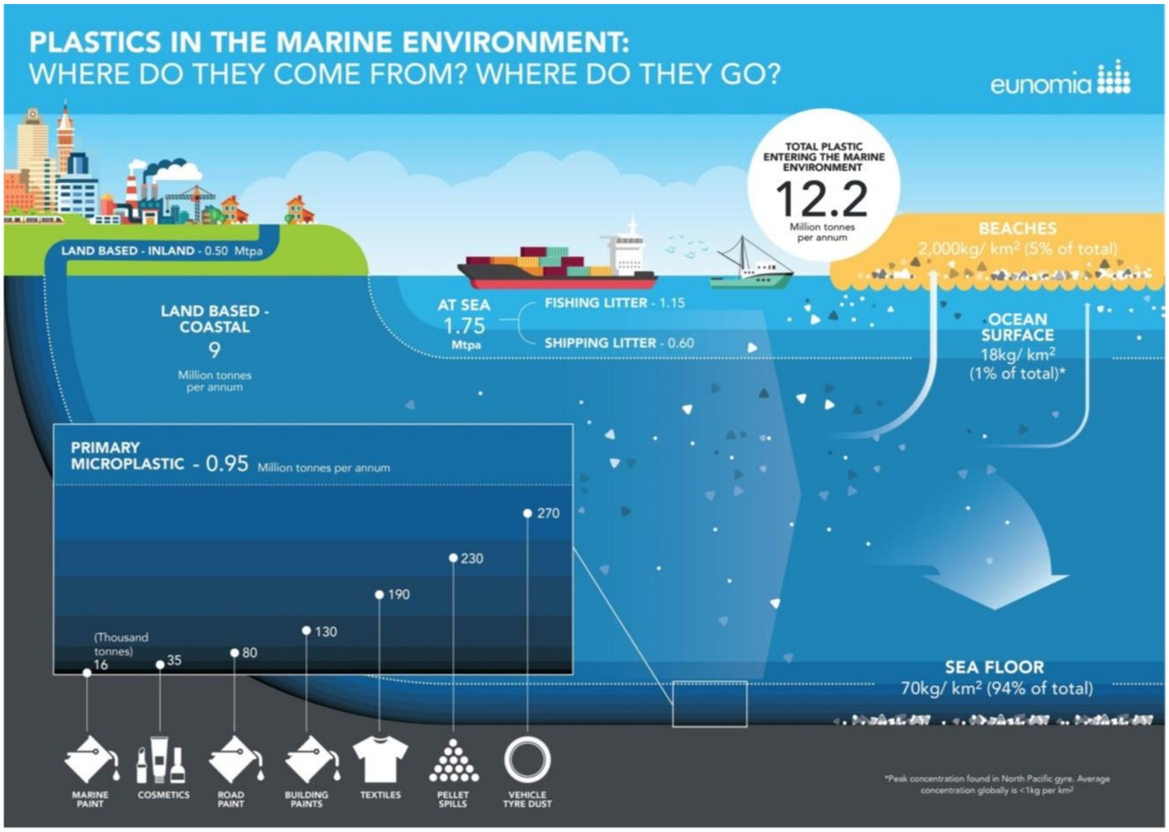
According to the data collected from the surveys, the percentage of plastics among the waste collected on beaches around the world ranges from 46% to 90% (Niaounakis, 2017). Based on data from the OSPAR Commission (Convention for the Protection of the Marine Environment of the North-East Atlantic) the plastic waste collected from the beaches included, among others, bags of various sizes and for various uses, packaging plastics, bottles and glasses (OSPAR, 2010). The highest density of plastics found on beaches, corresponding to 670 objects/m2, is found on Henderson Island, which belongs to the Pitcairn Islands, indicating the presence of plastic waste on all beaches worldwide (Lavers & Bond, 2017).

Factors affecting the accumulation of this waste on beaches include the shape and location of the beach as well as the nature of the waste. In addition, the amount of litter along beaches is expected to increase in the coming years due to projected sea level rise, wind speed, wave height and changing rainfall patterns (Napper & Thompson, 2019).

3.9 Microplastics Polluting the Sea Environment

The microplastics are further categorized into primary and secondary depending on their source. The majority of primary microplastics in the environment come from industrial and household products that contain very small particles. These plastics are released into the environment in the form of small particles and are used as a raw material in the plastics industry, in synthetic fabrics, in hygiene and personal care products as well as in electronic equipment (GESAMP, 2016). Secondary microplastics result from the fragmentation of larger plastic objects into smaller fragments, due to, among other things, weather conditions, solar radiation that facilitates the oxidative degradation of polymers and salinity (Solomon & Palanisami, 2016).

Marine plastic waste is classified according to its source, from terrestrial and marine sources, as shown in Figure 3.1 below. Land-based sources account for up to 80% of marine plastic waste that is transported to the sea via sewage systems, natural waterways, wind and human negligence (Derraik, 2002). The remaining 20% comes from marine sources such as ships, pleasure boats, offshore facilities and commercial fishing vessels which discharge waste directly into the sea. Researchers estimate that plastic waste represents up to 80% of all marine litter (Sheavly & Reister, 2007).



