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ΤΜΗΜΑ ΝΑΥΤΙΛΙΑΚΩΝ ΣΠΟΥΔΩΝ

ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ

στην

ΝΑΥΤΙΛΙΑΚΗ ΔΙΟΙΚΗΤΙΚΗ

MARINE POLLUTION: MICROPLASTICS, WASTE AND BALLAST WATER

Χαράλαμπος Παλαύρας

Διπλωματική Εργασία

που υποβλήθηκε στο Τμήμα Ναυτιλιακών Σπουδών

του Πανεπιστημίου Πειραιώς ως μέρος των

απαιτήσεων για την απόκτηση του Μεταπτυχιακού

Διπλώματος Ειδίκευσης στην Ναυτιλιακή Διοικητική

Πειραιάς

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ΠΕΡΙΛΗΨΗ

Η παρούσα διπλωματική διατριβή εκπονήθηκε στο πλαίσιο του Μεταπτυχιακού Προγράμματος «Ναυτιλιακή Διοικητική» του Πανεπιστημίου Πειραιώς. Πραγματεύεται το περιβαλλοντικό πρόβλημα της θαλάσσιας ρύπανσης καθώς και το σύγχρονο διαχειριστικό πλαίσιο για την αντιμετώπιση της γενικότερα από τον κλάδο της ναυτιλίας αλλά και ειδικότερα από τα πλοία και την ανθρώπινη δραστηριότητα. Πραγματοποιείται μία εκτενής αναφορά στο ίδιο το πρόβλημα της θαλάσσιας ρύπανσης σε συνάρτηση με το θαλάσσιο έρμα, τα κάθε είδους απόβλητα καθώς και τα μικροπλαστικά τόσο ως μορφή απορριμμάτων όσο ως εισβολείς στο ανθρώπινο διατροφικό σύστημα. Επισημαίνονται επίσης οι ισχύοντες κανονισμοί όπως προτείνονται από τους διεθνείς οργανισμούς και συμβάσεις (MARPOL, BWM, Basel Convention κ.ά.). Τέλος, αναλύονται τα αποτελέσματα χρόνιων επιστημονικών ερευνών όπως και προτεινόμενοι μέθοδοι διαχείρισης και επίλυσης όχι μόνο της θαλάσσιας ρύπανσης αλλά και των επιμέρους προβλημάτων που αυτή δημιουργεί.

Λέξεις κλειδιά: Θαλάσσια Ρύπανση, Βιοποικιλότητα, Θαλάσσιο Έρμα, Απόβλητα, Πλαστικά

ABSTRACT

The present thesis was compiled within the framework of the Postgraduate / Master's Studies in "Shipping Management" at the University of Piraeus. It addresses the environmental problem of marine pollution as well as the modern management system for dealing with it in the maritime sector in general, as well as in vessels and human activity in particular. An extensive reference of the problem of marine pollution associated with ballast water is presented, with all kinds of waste, as well as microplastics, both as a form of waste and as invaders to the human dietary system. The applicable regulations as proposed by international organizations and conventions (MARPOL, BWM, Basel Convention, etc.) are also highlighted. Finally, the results of chronic scientific researches are analyzed, as well as proposed methods of management and treatment not only of the marine pollution but also of the individual problems

Key words: Marine Pollution, Biodiversity, Ballast Water, Waste, Plastics

INTRODUCTION

OBJECT

Its basic object is the emergence of the marine pollution phenomenon from the perspective of commercial shipping as well as the already applied and suggested methods of management – treatment in interaction with the aquatic ecosystem.

TARGET

Its aim is to analyze the aquatic pollution in a global scale, starting from its origins, the size it gained, the types of pollution that came up, the impact of human element and the future strategies designed to contain the issue.

METHODOLOGY

Firstly, this thesis presents original status of marine pollution, followed by the escalation of the problem up to the present day. There are numerous precise examples mentioned throughout this dissertation concerning the Mediterranean ecosystem and its particularities. Furthermore, factors behind the issue are specifically stated, accompanied by the relevant tables or figures. Special reference shall be made to the images used, especially for those that concern the impact of marine pollution to local fauna and flora. A detailed breakdown of the species that were identified as invaders in biodiversity chapter was used. Finally, the thesis is complemented by referencing the Annexes themselves as well as any amendments made upon them throughout the past years.

STRUCTURE

CHAPTER 1

An extensive definition of the term “ballasting” is presented, followed by some figures and data concerning the annual ballast water movement within the merchant shipping industry. Moreover, biodiversity as a notion is thoroughly analyzed and some principles of the Convention on Marine Biodiversity (CBD) are stated.

Reference of critical importance is also made to the alien species which invade and cause harassments to marine ecosystems. Mediterranean Sea does not elude the rule and a list of Mediterranean countries is depicted with emphasis on number of non-native species that each contain.

CHAPTER 2

There is a meticulous description of the invasive species and specifically a wide variety of alien species are introduced; from seabed plants to mussels and invertebrates. Furthermore, not only a series of human diseases caused by these species are mentioned but also substances produced by the intruders' themselves such as toxins are highlighted. Thus, both humans and other marine organisms suffer from the side - effects coming from invasive species. Again, special reference is given to the Mediterranean ecosystem and to the one of Black Sea as well.

CHAPTER 3

At this part of the thesis, a comparison between the consequences of invasive species and the ones of an oil spillage takes place. It shows the resources and efforts put for dealing with oil spillage incidents, unlike that of the invasive species. Society seems to be selectively sensitive towards these matters, not focusing enough on other sources of marine environment harassment.

CHAPTER 4

The fourth chapter of this dissertation introduces the Ballast Water Management (BWM) Convention which is is under the auspices of the IMO. BWM regulates the way through which the industry shall work using specific articles and standards. US Coast Guard and its respective Ballast Water Discharge Standards are also presented. Finally, currently applied methods of ballast treatment are mentioned and compared with each other, ending with the reference to the MARPOL 73/78 Convention and its cargo tank cleaning regulations.