Picture 2: Plastics in the Marine Environment

4th Chapter – Effects of Plastic Accumulation

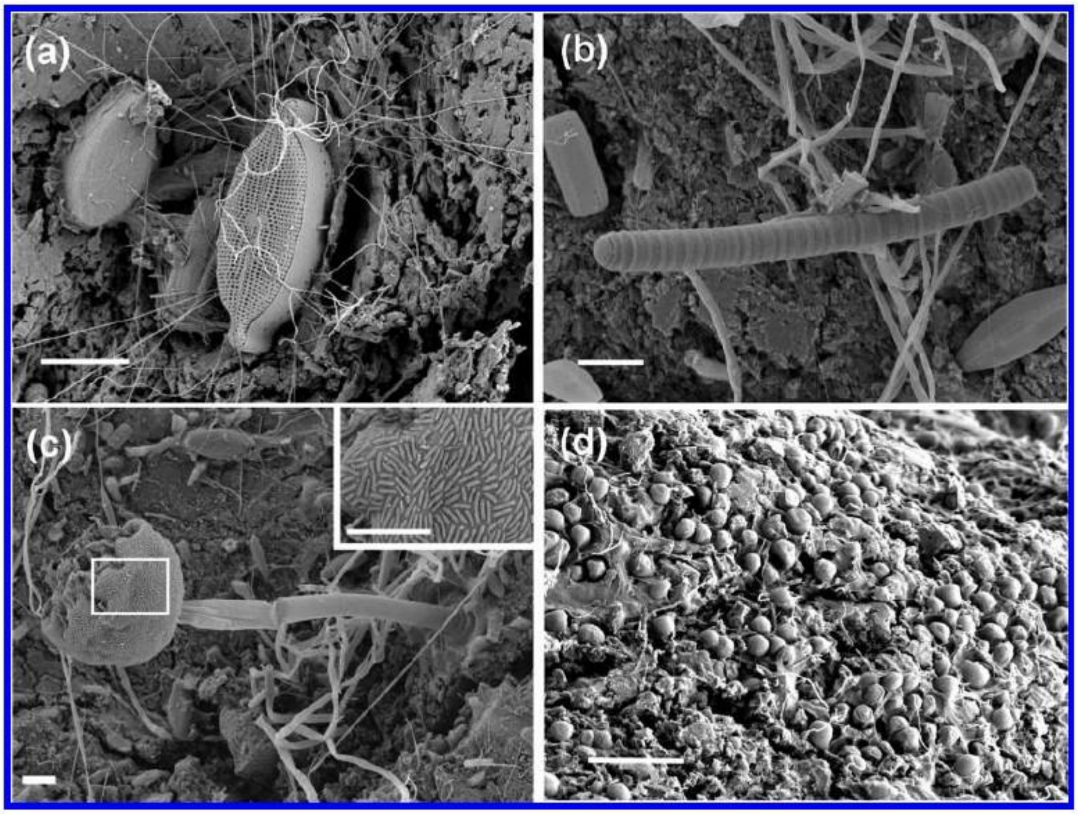
4.1 The Impact of Plastics' Pollution

The marine and coastal environment is a highly complex system with various subsystems, which are characterized by extremely rich biodiversity (Thusari & Senevirathna, 2020). Plastics are one of the most important sources of pollution of aquatic ecosystems around the world (Deplede et al., 2013) representing up to 80% of marine litter (Sheavly & Reister, 2007). Plastic waste accumulating in aquatic ecosystems comes from both terrestrial (such as sewage, human activities, industrial spills) and aquatic sources (such as fishing or shipping) (Sadri & Thompson, 2014) and brings about a variety of economic, social and environmental consequences. (Tessnow-von Wysocki & Le Billon, 2019). These consequences depend on the type of plastic, its toxicity and its different physicochemical characteristics (Ryber et al., 2018).

4.1.1 Impact to Marine Species

The increase in plastics – and especially microplastics – raises concerns regarding the mechanical, chemical and microbiological consequences it brings to organisms (Freeman et al., 2020). The mechanical effects are related to the size and amount of plastic and include reducing the motility of organisms and blocking their digestive tract (Freeman et al., 2020). When ingested, plastics become stuck in the digestive tract causing injury, suffocation or even starvation, as a false sense of satiety is created which prevents them from foraging (McNicholas & Cotton, 2019). At the same time, studies have shown that ingestion of microplastics is associated with intestinal alterations in marine organisms (Peda et al., 2016). Sea turtles are just one example of these, as they are often led to ingest plastic bags which they perceive as food, namely jellyfish (Werner et al., 2006).

The chemical consequences concern the burden on the environment and organisms from the transport of monomers, polymers and other chemical elements (Freeman et al., 2020). Chemical exposure has negative effects on the health of marine organisms (such as endocrine disruption, liver and oxidative stress), leading to the energetic depletion of organisms and the reduction of the rate reproduction (Freeman et al., 2020). Finally, plastics can act as vectors for pathogenic microorganisms (e.g. bacteria Figure 4.1, viruses) (Freeman et al., 2020). However, research in this field is still limited, with the result that the evidence for their effects on the health of marine organisms, as well as on humans, is minimal (Zettler, 2013).



Picture 3: Microorganisms in marine plastic waste (Source: Zettler, 2013)

4.1.2 Impact to Marine Environment

Every year 5 to 10 tons of plastic end up in the oceans with devastating consequences for the marine environment (Hohn et al., 2020). The exact residence time of these plastics in aquatic ecosystems is unknown and is estimated to range from hundreds to thousands of years (Barnes et al., 2009). Of particular interest are microplastics, which, due to their small size and high surface-to-volume ratio, store larger amounts of chemical and environmental pollutants compared to larger plastic objects (Cole et al., 2011). Microplastics, depending on their shape and density, are found at various depths and interact with different types of aquatic organisms (Cole et al., 2011). Their small size and high mobility result in their quick capture by both plant and animal marine organisms and their subsequent entry into the food chain (Georgatzoglou, 2019).

Also, microplastics are responsible for the transport of invasive species, capable of causing damage to the marine environment, as well as pathogenic microorganisms (e.g. bacteria) (Amuthu et al., 2019). Despite the widespread presence of microplastics in the marine environment, there is insufficient evidence on their effects (Cózar et al., 2014). In addition to microplastics, macroplastics affect the marine environment with their presence. The example of coral reefs is typical, as can be seen in Figure 4.2, where the existence and transport with currents of nets and ropes causes serious damage to the "living" reefs (UNEP, 2016).

Picture 4: Fishing nets entangled in reefs (Source: https://marinedebris.noaa.gov/)

4.1.3 Impact to Human

Marine plastic pollution does not only affect marine organisms and the environment. On the contrary, the presence of plastics - and especially microplastics - in marine ecosystems appears to represent a potential risk to human health (Karbalaei et al., 2018). Microplastics, due to the small origin, they enter the food chain mainly through the consumption of fish, seafood and other marine products, such as salt (Yan et al. 2015). Their size allows them to enter even organisms that are very low in the food chain (such as zooplankton), while important factors for their bioavailability - apart from their size - are their density, the abundance in which they are found and the their color (Desfores et al., 2015, Wright et al., 2013)

The effect of plastics on humans and their health is a particularly complex issue, to which scientific research has not yet provided clear answers (Gallo et al., 2018). According to the International Food and Agriculture Organization (FAO), toxicological data regarding the risks arising from the consumption of microplastics or nanoplastics are incomplete (Lusher et al., 2017).

Furthermore, apart from the microplastics that end up in the human body and their possible negative consequences, plastic waste can affect human health in a variety of other ways. One of them is the injury - mainly to a bather - from dangerously sharp materials, such as various medical objects (e.g. syringes) and to divers, who come into contact with plastic objects submerged or floating in the water (Nelms et al., 2017).

4.1.4 Socioeconomic Impact Due to Plastics' Pollution in the Sea Environment

The burden of marine and coastal ecosystems with plastic waste has significant economic and social impacts (Martínez et al., 2007). The economic consequences are mainly felt in fisheries, where there is a limitation of fish stocks, destruction of fishing equipment (e.g. nets) and fishing vessels, as well as wasted fishing time (Mouat et al., 2010). A particularly adverse consequence in the fishing sector is the "abandoned" nets, which are carried by the currents and trap a large number of marine organisms, negatively affecting both commercial and recreational fishing (Anderson & Alford, 2013). A typical example is the case of the USA, which - according to the United Nations Environmental Program (UNEP, 2009) - lost 250 million dollars in just one year due to the trapping of a large number of lobsters by "abandoned" nets.

At the same time, the consequences of marine pollution in the tourism sector are visible. The plastic objects that end up in the seas and beaches, as can be seen in Figure 4.3, degrade the aesthetic and recreational value of the environment, leading to a decrease in tourists, but also a degradation of the overall well-being (Thushari & Senevirathna, 2020). In research by Wyles et al., it was found that seeing beaches with severe pollution problems has a negative psychological impact on the individual (Wyles et al., 2016). As can be expected, the degradation of the aesthetic side of the environment and the consequent reduction of tourists, brings significant economic problems, especially in areas that rely exclusively on tourism (Jan et al., 2014).

Picture 5: Negative consequences of plastic waste pollution in the coastal and near marine environment (Source: Thusari & Senevirathna, 2020)

4.2 Economic Impact and the Industry

Another approach to how the material ended up in the sea is the man himself who will thoughtlessly dispose of the useless post-use plastic packaging in the water. So, one thought for this category of people is that their careless behaviour towards their waste is due to the level of human development they possess. This level includes responsibility towards nature and the environment. But apart from human development, we look for the causes of the problem in economic factors as well. We wondered whether a country in the high or near-high income category is associated with good waste management and good levels of recyclable waste.

Until the middle of the 20th century no country had a defined environmental policy. The great emphasis on the economic development of each country with the degradation of the environment and the exhaustion of every natural resource with the ultimate goal of economic interest, led to the reduction of natural ecosystems. (Koroneos and Rokos, 2012). Even ingredients derived from the environment began to show a decrease in quality due to pollution. The exploitation of the planet's productive sources, the development of industrial activities, the industrialization of agriculture, urbanization and the increased pollution of aquatic and terrestrial ecosystems with the main purpose of profit marginalized the needs of the environment, which in the course of developments created environmental movements and aroused scientists to express themselves and act (Garside, 2020).

So, looking back at the times we live in, if we focus on industry, someone can notice that it is inevitably the sector with the largest source of plastic waste and promotes plastic in the following common ways:

1) Large quantities of production and supply of products in plastic packaging one use.

2) Manufacture of products with a major component of some form of plastic.

3) Use of single-use plastic tools and materials during or after production use are eliminated.

The industry made up of large and small and medium-sized enterprises, organizations and services operating with the supply-demand method make up the so-called economy. It is the result of a set of processes that, among others, include the ecology of the environment as the main factors. The so-called sustainability economy or green economy is based on the fact that natural resources are not an inexhaustible good. The use of natural resources must be balanced and the entire life cycle (manufacture - use - and finally disposal or recycling) of the products must be taken into account. The natural environment cannot be a recipient of the residues of production but is part of the sustainable cycle of green economic activity (Shahbazi et al., 2018).

The industry sector with businesses or companies recognize the need to implement sustainability practices and tend towards green and innovative solutions but they need the right incentives to invest in them. These are changes in production processes, their products, short-term and long-term decision-making, performance measurement systems and reporting systems, Industrial waste constitutes the largest and most massive amount of waste on a daily basis that can be a disadvantage with economic and environmental costs. Reducing industrial waste is as much about changing behaviour as it is about developing new technologies and processes.

5th Chapter – Law and Regulations About the Sea Plastics' Pollution in the Environment

5.1 Law and Regulations in Worldwide Basis

The pollution of the marine environment has been and continues to be one of the major issues that concern the global scientific community. Plastic objects play a leading role in marine pollution, while a particularly discouraging element is the continuous increase in the total production of plastics (WWF, 2019), which in 2019 reached 368 million tons globally, of which 57.9 million tons were produced in Europe (Plastics – the Facts, 2020).

A number of laws and regulations have been established at the international level with the aim of reducing marine pollution and protecting the marine environment (Sheridan et al., 2020). The United Nations Convention on the Sea (UNCLOS) 1982 is the most important effort made in this direction. This convention has been signed by 167 states and regulates the jurisdictions concerning the marine environment, while defining the general provisions concerning the conservation and protection of the seas (Sheridan et al., 2020). Other important international agreements are the 1972 London Convention on the Discharge of Wastes among other issues as well as the 1988 MARPOL International Convention on the Prevention and Treatment of Ocean Pollution from Ships (Sheridan et al., 2020).

5.2 Law and Regulations in European Basis

During the recent years, important steps have been taken in terms of the management of plastic waste from the marine environment and at European level. Specifically, over 200 Directives and Regulations have been established by various EU bodies, such as the General Directorate of Shipping and Fisheries (Bi a li, 2015). However, despite the number of efforts, the results are not as expected due to the lack of appropriate infrastructure, mechanisms, as well as more general coherence between the Directives (Sheridan et al., 2020).

The European Directive 2008/98/EC established the necessary legal framework for the management of marine waste, the basic principles of which were subsequently modified and are still in force today. In 2015, the European Commission's Circular Economy Action Plan was a particularly ambitious step, upon the aim of reducing landfill, enhancing recycling and the possibility of reusing products (Kolliris, 2019).

Directive 2015/720/EU on plastic bags produced positive results, as the amount of plastic was reduced and at the same time the public was raised (Loizidou et al., 2020). The above directive called on EU states to establish national targets to reduce the use of thin plastic bags, set financial incentives and impose restrictions on marketing. In the same direction, the European Plastics Strategy was published in 2018, which attempted to respond to the large amounts of plastic that continue to end up in the environment. A series of goals have been set, the fulfillment of which wishes to lead to a significant reduction of plastic and an increase in its recycling (Sheridan et al., 2020).

In mid-2021, the Single-Use Plastics Directive is expected to be implemented, which aims to further limit the plastic found in widely used single-use plastic objects and aims for even more positive results for the environment and people (Loizidou et al., 2020). In particular, single-use plastics make up a third of the plastics produced worldwide, while in Europe they make up 50% of marine litter (Abril Ortiz et al., 2020). More specifically, this Directive targets mainly single-use plastics found on European beaches (e.g. glasses, straws), abandoned fishing equipment and biodegradable plastics (Abril Ortiz et al., 2020).

5.3 The Framework Directive 2008/56/EC "Marine Strategy Framework Directive"

The problem of marine litter has led to a variety of measures being taken internationally, based on different policy areas (water, marine, waste, marine products and fisheries policy), some of which focus on reducing entry of marine litter, through different pathways such as waste or sewage systems or through marine sources. For example, at the European Union level, Article 9 of the Joint Communication 1 deals with plastic pollution, in support of Goal 14 for sustainable development under the UN 2030 agenda.

According to the United Nations Environment Program (UNEP), which coordinates the United Nations' environmental activities, helps developing countries adopt strong environmental policies and promotes sustainable development through strong environmental practices, "Marine litter is defined as any manufactured or processed solid materials that have been discarded, deposited or abandoned in the marine and coastal environment. Marine litter consists of items: that have been manufactured or used by humans and have been abandoned by intentionally at sea, in rivers or on beaches; that have been indirectly carried to sea by rivers, sewers, rainwater or wind; that have been accidentally lost, including those lost at sea due to bad weather (fishing gear, merchandise), or intentionally left by humans on beaches and shores" (UNEP, 2009:232).

It is widely accepted that marine resources are often under excessive pressure and that policy action needs to be taken at the international as well as domestic level to minimize the associated negative impacts on the marine environment (Barnes & Metcalf, 2010). To this end, the European legal framework for the protection of European freshwater and marine environmental resources was established, but with some overlap with regard to estuaries and coastal waters.

Initially, in 1980, the "Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities" (UNEP/MAP) was established with the aim of controlling waste entering the oceans and reducing waste as well as of plastics from land-based sources, other legislation followed, such as Directive 2008/56/EC. In particular, the most important legislative acts related to the pollution of marine waters, including plastics and microplastics, are Directive 2000/60/EC (Water Framework Directive - WFD) 3 and mainly Directive 2008/56/EU (Marine Strategy Framework Directive).