CHAPTER 5

The fifth chapter deals with the types of waste dumped into the oceans including the port ones and the categories of vessel waste. The thesis proceeds with an analytical breakdown of all MARPOL Annexes that concern oily waste, as well as the reference on Basel Convention.

CHAPTER 6

An extended analysis of the plastics in general and microplastic in particularly is presented. There are some special characteristics from which microplastics are defined such as color, density and size. Their origins are also mentioned with a small description of the fouling procedure.

CHAPTER 7

At this chapter, the hazards of transferring microplastics to the food chain are imprinted. It becomes evident that both marine organisms and humans are both in danger from the toxic pollutants that plastic garbage release in the water. Last but not least, the impacts of chemicals originating from the fore-mentioned plastic pollutants are recorded alongside with the Stockholm Convention which was adopted to encounter it.

CHAPTER 8

The eighth chapter presents the conclusions of the thesis, personal concerns and some indicative solutions that can assist with the encountering of the marine pollution issue.

1 BALLASTING

Ballasting is a basic and crucial process for the proper navigation of vessels on condition that they do not carry the required number of tons or on condition that they carry no cargo at all, in order for the propeller to be underwater. In general, a vessel is able to load ballast water during its entrance in a port, so as to keep the propeller sufficiently sunk, preserving thus a safe passage under bridges and discharges ballast so as to safely sail through areas with reefs. This process ensures the stability, trim and flexibility of the vessel during a voyage by aiding the propulsion plant in retaining its efficiency or in case of intense storms when more stability is required. In other words, the ballast water's main function is to offset the changing effects of tonnage distribution within the ship structure. Naturally, every vessel type differs on the ballast management. Specifically, heavy cargo loads such as fuels, transported goods and spare parts – machineries are spread over the entire length of the vessel affecting its stability and resistance. Consequently, regarding the application of ballast practice, shipowners ensure that their assets sail in a manageable balance and weight. Ballasting shall always be carried out under some strict regulations imposed by the responsible shipbuilder and the Classification Society so as to avoid any potential bends, curvatures or permanent deformations into the ship's holds.

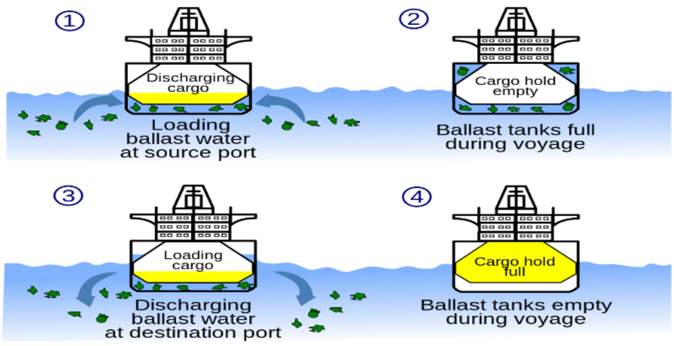

Diagram 1: Diagram showing the water pollution of the seas from untreated ballast water discharges (Hartmann 2014)

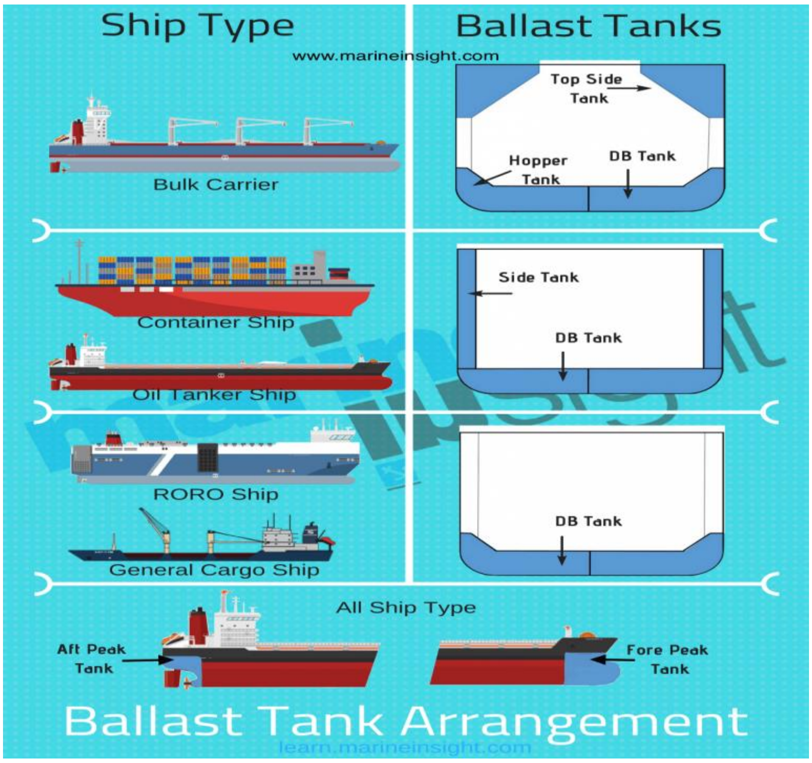

Image 1: Ship and ballast tank types. As depicted, tanks vary depending on the type of ship they are belong to. Likewise, the same rule applies for tanks' positions (Wankhede 2019).

1.1 BIODIVERSITY

Seaborne trade accounts for about 90% of the global trade, and as per UNCTAD covering 998 billion ton-miles (2016 estimate). At an annual basis, vessels move more than 12 billion tons of ballast water around the world. Similarly, at a daily basis more than 7000 animal species are being transported within the ballast water tanks. The overwhelming majority of those aquatic species transported within the ballast water do not survive the voyage, as the cycle of loading - discharging (shown previously in Diagram 1) and closed-off environment inside the ballast water tanks can be highly hostile towards the survival of those organisms. Therefore, it is by nature rational that biodiversity (marine ecosystem, flora and fauna) gets severely affected. Likewise, the global economic impact of invasive aquatic species has not been thoroughly quantified but is likely to be estimated in terms of tens of billions of US dollars per accounting year. At this point, the contribution of ballast water to the disturbance of the 'marine biodiversity' needs to be extensively analyzed. But prior to proceeding with the analysis, a brief definition of the term 'biodiversity' shall be stated. It consists of species and ecosystemic diversity. According to the second article of the Convention on Biological Diversity (CBD), biodiversity is defined as:

> "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." (Convention on Marine Biodiversity, (1992) 'Article 2 Use of Terms' https://www.cbd.int/convention/articles/default.shtml?a=cbd-02

1.2 ALIEN SPECIES – INTRUDERS FOR MARINE ENVIRONMENTS

The term alien species also known as exotic, invasive and non - endemic species are described as species of fauna and flora that have been intentionally or unintentionally introduced into a new ecosystem and have dominated it since they have spread there, having established populations in it (IUCN, 2002). In ecosystems from which the species originate, there are physical interactions which control their populations such as larger species of predators, parasitism and diseases and prevent their hyper-growth. But their introduction in a totally new ecosystem is not always compatible with these interactions, turning them often into intruders in it.