Although both aim to achieve good ecological / environmental status, there is a difference between them when it comes to plastic waste. In the Marine Strategy Framework Directive, Guideline 10 "marine litter" - one of the 11 indicators of appropriate environmental status - defines waste, while the Water Framework Directive does not mention this waste. In a possible future revision of the Water Framework Directive this deviation may be removed.

Very important in this regard is the adoption by the European Commission of the Marine Strategy Framework Directive (MSFD) 4 for the protection and sustainable use of marine ecosystems. The Directive is based on sectoral approaches such as the Common Fisheries Policy, Natura 2000 and the Nitrates Directive. It is the environmental pillar of the integrated maritime policy for the European Union, which aims to achieve sustainable development of the marine sectors (Markus et al., 2011).

The MSFD establishes a framework within which Member States are invited to take action to achieve or maintain Good Environmental Status (GES) for the marine environment by 2020. It specifically addresses the management of human activities, recognizing that "environmental condition" also includes the effects of anthropogenic activities.

Based on the Framework Directive, EU member states are obliged to implement six steps between the years 2012 and 2016 to develop a marine strategy for their waters: i) initial assessment of the current environmental situation (Article 8, 2012) ii) definition of good environmental situation (Article 9, 2012), iii) drawing up a comprehensive set of environmental objectives and related indicators (Article 10 paragraph 1, 2012), iv) drawing up and implementing a program monitoring and continuous evaluations, together with regular updates of the set targets (Article 11(1, 2014), v) development of a measurement program that has designed to achieve or maintain good environmental status (article 13 paragraphs 1 to 3, 2015) and vi) implementation of the measurement program (article 13 paragraph 10, 2016).

Following the initial assessment, EU Member States will draw up a series of characteristics defining the EEZs of their relevant waters, taking into account the indicative 'pressures' and 'impacts' listed in Annex III of the Directive. These characteristics must be determined on the basis of the 11 qualitative descriptors listed in Annex I and in relation to Commission Decision 2010/477 / EU on "Criteria and methodological standards for the good environmental status of marine waters", the which proposes 56 indicators. This approach aims to establish coherent criteria and methodologies across the European Union (EU), together with a substantial harmonization of the achievements of good environmental status - GES in different regions.

The Framework Directive 2008/56/EC (Marine Strategy Framework Directive) of the European Parliament and of the Council of 17 June 2008 and other provisions" which was introduced into the Greek legal order by Law 3983/11 "National strategy for the protection and management of marine environment - Harmonization with Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008 and other provisions (Government Gazette 144 /A/17.06.2011).

Regarding the provisions of the Marine Strategy Framework Directive 2008/56/EU (Marine Strategy Framework Directive), which entered into force in December 2000, it does not oblige Member States to take measures against waste in surface waters, but if they do, they must report it. Recital 40 states that "as regards pollution prevention and control, Community water policy must be based on a combined approach that uses the control of pollution at source through the setting of emission limit values and the establishment of environmental quality standards".

Article 10 entitled "Establishment of environmental objectives" describes that "Member States shall establish, for each marine area or sub-area, a detailed set of environmental objectives and indicators for their marine waters to guide progress towards a good state of the marine environment", i.e. institutional framework in terms of controls, emission limit values or best environmental practice in the case of diffuse impacts and further highlights a set of relevant Directives.

Microplastics are not explicitly mentioned in the Marine Strategy Framework Directive 2008/56/EU, although as mentioned above this discrepancy could be addressed in a possible revision expected within 20196. However, Wesch, Klein, & Paulus (2014) argue that plastic waste is already indirectly covered by the Water Framework Directive, 2000/60/EC (Water Framework Directive -WFD), as it currently applies. In their view, since litter - including microplastics - can affect water quality, it is important in determining the good ecological status of freshwater systems.

The framework Directive 2008/56/EU recognizes that the achievement of good GES environmental conditions is not a one-off issue, but one that must continue to evolve and adapt due to the existence of a series of dynamic factors such as ecosystem changes, addition of new scientific knowledge as well as the development of new technological capabilities (Juda, 2010).

Periodic assessments of the state of the marine environment, along with the monitoring of efforts and the formulation of environmental objectives, are considered as part of ongoing management processes. Thus, relevant provisions have been established to modify the approved strategies and measures for the issue in question whenever this is deemed necessary. In 2010 the Commission adopted Decision 2010/477/EU on criteria and methodological standards for the good environmental status of marine waters 7 which established a set of criteria and indicators for each of the 11 description parameters of Annex I of the Directive - Marine Strategy Framework (2008/56/EC) which assesses the extent to which good environmental status is achieved in marine waters.

Subsequently, in 2010, as a follow-up to Commission Decision 2010/477/EU, the Directorate-General for the Environment (Directorate-Gen eral for the Environment - DG ENV) of the European Parliament recommended a Committee for the establishment of a technical subgroup within the GES working group (WG GES) for the implementation of Descriptor 10 of the Framework Directive. Based on the UNEP (United Nations Environment Program) definition (Cheshire et al., 2009), this Commission defined marine litter as any durable, manufactured or processed solid material discarded, or abandoned in the marine and coastal environment. Litter consists of objects that have been made or used by humans and are intentionally discarded or left in the sea or on beaches, including materials carried from land to the marine environment by rivers, runoff, sewage systems or winds. The team's mandate included the following work items:

- ✓ identification and revision of existing data and continued collection of data on marine litter description of needs and methods for data processing and future assessment of marine litter;
- ✓ considering standards for monitoring marine litter;
- ✓ drawing up proposals for the development of impact indicators for each of the regions dealing with the ways of developing the targets (characteristics of GES), the environmental targets and establishing relevant indicators in relation to marine litter
- ✓ discussion of effectiveness of measures to reduce marine and proposal of actions for further research priorities.

The work undertaken by the group resulted in a report entitled "Marine Litter - Technical Recommendations for the Implementation of the Framework Directive"8. This report identifies and presents 15 options (a so-called toolbox) for monitoring marine litter in different marine compartments, together with the biological impact of discarded litter or micro-litter such as microplastics. It also sets out a follow-up roadmap, which together with a detailed work plan, has been approved by the EU Marine Directors Service to further support the monitoring programs carried out under the MSFD Framework Directive, including the development of monitoring protocols and additional recommendations for general monitoring strategies and taking intervention measures.

5.4 The Greek Institutional Framework

The first systematic efforts of Greece to deal with the problem of marine pollution can be found in the 1970s. Specifically, Article 24 of the 1974 Constitution, as well as Law 1650/86 laid the foundations of environmental protection in the Greek area. As can be expected, domestic regulations are in direct relation, supplemented and expanded based on Global and European Regulations, Directives, Conventions and Protocols (Korkizoglou, 2017).

Regarding specifically the management of plastic waste that ends up in the environment, Greece harmonized with the European Directive 1994/62/EC "on packaging and packaging waste" and the following amendments to Directive 2004/12/EC and Directive 2013/2 /EU. The Hellenic Recycling Organization (EOAN) is the competent institution that plans and implements the policy for the alternative management of waste and other products based on Law 2939/2001, as amended by Law 4496/2017 and in force (Korkizoglou, 2017).

Upon the Law 3983/2011 "National Strategy for the protection and management of the marine environment - Harmonization with Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 and other provisions", the Directive was incorporated into the Greek legal order 2008/56/EC (Marine Strategy Framework Directive) regarding the framework for community action in the field of marine environment policy.