Subsequently, with the definition of the International Association for the protection of nature, which was adopted by the Conference on Biodiversity, species-intruders are those installed in a natural or semi-natural ecosystem or environment and they have become the reason of change, increasing their populations and their distribution, threatening thus the native biodiversity (IUCN, revised 2012). The total sum of these harmful organisms, pathogenic or not, is one of the most basic sources of marine pollution. Introduced in places out of their natural range by the human element and can be harmful both to biodiversity and to the ecosystemic setting since they often collide or replace native species and cause complex changes in the structure and operation of the new ecosystem that hosts them (Galil, 2007, 2009). We could say that species - intruders owe their colonization success to new ecosystems in specific characteristics which make it more difficult to be controlled. Such characteristics include the ability to thrive in different environments and to withstand a wide range of environmental conditions, the high growth and rapid recreation rates, the lack of natural predators as well as the potential of taking advantage of a wide variety of feed sources (Otero M. et al., 2013).

1.2.1 THE EXAMPLE OF MEDITERRANEAN SEA

Marine invasive species are considered as one of the main causes of biodiversity loss in the Mediterranean Sea, potentially altering all aspects of aquatic and freshwater ecosystems (Otero M. et al., 2013). More than 5% of marine species living in the Mediterranean are considered as non - native species (Zenetos et al., 2012). They are a huge problem, amongst others, because of the unprecedented rate of their introduction and so the unexpected as the harmful impacts they have on the environment, economy and human health (Galil, 2008).

Country	Number of non native species
Albania	9
Morocco	10
Algeria	11
Slovenia	11
Croatia	18
Malta	23
Lybia	31
Spain	39
Syria	45
Tunisia	50
Cyprus	75
France	83
Greece	88
Lebanon	113
Italy	120
Egypt	141
Turkey	182
Israel	261

Table 2: Number of non – native marine species in Mediterranean countries (Zenetos & Polychronidis 2010).

2. INVASIVE SPECIES

Given the fact that the marine ecosystem is indisputably the richest source of life on planet Earth, housing more than 250,000 discovered species and probably thousands more that are yet to be discovered - Europe's marine biodiversity of higher organisms is assumed as the best known in global scale - it is apparent that new non-endemic species of living organisms (zoobenthos), plants (phytobenthos) and pathogens become a threat to a specific biodiversity through their invasion into it. One distinct instance of these living organisms are the freshwater *zebra mussels (Dreissena polymorpha),* native to the Caspian, Black and Azov seas which are believed to have been transported to the Great Lakes via ballast water from a transoceanic ship. Zebra mussels are mostly responsible for damages on the local fisheries and aquacultures as well as stocks of shore drinking water. According to a 2015 research (Matej 2015), the approximate estimated sums that had to be spent for reparations and damage checks for the long – term period of 10 years exceeds the amount of 500 million US dollars. They also cover and replace the native mussel species that are eventually led to extinction.

In the same context, *water primrose (Ludwigia grandif lora***) (**Hook & Arn 2017) which is a plant species found in the seabed as well as the wetlands, has appeared to be highly invasive not only in the Baltic Sea but throughout European aquifers, too. It is responsible for exterminating fish and other marine species by preventing them from absorbing oxygen. Also, *green crabs (Carcinus maenas)* (Wikipedia 2019) which were transported from European coasts to Australia and South Africa, are to blame for increased incidents of cancer to native human populations.

Similarly, *toxic dinoflagellates* have spread not only in many European regions but across the globe, too, through vessels' ballast. Under certain circumstances, they multiply in an extremely rapid manner, forming the "red tides". On condition they get absorbed by clams, scallops and other shellfish they are able to release toxins causing paralysis or even worse death to humans who are going to consume this kind of shellfish. Last but not least, the *sea squirt (Styela clava)* is an immobile marine invertebrate which extracts food such as planktonic and other organic material from seawater pumped through a branchial sac in its body cavity. Originally, it could be found within the wide region of China, Japan and Korea but it has currently invaded the waters of Australia, northwest Europe and USA. The sea squirt is usually responsible for biofouling upon vessel hulls as well as harassment of local food chain.

2.1 ISSUES CAUSED BY INVASIVE SPECIES

Except for the natural habitat, all these invading species can be a threat to human health, too. Amongst others, some significant issues that intervening organisms cause are:

- Biological and chemical changes within the natural environment
- Disruption of the ecosystemic stability and balance
- Alteration of nutritional cycles and food chain
- Deterioration of sea-water quality as well as its acidification
- Introduction of highly infectant diseases
- Formation of new hybrid and potentially dominant species
- New modifications to native species and acquiring of new behaviors and features (World Maritime University 2013)

Regarding the impact of distorted marine biodiversity on human health, it has been noted that in coastal zones with higher density population, the exposure of human element to hazardous consequences is remarkably increased. These adverse impacts on human health can cause certain diseases such as Cholerae (caused by the bacterium *Vibrio Cholerae), Escherichia Coli* and *Cryptosporidium*. Special reference to the disease of cholera shall be made as the deadly impact it left to the coasts of South America was massive. In particular, the transport of cholera began from Argentina during the early 90s. According to the scientists, in 1991 the bacterium of Vibrio Cholerae originally infected three Peruvian ports and periodically spread throughout the continent of South America. Its deadly path left behind 1,000,000 persons as patients and 10,000 dead. Of course, these diseases are the results of harmful pathogens and bacteria in water and / or seafood. Upon the transfer of the above-mentioned pathogens to the aquifer, the contribution of ballast water dumping and the sediments that it contains, is further addable. At the same page, biotoxins cause food poisoning. Accordingly, phytoplankton is responsible for the production of massive blooms which result in oxygen depletion leading to mass mortality of marine life.