According to article 11 of Directive 2008/56/EC, the member states are obliged to designate the competent authority which is responsible for the implementation of the monitoring programs. In Greece, the competent authority for the formulation and coordinated implementation of the monitoring programs of Article 11 of the Directive is the Special Water Secretariat of the Ministry of Environment and Energy. The Special Water Secretariat is responsible for publishing and submitting to the public for comments the summaries of the monitoring programs or their updates and also notifies the European Commission of the monitoring programs within three months of their establishment.

The monitoring programs are formulated by the Special Secretariat of Waters, based on the indicative lists of elements contained in Annex III and the list of Annex V of Law 3983/2011 (Α΄ 144) and in relation to the environmental objectives provided for in article 10 of of the same law and are specified in Ministerial Decision No. 1175/2012 (Β΄2939).

It is obvious that the monitoring programs must cover the requirements of the 11 characteristics of the qualitative description, for the determination of good environmental status defined in Annex I of Law 3983/2011 (A΄ 144) and which as specified in article 4 of N 3983/2011, are called Descriptors. The monitoring programs formulated and implemented by the Special Water Secretariat include information on the network of monitoring points, the frequency of samples and the type of individual scientific parameters to be monitored (criteria and indicators) for each Descriptor, according to the relevant EU Guidance Documents. Regarding plastics and microplastics, they belong to Descriptor 10 "Marine litter" whose criteria and indicators are as follows:

✓ Criterion 10.1: Characteristics of litter in the marine and coastal environment. Environmental indicator

✓ GR 10.1.1: Garbage washed up and deposited on shores. Number of objects per sampling kilometer and waste category. Environmental indicator

✓ GR 10.1.2: Waste on the seabed. Number of items per square kilometer and waste category Environmental indicator

✓ GR 10.1.3: Floating microplastics. Amount of microplastics (pieces per square kilometer) floating on the surface of the sea.

✓ Criterion 10.2: Effects of litter on marine life Environmental indicator

✓ GR 10.2.1: Quantities and composition of litter entering marine animals through ingestion'.

Some researches have focused on the study of the degree of accumulation of plastics and microplastics in the seas and coasts of Greece, they show that the problem exists and in fact is intense in our country. One reason that has contributed to this development, according to previous research, is the density of the population. It is a fact that population densities vary greatly between mainly river basins towards the sea and range from 0 to more than 1000 people per km2 in 2000. Population density is high along the coasts of the northern part of the African continent (Nile estuary, Morocco, Algeria and Tunisia), western Asia (Israel, Lebanon) and parts of Europe (Greece, Italy, the area around the Black Sea, United Kingdom, Northern France, Belgium and the

Netherlands). Population density is lower in large areas of Africa, while in Sweden, Norway and Finland.

Of course, it should be pointed out that the problem of the accumulation of plastics and microplastics is part of the acute problem of the accumulation of plastic waste in the Mediterranean region in general. On the shores of the Mediterranean live, about 10% of the world's coastal population (about 100 million people on the coastline (CIESIN, 2017).

The Mediterranean basin is one of the world's busiest seaways (UNEP, 2009) which receives large amounts of water from densely populated river basins (e.g. Nile, Ebro and Po). In addition, the Mediterranean Sea is connected to the Atlantic Ocean only by the Strait of Gibraltar which aggravates the situation (Lacombe et al., 1981). Estimating both terrestrial and marine inputs, Lebreton et al., (2012) modeled the transport and distribution of floating plastic litter in the Mediterranean. Model simulations identified the Mediterranean Sea as a potentially important plastic accumulation zone on a global scale. Recently, the calibration of this model using a global data set was applied to estimate the surface plastic load in the Mediterranean Sea which amounts to 23,150 tonnes (Eriksen et al., 2014).

The abundance of plastic debris floating in Mediterranean waters was first reported by Morris in 1980 (Morris, 1980). Using a quantitative survey, Morris reported the existence of approximately 1,300 plastic objects per square kilometer in a central area of the Mediterranean basin. However, all other measurements carried out in different areas of the Mediterranean since then have reported less than 200 objects per square kilometer (McCoy, 1988; Suaria and Aliani, 2014).

Surface pollution has also been quantified in surveys, in surface clear waters, allowing the detection of smaller plastic sizes, in the coastal areas of northwestern Italy, southern France (Eriksen et al., 2014, Collignon et al., 2012) and western Sardinia (de Lucia et al., 2014). These studies reported concentrations ranging from tens of thousands to hundreds of thousands of microplastic objects per square kilometer, indicating the abundant presence of microplastics and plastic debris in the Mediterranean basin.

In a study, Cózar et al., (2015) carried out extensive sampling in the entire Mediterranean basin, in order to have the first-order approximation of the magnitude of plastic pollution in Mediterranean surface waters. The concentrations of plastic found in the Mediterranean Sea are compared to these referring to relevant studies of the five areas of accumulation of plastic debris in the open ocean. Based on the results of the survey, plastic waste was found in all the surface networks that end up in the Mediterranean Sea. In particular, five different types of plastic items were identified (pellets/granules, films, fishing lines, foam, fragments), with the majority of items being fragments of larger rigid objects (87.7%, e.g. bottles, caps) and thin films (5.9%. eg pieces of sacks or wrappers).

Eighty percent of the total number of objects collected were smaller than 5 mm in length, commonly referred to as microplastics. The shape of the plastic size distribution was similar to that observed in the accumulation zones in the open ocean, with a gradual increase in the abundance of small-sized plastics and a gap of less than 1 mm, indicating the absence of plastic objects of size less than 1 mm at the surface of the Mediterranean Sea as suggested for the open ocean (Cózar et al., 2014).

However, some differences were evident in the survey, at the lower and higher end of the size distribution. In particular the proportion of plastic below 2 mm was lower in the Mediterranean Sea than in the open ocean, while the relative abundance of all types of plastic above 20 mm in size was higher in the Mediterranean. Regarding Greece in particular, in a study by Kaberis et al., (2012), they studied the distribution of microplastics on the coastline of the island of Kea at the end of the summer season in 2012. The results of the research showed that the northern and southern beaches of more were found on the island of Kea contaminated with microplastic beads and fragments. The fact that the beaches in the western and eastern part of the island were almost free of plastic waste and at the same time with very low concentrations of microplastics reveals, according to the researchers, that the origin of microplastics is the open sea.

Kea is a remote island far from land sources, yet it appears to be very vulnerable to microplastic pollution transported from the open Aegean. The greatest abundance of microplastics, beads and fragments were found at Otzias beach in the northern part of the island. Polyethylene was identified as the predominant polymeric material in pellets and fragments.

In addition, the IR spectra showed that the microplastics in the island's sea have undergone abiotic and biological degradation, which makes them a more suitable substrate for the absorption of persistent, bioaccumulative and toxic pollutants and therefore more harmful to the marine environment. A significant abundance of colored pellets and fragments of plastics and especially microplastics was also observed, which are also important for the marine environment, as these microplastics confuse marine living organisms, which consume them thinking they are food.