In addition, some species of phytoplankton produce toxins that accumulate in fish and shellfish and may therefore be transmitted to humans (WHO, 2003). As World Health Organization (WHO) stretches, the latter may suffer from diarrhea, amnesia, paralysis and neurotoxic poisoning, and possibly even pass away. Fish and shellfish do not stay intact from biodiversity distortions. Particularly, nutrition gaps are noted owing to constant disruptions to primary production. Furthermore, the marine habitat gets disturbed and fish tend to turn into voracious predators, complicating thus the trophic pyramid.

2.2 BLACK SEA ANCHOVY EXTINCTION

The Black Sea anchovy can be characterized as a representative sample of fauna harassment. The Black Sea anchovy was almost extinct in the 1980s due to the invasion of a foreign medusa (jellyfish) species of *"Memphiosis Leidyi"* which is considered to have been introduced into the Black Sea during the 1980s by mistake, possibly through the water used for ballast by tankers. Regional overfishing had already reduced the abundance of fish and had created ideal conditions for the invader to spread. The decreased number of plankton-consuming species caused an increase to the population of *"Memphiosis Leydyi"* and the breakdown of sea water fisheries (such as anchovy).

2.3 THE CASE OF MEDITERRANEAN SEA

These invasive species often can change the structure and function of the environment. For example, the intrusion of an ecosystem from alien herbivores species like the *silver-cheeked toadfish (Lagocephalus sceleratus*) (Froese R., 2006) may alter the landscape of rocky coast with algae, stripping them as time goes by. A similar case is that of the clam *Ruditapes philippinarum*, which apart from the fact that displaces native species, has a negative impact on the surrounding area since the harvesting process from fishermen has increased the loads of suspended solids (Occhipinti A., 2002). In addition, the vulnerability of an ecosystem towards invasive species has to do with the state of the environment: polluted or environmentally degraded places are more likely to accept the invasion of alien species rather than healthy parts. One example is the sea worm *Hydroides elegans (serpulidae)* which has already dominated the aquatic fauna of marinas with contaminated water, whereas it is rarely found in marinas with clean water (UNEPMAP, 2010).

2.3.1 MEDITERRANEAN PLANTS

Non - endemic macroalgae (seaweed) are very likely to develop an invasive persona to new coastal areas due to their ability of easily monopolizing the new surrounding area (Otero M. et al., 2013). The Mediterranean already holds the highest number of invasive plants in the world. More than 60 macroalgae have been introduced and 8 or 9 of them have been proven to cause serious intrusions (Piazzi and Balatta, 2009; Boudouresque and Verlaque, 2002). The two most common types are the algae *Caulerpia taxifolia* and *Caulerpia racemosa*. The first one creates dense layers on the bottom that hinder both marine life (closing sea pathways, displacing other plant species, reducing the available space for nutrition and reproduction of fish, etc.) as well as for humans (difficulties in diving, parasitism etc.). Moreover, the toxins produced make it unpleasant in taste so that not to be preferred for consumption by herbivores fish and in combination with the fast growth rate (one sprout - propagule is sufficient for creating a colony) and to make its spreading even easier (UNEP-MAP, 2010). The relative species C. racemosa again, thanks to the rapid growth of the offshoots, can overlap other macroalgae, mostly turf and encrusting species. It has been noticed that the growth of C. racemosa in the seabed causes problems to fishermen, too by blocking or filling their nets with algae (UNEP-MAP, 2010).

2.3.2 SEDIMENTATION

Before proceeding with presentation of the problem, a closer look to the above-mentioned sediments shall be made. During the navigation of the vessels, a sedimentation procedure is performed inside the ballast tanks where specific aquatic micro-organisms such as fish eggs, larvae and seaweed floating particles accumulate and sink at the bottom of the holds (adult micro-organisms can reproduce and release larvae into the ballast, while adults remain into the sediments), as well as in the transverse and longitudinal elements of the ship which form parts of the construction. Therefore, the anticipated impact of this so-called sedimentation is in fact the organic concentration itself. Systematically, larger organisms survive by feeding upon the smaller ones. When they face harsh conditions, some micro-organisms and plankton species will proceed into forming “spores” or other species coated with hard integument for protection. Under the form of a “spore”, an organism can survive for a considerable amount of time without food or in an environment with different salinity and temperature from its original one. The organism reenters its original state once the marine environment becomes favorable again, such as reaching a new port.

3 INVASIVE SPECIES IN COMPARISON WITH OIL SPILLAGE

Perhaps an unorthodox method to highlight the importance of the marine biodiversity harassment owing to ballast water invasive microorganisms would be to directly compare it with the unfortunate and major in-sea oil spillage incident. The latter is truly a biological disaster, forcing the international community to conduct an ongoing and fruitful attempt to tackle it. Unfortunately, it is still difficult for common people to conceive how the effect and influence of the transferred microorganisms through ballast can cause long-term serious adverse effects on humanity and the environment. Whereas the effects of oil spills were gradually reduced as they are being taken care of by the international community, the consequences from the invasion of aquatic species, though invisible, may be catastrophic and irreversible as the population grows. In contrast with oil spillages, where a spectrum of response has actually been developed through the application of decontamination practices, since the moment that a micro-organism invades and creates a sustainable for him environment, it becomes almost impossible to detach him. To date, there have been no records of successful rebuff and eradication of aquatic invasive organisms located in the high seas.

The solely exclusive cases of successful control which have been recorded, were when invading species were detected at an early stage in closed waters such as those of a marina or a small bay where they can be enclosed and use biocidal products against them.

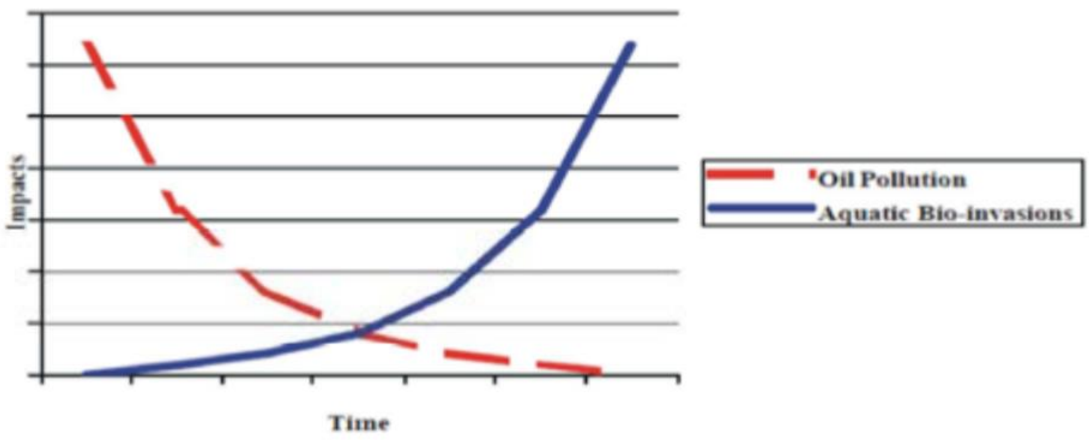

Figure 1: The relationship of the effects of aquatic organisms in relation with the oil spillages are inversely proportional (Alaa, M.I. & Manal, M.A. 2012).

4 International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM)

International Convention for the Control and Management of Ships Ballast Water and Sediments was established in 2004. The Convention is under the auspices of the International Maritime Organization (IMO) and aims to prevent, minimize and ultimately eliminate the transfer of harmful marine organisms and pathogens through the control and management of ships' ballast water and sediments.

4.1.1 IMO

At this point, a thorough description of the key characteristics of the IMO shall be placed. The International Maritime Organization (IMO) is a specialized agency of the United Nations tasked with developing regulations for the shipping industry. Their mission statement is to ensure "safe, efficient shipping on clean oceans," reflecting a commitment to safety of life at sea, to working with the industry to ensure it can carry out its work, and to the protection of the marine environment. Founded in 1959 originally as an inter-governmental organization, the Intergovernmental Maritime Consultative Organization (IMCO), the IMO changed its name in 1982, reflecting a stronger commitment to a vibrant international institution (IMO, 2004).

The IMO is headquartered in London, UK (the only UN agency currently located in London), and has a Secretary-General and Secretariat comprised of several hundred full-time employees. An Assembly of national delegations from its currently 169 member states is the governing body of the IMO and the negotiating work is assigned to several Committees, separated by topic (e.g. Legal, Safety, Environment, Technical Co-Operation), and this work is further delegated to Sub-Committees.

4.1.2 BWM AND USCG

In the 1990s, the IMO developed guidelines for the control and management of ships' ballast water, while at the same time preparing for a binding international treaty. This was finally put into practice at a diplomatic conference in 2004, which adopted by consensus the “International Convention for the Control and Management of Ships’ Ballast Water and Sediments (BWM Convention)” (IMO, 2004). The BWM Convention eventually entered into force in 8th of September 2017, taking thus 13 years from adoption to enforcement. At the end of 2017, 80 states (including China but not USA) constituting 80% of the world’s merchant gross tonnage had ratified the Convention. The US is not a signatory to the Convention and has a separate national legislation on ballast water. The US Coast Guard (USCG) regulations are coupled to the scheduled drydocking date, but the discharge standards are similar with IMO requirements. According to some estimations, BWMC will have been fully implemented by the end of 2024 (for vessels less than 400 GT).

4.2 REGULATIONS D-1 & D-2

The BWM Convention provides a set of management tools through which the maritime industry can be regulated. The Convention is divided into Articles (22 Items) and an Annex with Section A-E which includes technical standards and requirements. Under the Convention, all ships in international traffic are required to manage their ballast water and sediments to a certain standard, according to a Ship-specific Ballast Water Management Plan. At its core are two different protective ballast water management regimes with a sequential implementation: 1. Ballast Water Exchange Standard (Regulation D-1) requiring ships to exchange a minimum of 95% ballast water volume at least 200 nautical miles from the nearest shore and in waters of 200 meters depth or more (for US waters 200 nautical miles and 2000 meters in depth). The volume of each tanks gets pumped through three times. According to the same Regulation “a ship shall not be required to deviate from its intended voyage, or delay the voyage, in order to comply with it“; 2. Ballast Water Performance Standard (Regulation D-2), which requires that discharged ballast water contain viable organisms only in numbers below specified limits. The D-2 discharge standard necessitates installation of a treatment system that removes or sterilizes organisms before the discharge of ballast water in the port of call. In order to ensure uniform implementation of the Convention, a set of regulatory and technical guidelines were needed, which the IMO developed together with representatives of the member states, industry, and other organizations.

4.2.1.1 D-2 STANDARD

Regarding the implementation of D-2 Standard on the fleet, each vessel must have onboard:

i) International Ballast Water Management Convention confirming compliance with the D-2 standard, ii) a type approved Ballast Water Management System (BWMS) installed, iii) an IMO type approval certificate, iv) an approved Ballast Water Management Plan, v) Operational and safety manual for the BWMS and vi) an installation survey report to confirm compliance if type approval requires.

As it was already foreseen that one option of ballast water treatment would be the use of active chemicals or radiation to achieve the D-2 standards, regulations had to be put into place to make sure that the employment of such treatment methods would not cause inacceptable risks to the aquatic environment, human health, or the safety of the ship itself. Hence, IMO guideline G8 (IMO, 2008a) outlines the approval requirements of ballast water management systems (BWMS) by competent flag state authorities and IMO procedure G9 (IMO, 2008b) controls the approval of specifically those BWMS that make use of active substances, which must be endorsed by the IMO Marine Environment Protection Committee (MEPC).