Specifically, as part of the research, a total of 20 sand samples were collected on six beaches of the island of Kea, and a total of 3309 plastic objects smaller than 4mm and larger than 2mm were measured, of which 70% were fragments of plastic beads. The highest average abundance of plastic particles was found at Otzias beach (575 objects/m2) in the northern part of Kea. The average density of 218 objects/m2 was found at Koundouros beach in the southwestern part of the island, while at the western beaches of Vroskopou and Xyla 43 and 10 species/m2 were collected respectively. At two beaches of the eastern part, Sikiaia and Kalidonychi, a negligible amount of microplastic particles was found.

5.5 Measures and Monitoring of the Situation

The first and main concern of every country in this particular issue is the proper management of urban solid waste. In countries where municipal solid waste (MSW) management is implemented, plastic is collected for recycling, incineration or landfill disposal Brouwer et al., 2018, Van Eygen et al., 2018, Huysman et al., 2017. In countries that do not have MSW, plastic can be collected by informal waste collectors, but is usually dumped or burned. The uncontrolled disposal of this material has similar consequences. The better and more organized a waste management system a country has, the better it controls the source of plastic waste to the environment originating from waste within each country.

In addition to urban waste that needs better treatment, measures are also being taken for the already existing problem and for its future course. The European Union, like other international organizations, invests in the development of programs to monitor the accumulation of waste and in the creation of tools for continuous monitoring of a situation (long-term monitoring) as in our case of the mass of plastic, which can be easily used by the relevant government agencies and legislators. Here are examples of such applications and networks:

RIMMEL

One such example is the RIMMEL Monitoring Network, set up by the European Commission's JRC (Joint Research Council) to estimate the amount of floating litter on the water surface, ending up via rivers in marine waters, collecting data through a European observation network whose descriptions are analyzed on the official page of the European Commission. The applications from the JRC are intended to control and monitor areas that are difficult to know their situation precisely, as in our case, where the process of collecting data on the amount of plastics in seas and rivers is quite complex and requires many actions for an effective monitoring which still cannot guarantee complete and accurate information. (Huysman, et al., (2017)).

LCA

Large companies and international organizations now make sustainability decisions based on LCA, which as Karin Vann analyses in her related article in Greenbiz, "*is an analysis method that has evolved over the last 60 years to give corporate strategists and policy makers the ability to make sustainability decisions by measuring the environmental impact of various materials and products from "cradle to grave*".

ZEROWIN

In the business sector the EU-funded project ZEROWIN (Kopacek and Schadlbauer, (2012)) brought together different businesses to form regional networks, showing that recycling and reusing waste not only has economic significance but can be easily achieved. The project is based on the concept of industrial symbiosis where a company's waste from a different sector can be a raw material for another company. The report for the said project lists countries that charge fees for the sustainable operation of a business, companies and supply chains that apply a circular economy to their products as well as other innovative environmentally friendly applications are listed, while others manufacture with fully recyclable materials.

Non-profit groups with the aim of promoting the problem through group actions (Plastics for Change, NOAA Marine Debris Program (MDP), HNODC, DAFNI, SeaDataNet, PlasticsEurope, ISWA, ISea, etc.), professional ocean clean-up actions with innovative tools (THE OCEAN CLEANUP, CLAIM) as well as technologies applied to the continuous analysis of the problem link the chain of dealing with plastic water pollution.

Finally, someone could identify another important factor in the measures to deal with plastic pollution. Compliance of suppliers to international standards is also one of the criteria for green solutions by promoting friendly products. Trade is evolving as analyzed by Alan Wm. Wolff in his official speech on trade and climate changes. The goal of many companies now is to minimize emissions of, fewer materials in their constructions and carefully selected to meet the necessary conditions. In other words, we are referring to the procedures that a company should follow to achieve sustainable plastic management.

It is the sustainable design (Santana, et al., 2016), the processes to support system requirements, for the management of complex areas such as that of ecological efficiency, where both processes and requirements are difficult to determine. The processes in Santana's report were designed in Business Process Model and Notation (BPMN). Each case study shows how information is obtained during process mapping and how this information can be used in requirements engineering. Based on this article we find that corresponding procedures can be defined for the sustainable design towards plastic packaging that a company is asked to follow as well as the procedures that it may include in its business model for sustainable results. The report presents key insights into the sustainable model and best practices, as well as a reference process for the design of information systems based on Product-Service System (PSS), Life Cycle Assessment (LCA), social and economic aspects.

The discourse on sustainable plastic management ultimately focuses on the industrial sector with businesses, supply chains, services and organizations. In the private sector they are aware of the problem of plastic and are responding with efforts to reduce excess plastic or circulate products made from recycled plastic.

Start-ups and entrepreneurs have also begun to capitalize on public attention. Each sustainable initiative is an example of business models that attempt to provide an environmental service while simultaneously capturing revenue, and are often called sustainable business models (Dijkstra, Beukering and Brouwer 2020). The study of sustainable business models can help researchers, practitioners and businesses identify barriers and interventions to achieve economic or environmental goals. Sustainable innovation in our time surrounds the circular economy a form of sustainable economy that is considered to be able to offer a noticeable reduction of plastic initially in urban waste and by extension in the aquatic ecosystem that ends up a large part of it and is promoted to be applied to as much as possible more areas. (Fratini, Georg and Jørgensen, (2019), Gupta, et al., (2018), Rossi et al., (2019), TALEB and Al Farooque, (2020), Yadav, et al., 2020).

In conclusion, understanding the factors that support or hinder innovation can be useful in promoting an enabling environment for sustainable innovation with the aim of maximizing outcomes. The only thing that is certain is that we are still at an early stage for the essential evolution of both man and his actions as well as technology to be able to deal with the problem in question.

6th Chapter – EMSA 2016 Guidelines and Initiatives on Plastic Pollution and Prevention

6.1 Global Scale Initiatives

One of the most important measures to deal with marine pollution from plastics is to raise the awareness of all involved entities, “players” of the plastic industry and fishing and consumers - citizens, about the consequences of this environmental problem (Hammami et al., 2017). Public awareness is an integral part of primary prevention strategies and aims on the one hand to reduce plastic waste in aquatic ecosystems, and on the other hand to ecologically awaken and activate the individual (Niaounakis, 2017).

The education of both professionals and citizens is the first component of programs aimed at reducing marine plastic waste (Niaounakis, 2017). Undoubtedly, however, changing attitudes and behaviors is not an easy task, especially when it conflicts with existing and established social norms, knowledge and habits (Ea le et al., 2016). Therefore, well-organized and coordinated efforts using carefully selected educational strategies are required so that the public becomes aware and subsequently takes active action (Black et al., 2020). At the same time, the inclusion of primary prevention programs in schools is considered important, in order to develop ecological awareness and responsibility from childhood (Niaounakis, 2017).

Many environmental campaigns are organized with the aim of informing, raising awareness and educating the public on issues related to marine plastic pollution (UNEP, 2016). The exploitation of the media, modern social networks and multimedia, make possible the immediate and widespread informing people of all ages, genders, ethnicities and educational backgrounds (Boucher & Friot, 2017). The majority of campaigns take advantage of more than one means to achieve their goals, with illustrative examples being television, radio, newspapers, organizing days and conferences, organizing coastal cleanup actions (Coastal Cleanup), designing special applications for mobile phones etc. (Sherrinton et al., 2014).