4.2.2 BWDS

Except for the Ballast Water Exchange Standards, the existence of Ballast Water Discharge Standards (BWDS) (adopted and applied by US Coastal Guard) shall be marked. The role of BWDS is to protect the environment and provide targets for treatment efficacy. Literally, it can be said that is is the backbone of a series of sensible, quantitative environmental regulations. The six biological ballast water discharge standards: 1. For organisms greater than or equal to 50 micrometers in minimum dimension, discharge must include fewer than 10 organisms per cubic meter of ballast water. 2. For organisms less than 50 micrometers and greater than or equal to 10 micrometers, discharge must include fewer than 10 organisms per milliliter (mL) of ballast water. 3. For live Escherichia coli the concentration must include fewer than 250 colony forming units (CFU) per 100 mL. 4. For live Enterococcus spp. the concentration must include fewer than 100 CFU per 100 mL. 5. For live Vibrio cholerae, regarding Serotype O1, the concentration must include fewer than 1 CFU per 100 mL. 6. Again for live V. cholerae, regarding Serotype O139, the concentration must include less than 1 CFU per 100 mL. ([1] Welschmeyer, et al, 2019) According to Welschmeyer, two-thirds of Ballast Water Discharge Standards are scientifically irrelevant; specifically, BWDS for pathogenic bacteria provide little, if any, useful quantitative information for treatment efficacy, environmental protection, or Type Approval determination. This phenomenon takes place due to the fact that 80% up to 100% of uptake ballast water passes with no treatment whatsoever.

4.2.3 BWM CONVENTION ARTICLES

Getting back at the BWM Convention, according to article 2, all country – members are obliged to take measures such as prevention, decrease or / and extinction of dangerous marine organisms and other pathogens through control and management of ballast and vessel sediments. Article 5 of the convention refers to the ports' and terminals' ability to provide reception for the sediments during a reparation or cleaning process of ballast tanks. Article 6 alongside, urges country – members to conduct scientific and technical research - either individually or in cooperation with each other – on ballast management as well as the its impact on the aquifer within their jurisdiction.

Vessels are obliged to undergo both an inspection and certification (article 7) but it is possible to be inspected from port state control officers (article 9) who verify the valid certificate of the vessel (book of ballast reports). BWM's Convention annex and specifically on the second part, is stated that all vessels should possess and apply a ballast water management plan that was approved by the qualified authority (B-1 regulation). This plan is unique for each vessel and contains an analytic description of all actions towards the application of ballast management demands but also for supplementary practices. B-2 regulation is referring to keeping a book for ballast water that records data each time the vessel loads ballast, its use and its discharging. B-3 regulation contains a detailed breakdown of the ballast management demands:

i. Vessels built before 2009 with ballast capacity between 1500 and 5000 cubic meters have to execute the ballast management system until it reaches the ballast water exchange levels or operate in an efficient way till 2014.

ii. Vessels built before 2009 with ballast capacity less than 1500 or more than 5000 cubic meters have to execute the ballast management system until it reaches the ballast water exchange levels or operate in an efficient way till 2016.
iii. Vessels built in 2009 or afterwards but definitely before 2012 with ballast capacity over 5000 cubic meters have to execute the ballast management system until it reaches the ballast water exchange levels according to the fore-mentioned D-1 or D-2 till 2012 and operate in an efficient way until 2016.
iv. Vessels built before 2009 with ballast capacity less than 5000 cubic meters have to execute the ballast management system until it reaches the ballast water exchange levels or operate in an efficient way.

4.3 TREATMENT OF BALLAST WATER

It is of vital importance that the effective management of ballast water and the methods that have been developed for its treatment are continually counterpoising the issue. These methods of ballast treatment are divided into two categories: a) processing ballast water within the port, b) processing ballast water within the vessel itself.

Regarding the first method of ballast treatment, the deposition of ballast within the port of destination takes place in specially designed facilities that ensure the safe release of the ballast once the process is completed. After this stage, there are specially designed facilities for seawater in which the vessel must move to. Thus, the vessel absorbs clean ballast upon departure, whereas ballast is not deposited in destination ports, but is stored in clean tanks and finds its way back into the departure port.

When it comes to the second and most popular method of ballast treatment, there are two categories for processing the ballast water: the continuous category and contiguous flow one. Continuous ballast treatment means that ballast tanks are being emptied and filled in a constant flow using the water from open sea. Water separation is achieved via natural ways such as filtration system and cyclonic separation (vortex).

Contiguous flow means that there is a partial filling and emptying of the ballast tanks. In contrast with the first category, the second contains certain processed methods. To be more precise, vessel tanks have undergone a series of mechanical and chemical methods either independently or in a combined manner. Usually, the most widespread methods of natural separation are the thermal treatment, the ultraviolet radiation - light, the ultrasound technique and the electrical-magnetic field. The chemical methods include the use of biocides, chlorine, electrochlorination, hydrogen hyperoxide, peracetic acid, ozone, chlorine dioxide, etc.

4.3.1.1 UV IRRADIATION

As for ultraviolet light – irradiation (UV), high UV light dose is often used for killing or inactivating the majority of organisms, blocking not only their reproduction but their metabolism, too. At the stages of ballasting and de-ballasting ultraviolet light serves as filtration / disinfection method. Its most major drawback is that UV irradiation is not effective when water contains floating matter, therefore ballast should be filtered before the process. It shall be marked that this treatment – neutralization is performed twice during the fore-mentioned stages.