"Fishing for litter", is an example of a public awareness campaign, which was implemented in the Adriatic-Ionian region and included various activities, such as scientific conferences and social events (Ronchi et al., 2019). The high cost of the above efforts necessitates financial support from government agencies and international organizations, as well as the utilization of charitable initiatives (Abalansa et al., 2020).

The "Sea Surface Marine Litter Cleaning Operation" in Turkey is a successful effort to reduce floating plastic litter. For this purpose, collection vessels are used which transport the waste on a daily basis, in cooperation with the respective Metropolitan Municipalities, to collection warehouses on land and then sent to recycling facilities. The result of the effort, which began in 1999 and continues to this day, is the noticeable reduction of waste on the surface of the sea (Orthodoxou et al., 2014).

The sea cleaning vessel "Battello Spazzamare", ("Sea cleanin vessel "Battello Spazzamare") in Italy includes a vessel for the collection of floating and solid waste in the Italian Marine Protected Areas. During the voyage, the floating waste is collected and stored and then subdivided into various categories such as plastic, glass, aluminum, wood and delivered on a weekly basis to the responsible company of the Municipality. The effort was started in 2005 by the Ministry of Environment and Land and Sea Protection and continues to this day (MARLISCO, 2021).

The "Buy Back" program is another successful effort to reduce marine litter. Developed in 2003 in Korea by the Ministry of Maritime Affairs and Fisheries, it involves the transport by fishermen to ports, of abandoned fishing gear and other marine waste encountered during fishing activities, by paying an incentive fee to fishermen. The program presents a cost-effective way to remove marine waste and at the same time provides an additional source of income for fishermen, thus contributing to the preservation of the marine environment. In addition, it increases the environmental awareness of fishermen, reducing the exploitation of marine wealth and uses the already existing resources, i.e. the fishing fleet (Plan, 2015).

6.2 Eco-Friendly Concepts for Controlling Plastic Pollution - Reuse, Recycle, and Reduction (3Rs) of Plastic

Plastic Pollution Reduce – Reuse - Recycle

The plastic products should be designed in a way that makes them as durable as possible to increase the number of times they can be reused. In this way, it is possible to reduce the amount of plastics consumed daily, helping to prevent their leakage into the marine environment. The advantages of the method include saving money, energy and natural resources (Abalansa et al., 2020). However, many plastic items - either because they are designed to be used once, or because they contain toxic substances and composites - are impossible to reuse or recycle (Ten Brink et al., 2018). The solution, therefore, can be provided through an initial design that will take into account the future of the plastic after its first use (Ten Brink et al., 2018).

Strong political actions to reduce unnecessary plastic packaging from the perspective of short-term use, such as banning the distribution of free single-use plastic bags or increasing the recycling rate of plastic waste, such as the refund system for plastic bottles, are necessary in a regional or national level. Initiatives to promote the recording of the types and amounts of plastic used by companies or communities contribute to increasing responsibility and implementing measures to reduce the use of plastics by the private and public sector (Gallo et al., 2018).

In addition, several types of plastic waste have the potential to be replaced by more sustainable alternatives such as food containers, disposable cups, bottle caps, cotton buds, cutlery, straws and stirrers. Options for these items include, in addition to replacing them, reducing them, changing their design, for example replacing them with materials such as paper and wood, which are environmentally friendly, or designing the lids in such a way that they do not there is the possibility of being detached from the bottle as well as the option of charging by European Member States at their points of sale (European Commission, 2017).

One way to reduce the influx of resistant plastics into the marine environment is the use of biological and biodegradable polymers. Despite the risks involved in the production and use of plastics, their versatile usability and multiple advantages make it difficult to replace and limit them in everyday life. The above reasons led to the development of biological ("bio-based") and biodegradable ("biode radable") plastic polymers, which are often referred to as "bioplastics" (Lambert & Wa ner, 2017).

The bioplastics contain organic carbon, which comes from renewable sources such as plants, animals, fungi and microorganisms (Lambert & Wa ner, 2017). Biodegradation, on the other hand, refers to any chemical or physical change that plastics undergo by natural microorganisms, such as bacteria, fungi and algae (Chia et al., 2020). A plastic can be considered biodegradable if it meets certain conditions: 50% of its mass is organic, it contains certain amounts of heavy metals, 90% of it degrades within six months and its by-products are environmentally friendly (Sol et al., 2020).

The goal of producing biological and biodegradable plastic polymers is to achieve sustainability (RameshKumar et al., 2020), as they can reduce plastic pollution and avoid the depletion of natural resources (RameshKumar et al., 2020). Their ecological value lies in their smaller carbon footprint in the atmosphere, their recyclability and their complete biodegradation and composting (Wierckx et al., 2018).

Today, bioplastics are the fastest growing line of biological products worldwide (Iles & Martin, 2013). In recent years, companies have made significant efforts to replace conventional plastics (e.g., corn-based packaging, corn fiber clothing, sugarcane bottles), while offering economic and ecological benefits (Iles & Martin, 2013). International companies, such as Coca Cola, Carlsber and Tetra Pak, moved in this direction (Lambert & Wa ner, 2017).

The global production of bioplastics is difficult to estimate and is mainly based on forecasts based on the ever-increasing scope of bioplastics, as well as the growing interest of industries to invest in this sector (RameshKumar et al., 2020). According to a report by the Nova Institute (European Bioplastics, nova-Institute, 2018), the global production of bioplastics in 2018, was estimated at 2.11 million tons of which 55% comes from Asia, as shown in Figure .1, while it is expected that in 2023 it will reach 2.62 million tons (European Bioplastics, nova-Institute, 2018).

Re-use in the Construction Industry

The use of marine plastic waste in the construction industry is a new concept for its reuse. The first report of their use in road construction was in 1993 (Lian et al., 1993), as a partial replacement of asphalt/bitumen (Williams-Wynn & Naidoo, 2020). Since then, much progress has been made in this area with a prime example being the construction of over 9,900 miles of road in India (Rajput & Yadav, 2016).

The addition of plastics to asphalt can be done in two ways, the wet and the dry process. In the wet process the plastics, after first being shredded, are added directly to the hot asphalt and mixed enough to obtain a homogeneous mixture. In the dry process, the aggregates are heated and then the plastics are added, preferably in chopped form, thus coating the aggregates before they are introduced into the asphalt mix (Saran, 2019). The use of plastic waste with the above processes, reduces the need to use asphalt by 10%, develops a technology which is environmentally friendly and allows increasing asphalt performance and water (Williams & Ran el-Buitra o, 2019).

Plastic waste in addition to its use as an element of asphalt in the construction of roads, can be used as an ingredient in concrete and mortar. In structures where the imposed loads are relatively small and durability is less important, a certain amount of plastics can be used in the concrete. In addition, plastic fibers can be used in concrete to control cracking, shrinkage and creep, unlike expensive synthetic or steel fibers, potentially reducing costs (Babafemi, et al., 2018). In the study carried out by Bahij et al. for the use of plastics in mortars, it was observed that they enhanced the cohesion of the mortars, possibly due to the smooth surface of the plastic particles compared to sand as well as the low water absorption capacity, causing with excess water an improvement in workability (Bahij et al ., 2020).