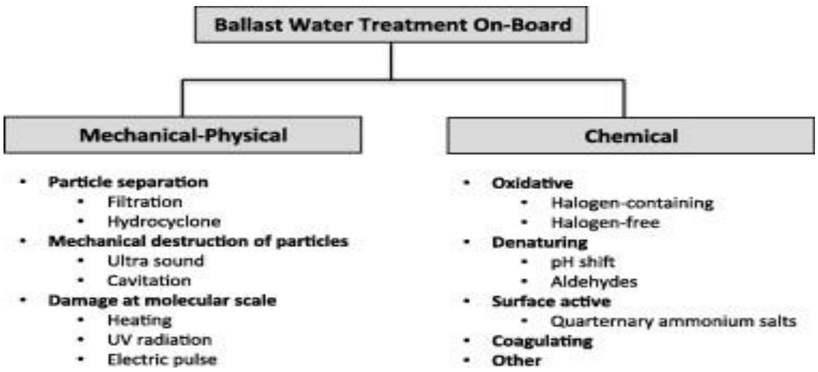

Fig. 2. Overview of ballast water treatment measures on board a ship.

4.3.1.2 ELECTROCHLORINATION

Concerning electrochlorination, the salinity of seawater is used for producing chlorine by the process of electrolysis, aiming to total extermination of ballast organisms. In comparison with ultraviolet light, at the stage of ballasting only, chlorine serves as filtration / disinfection method. Regarding the stage of de-ballasting, in case that there is too much chlorine remaining in the water [scientific community calls the effect "Total Residual Oxidant" (T.R.O.)], electrochlorination serves as neutralization.

Whatever applied for UV light treatment, applies also for electrochlorination exactly with the same time frequency, in the exception that after five days of ballast water remaining within the tanks, neutralization process is no longer necessary. According to some recent studies, chlorine might react with seawater, creating toxic chemicals; perhaps discharging of ballast water is not as safe as previously thought.

4.3.1.3 CHEMICAL DISINFECTION

The last method of ballast water treatment is the one with the assistance of chemical products. The main idea is just to add an active chemical substance in order to kill the organisms inside the tank. At the stage of ballasting, a plain chemical disinfection / treatment takes place, while at the stage of de-ballasting chemicals are not applicable. This null treatment – neutralization during de-ballasting is performed only once.

4.3.2 CENTRIFUGATION

Cyclonic separation - also known as centrifugation – is based on density differences so as to separate aquatic micro-organisms and sediments from ballast water. Hydro-cyclones create vortexes which force heavier particles to move towards the external boundaries of the rotating flow where they get trapped into special hydro-barriers from which they can be rejected prior to entering the ballast tanks. This method entraps particles with sizes from 50 to 100 millimeters. However, these systems face a specific challenge: several tiny aquatic organisms have similar density to the one from seawater, creating thus a tough condition for their removal with the use of cyclonic separation.

4.3.3 OZONE

Ozone is an oxidizing biocidal used for disinfecting the water stocks. Ballast gets processed while it is flowing through a device which inserts nitrogen gas to the water. Most of the nitrogen gas gets dissolved in the water, decomposes and reacts with the rest of chemical used in the ballast for exterminating the organisms. Ozone has three advantages: a) n order to make it functional there is no need to react with a chemical, b) no harmful chlorine by-products are formed and c) its highly effective regarding sweet fresh water. Ozone is toxic for human health and therefore the amount of ozone that cannot be dissolved must be destroyed before being released in the atmosphere. Ozone is usually highly effective against tiny micro-organisms rather than bigger ones, hence combining it with some other system specialized in eradicating bigger organisms would be more effective than using solely ozone. Perhaps, the major drawback of this system is its large size as well as the potential harmful / toxic chemicals (caused by the reaction with seawater) that should not be released in the environment.

4.3.4 THERMAL TREATMENT

Thermal treatment can be utilized for extermination of foreign micro-organisms by heating up the ballast water inside the tanks in a temperature high enough before being released back to the sea. Temperatures fluctuate between 35℃ and 45℃ and shall be maintained for quite some time to be effective. The source of the wanted heating can be easily found by the vessel's main engine. Certainly, the main engine itself cannot produce the desired degrees of temperature needed for the extermination of all bacteria. The solution is given by extra installations of heating production with a high cost of operation at a daily basis (Rigby et al. 1999, Rigby et al. 2004). Another restrictive factor is the amount of temperature than can come up which is not enough for the heating of huge ballast amounts. Owing to this reason, the voyage which will be conducted by the vessel applying that particular system must be big so as to have enough time period for high temperatures to be created.

4.3.5 ULTRASOUNDS

Ultrasounds are made with the aid of converters of mechanical or electrical power in vibrations of high frequency. This system is based on physical and chemical changes caused by the cavitation effect. Tiny bubbles are formed due to the sudden change of water pressure that rupture micro-organisms' cell membranes (Viitasalo et al. 2005). There are two types of ultrasounds: ultrasounds of low volume and ultrasounds of high volume. The first are not used for the eradication of micro-organisms, in contrast with the second that have the potential to produce vibration to the liquid exposed to the ultrasounds, so that they are able to destroy micro-organisms and bacteria in an efficient way. A specialized technology for ballast management has been developed but not on its full length. The latter is called "Electro-Ionization Magnetic Separation" and is still in the stage of studying as on ground test field it was effective against tiny sized organisms.

4.3.6 INERT GAS TECHNOLOGY

To sum up, a large number of Ballast Water Treatment Systems (BWTS) make use of "active substances", which are defined, according to the IMO, as "substances that have a general or specific action on or against harmful aquatic organisms and pathogens This interpretation of the definition is not accepted by the whole marine community. The majority of the above-mentioned treatment and management systems have already been assessed and approved by the IMO G9 guidelines with the exception of one management system which relies on the so-called 'inert gas' technology: Inert gas is simply a gas mixture, which is generated by the combustion of high purity fuel, released then into the ballast tanks, where its main purpose is to replace oxygen and thus create an anoxic environment. The conditions within the tank become so adverse that many organisms cannot survive. However, this practice poses a critical risk for the treated water. At the same time, elevated carbon dioxide levels in the combustion gas decrease the pH in the water, and several trace compounds such as sulfur and nitrogen oxides or aldehydes may contaminate the treated water.

The application of BWTS could be significantly abridged if vessels might avoid taking Ballast Water:

- In shallow waters.
- In vicinity of sewage out-falls or dredging operations.
- In areas with toxic phytoplankton blooms (harmful algae blooms such as Red tides).
- Where tidal flushing is poor or where the incoming or outgoing tide is known to be turbid.
- At night when bottom dwelling organisms may rise up in the water column.
- Near a known outbreak of diseases communicable through ballast water (e.g. cholera).