Recycling Procedures

Although the recycling measure has been widely adopted in most EU countries, there is still room for improvement. Of course, in order to effectively achieve recycling, plastics should be designed so that they can be easily recycled. Plastic packaging should be the priority area for recyclability design and in this direction the EU (European Union) has committed to make all plastic packaging used in the market easily recyclable by 2030. Achieving this goal can to be carried out through the strategy of Extended Producer Responsibility (Extended Producer Responsibility) which will provide incentives to reward sustainable projects (Bayhaqi & Sin h, 2019).

Between 1950 and 2015, 9% of plastic waste (primary and secondary) produced was recycled, of which only 10% was recycled more than once, while 12% was incinerated (Geyer et al., 2017). The US in 2016 exported 1.3 million tonnes of plastic waste to China and in the same year the UK exported 75% of its plastic waste to other countries (Cole, 2017). It therefore arises the need for countries that export plastic waste to implement measures to increase recycling. The EU in particular, in its effort to increase the demand for recycled plastics, is proceeding to standardize quality standards for recycled plastic waste. In this direction, cooperation with the chemical sector is necessary, in order to ensure that plastics are recycled to higher quality standards so that they can be used in the food sector (Bayhaqi & Singh, 2019).

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7th Chapter – Conclusion

The main concern and strategy of all shipping companies is the prevention of waste production, however there is no specific strategy by shipping companies. Reports from seafarers and ship workers indicate that supplies and materials unpacked on board are not unpacked at port, resulting in a large volume of household waste being produced on board. Also, most merchant ships have a built-in water purifier, but crew and passengers prefer bottled water resulting in a huge amount of plastic waste.

Also, the quantities of waste in Annex V of Marpol are difficult to study and predict as in rare cases a weekly waste production report is kept on board but only the quantities incinerated, the quantities discharged into the sea and discharged to waste reception facilities are recorded. In many ships cooking oil is treated as sludge. However, MEPC 68 states that cooking oil must be stored in a different tank, which is not the case with many ships. Another mixing that happens on many ships is mixing sewage with kitchen waste and then dumping it in the sea which is illegal.

The waste categories defined by Marpol are often not easily defined. For example, kitchen and restaurant waste containing plastics, cans and other packaging materials is treated as food waste. One solution to delivering as much waste as possible to port facilities is to have a strong incentive for accurate information on waste delivery quantities as ports need detailed information. Waste dumped in dump trucks is not recorded in the waste register except for waste delivered to a waste facility or dumped at sea. In addition, there is a need to improve the legal framework as well as control its implementation with sanctions to those who do not follow or degrade it and reward those who protect the marine environment.

The results from the secondary literature review showed that the problem of the accumulation of plastics and microplastics in the Greek seas is particularly high, causing serious concerns about its treatment and evolution. It is a positive fact that significant research is currently being carried out in this area, which we hope will, within the framework of special environmental action programs at both national and supranational EU level, be the driving force for planning effective actions, especially in terms of waste recycling, a sector which, as mentioned above, Greece lags significantly behind.

Of course, the research should develop further and include other areas. This is because while for the Greek coasts there is a lot of data available regarding their pollutant load, their pollution sources, and the accumulation of plastics and microplastics, on the contrary, the data available for the bottom of the Greek seas are rather limited, while the data available for the presence of floating plastic waste in Greek seas, are still limited.

An also important conclusion is that although as analyzed in the context of this study, the institutional framework, nevertheless, seems to be probably ineffective as in the last 15 years there has been a significant increase in plastic waste in the marine environment. This means that there is a necessity to revise the institutional framework and tighten it in order to have long-term positive results, while it is also necessary to tighten the control mechanisms of the implementation of the legislative framework as well.

The massive use of plastics today and the huge amounts that end up in the ocean are undoubtedly an international alarm. Current estimates are over 150 million tons of plastic in the ocean. This means that if the same situation continues, the proportion of plastics in the oceans by 2015 will be one tonne of plastic for every three tonnes of fish, while by 2050, the ocean may have more plastics by weight than fish (Deudero and Alomar, 2015). As the samples from the sea in terms of the accumulation of plastics are alarming, the fight against marine pollution, which to a very large extent is caused by plastics, is one of the areas of interest of the Sustainable Development Goal 14 "Life under water' of the UN Agenda 2010. The 2030 Agenda for Sustainable Development, its associated 17 Sustainable Development Goals (SDGs) & 169 sub-goals were adopted by the 70th United Nations General Assembly on 25 September 2015 by Resolution 70/1. In particular, Goal 14 states that "By 2025, prevent and significantly reduce all forms of marine pollution, in particular pollution from land-based activities, including marine litter and nutrient pollution".

In the context of this necessity, the UN, in 2018, raised the issue of plastics in the oceans among the 6 most important environmental issues (along with climate change, ocean acidification and loss of biodiversity). The main problem with plastics, apart from the fact of their long preservation in the marine environment, is their fragmentation (fragmentation) into tiny pieces (microplastics) and their easy dispersion in the marine environment. It is estimated that five trillion pieces of microplastics, with a total weight of 269,000 tons, have entered the global ocean, without currently having an estimate of their number for the Greek seas.

The accumulation of plastics and microplastics in the marine environment undoubtedly endangers not only the environment but also human life. Durable plastics, with an estimated lifespan of hundreds of years in marine conditions, can break down into micro- and nanoplastics in a shorter time, thus facilitating their uptake by marine organisms throughout the food chain. These polymers may contain chemical additives and impurities, including some known endocrine disruptors that can be harmful at extremely low concentrations to marine organisms, thus creating potential risks to marine ecosystems, biodiversity and food availability.

Of course, at present the data are not encouraging. The global production of plastic products follows a clear upward trend since the beginning of mass consumption and production of plastics in the 1950s and from the global production of 311 million tons in 2014 it is predicted to reach 1800 million tons in 2050. The amounts of plastics leaking into the oceans on a global scale are largely unknown. Reliable quantitative estimates of input loads, sources, and origin sectors represent a significant knowledge gap, but it is estimated that nearly 8 million tons of plastic leak into the ocean each year. It is estimated that the ocean may already contain over 150 million tons of plastic (McKinsey, 2015), of which approximately 250,000 tons, fragmented into 5 trillion microplastics, may be floating on the surface of the oceans (Eriksen et al., 2014). It is also estimated that the total amount of plastic in the ocean will almost double to 250 million tons by 2025 (Jambeck et al., 2015) which probably also represents a pollution load of millions of tons of chemical additives.

Although there is still a need for focused scientific research to fill the knowledge gaps regarding the effects of plastic waste on the marine environment (Wagner et al., 2014), the food chain and human health, the scientific evidence is already sufficient to support actions by the scientific community, industry, politics and civil society to limit the continued flow of plastics and the toxic chemicals they contain into the marine environment.

Without immediate preventive measures, the environmental impacts and economic costs will undoubtedly worsen in the short term. Continued increases in the production and consumption of plastics, combined with wasteful uses, inadequate waste collection infrastructure and inadequate waste management facilities, particularly in developing countries, mean that even meeting already set targets to reduce marine litter remains a huge challenge which is rather empty without a fundamental rethinking of the ways in which we consume plastics in modern societies.

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