4.3.7 GLOBAL COMMUNITY AGAINST BALLAST WATER POLLUTION – MARPOL 73/78

Global community has gradually undertaken the dealing of that severe issue, with the form of conventions. The latest sample of these conventions is the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978, also known as MARPOL 73/78. This Protocol contained the oil quantity which can be spilled into seawater through the ballast waters and enforced all countries owning ports to construct specialized facilities where the water would be thoroughly filtered prior to being dropped in the ocean.

Concerning large tanker vessels built after 1983, they are obliged to have either separated ballast tanks from cargo tanks or clean separate special tanks. Older tankers are allowed to diffuse less than 15 parts per million (ppm) oil into the seawater when they operate outside of special areas. It is estimated that in 1999 almost 2/3 of the total tanker fleet in a global scale had SBT[1] and all of which that had been built before the MARPOL Convention have now been dismantled.

4.3.7.1 CARGO TANKS WASHING PROCEDURES

After oil loading some residues remain inside vessels' tanks. On condition that tanks have to be cleaned in order to be loaded with - for instance - another type of cargo, considerable quantities of oil might be dumped in the sea. Washing out the tanks using seawater (Butterworth) was replaced during the 1970s by "Crude Oil Washing" (COW) since crude oil had better cleaning results and demanded for less water to be used. MARPOL 73/78 Convention set the use of COW as compulsory for all tanker vessels carrying crude oil over 20,000 deadweight tons of net cargo. Therefore, this method is applied to the biggest part of global tankers fleet.

Moreover, the demand to preserve oil residues onboard the ships has reduced in an even further degree the quantity of oil dumped in the sea due to tanks' washing. All dry-docking facilities must also possess special facilities for "accommodating" any oil residues coming from tank and cargo cleaning. MARPOL 73/78 was formed with the aim to eradicate the production of oil residues during the vessels' operation and particularly the tankers' leading to manufacturing improvements that significantly

[1] Segregated Ballast Tanks = isolated ballast tanks that do not allow seawater come in contact with oil residues located in the tanks.

decreased oil dumping in the aquifer. When it comes to the Mediterranean Sea, which was characterized as a special area (green zone), any dumping of oil or any of its derivatives from any vessel larger than 400 gross tonnage is forbidden and they should be kept within the vessel till their dumping into special facilities.

5 Pollution of Marine Environment

Before proceeding on analyzing the section of waste disposal, a brief recapitulation of the marine pollution should be made. Despite the fact that vessels (entertainment, merchant, cruising) are environmentally friendly means of transport, they produce pollution but not greater than the same kind of pollution coming from shore–based activities. The constantly growing populations on coastal territories put increasing pollution pressure on coastal marine ecosystems. The pollution from hypertrophy comes from a variety of sources, such as agricultural runoff and waste or domestic sewage discharges. This kind of pollution can be a burden to the aquatic environment due to high concentrations of phosphorus, nitrogen and other elements that produce algae which in its decomposition, consumes a great deal of oxygen that creates hypoxia and consequently kills the marine ecosystem.

In a global scale, areas directly affected by hypoxia are named as “dead zones”. In these “dead zones”, fish and other marine species do not thrive. Nowadays, about 500 dead zones exist in the world and many other areas are affected by negative effects caused by high pollution due to excessive concentration of nutrients. All this burden upon the marine ecosystem creates problems for both the health and safety of humans, as well as living organisms and creates a huge financial – social issue.

5.1 TYPES OF MARINE POLLUTION / WASTE

Marine pollution could be analyzed with various criteria, whether they relate to the place in which it was developed, the activities that took place, the cause and the type of the pollutants that caused it. Part of coastal pollution also includes harbor pollution which is a cause capable of deteriorating the environment owing to the pollution originating from merchant vessels. This kind of pollution is divided in two basic categories:

1. Operational pollution from the daily operations of each terminal or port, but also of the port mesh operations. (Pardali A., 2007). Operational pollution, which is the one coming from operating procedures of a merchant ship such as the following:
   - Leaks during the loading and unloading process
   - Leaks during ballasting and de-ballasting
   - Ship repairs and maintenance
   - Waste dumping during the washing of cargo tanks
   - Fuel transfers
   - Residual leaks in areas with cargo and engine room
   - Pollution from sewage and waste

2. Accidental pollution caused by the movement of merchant ships regarding the cases where they are involved in accidents. The main types of accidents mostly caused due to human error are the following:

- Collisions or vessels touching with permanent facilities
- Groundings or when the ship falls out
- Fire incidents and explosions on ships
- Vessels sinking or disappearing
- Damages to the vessel's structure and hull
- War casualties
- Rebunkering procedure
- Maintenance and reparation of the ship or its equipment (Goulielmos S. M., 2000, p.190)

Port pollution is caused as during the production of port product as during the production of port cluster products. At the stage of port productive process in addition to port product, unwanted by-products are produced, namely the negative port products and pollution (in its broad sense) is considered to be a negative port product.

The instruction towards the prevention and restoration of environmental damage is the 2004/35/EK according to which “the polluter always pays” (INSTRUCTION 2004/35/ European Parliament, council of 21st of April 2004) principle applies. Whoever causes environmental damage is responsible for it and must take the necessary preventive or remedying measures and take care of all the associated costs. The term “environmental damage” is defined as:

- damage which seriously affects the environmental (ecological, chemical or qualitative) state of water as defined in the directive concerning EU water and the directive concerning the strategy for the marine environment.
- ground damage which creates a significant danger to human health; damage to protected species and natural habitats, which adversely affects the preservation as defined in the directive concerning the preservation of wild birds and the natural habitats directive.

As already mentioned, internationally, one of the most important convention is that of International Convention for the Prevention of Pollution from Ships (MARPOL) 73/83 which was approved on November 2, 1973. In response to a series of accidents during the period 1976-1977, the Protocol of 1978 was approved which entered into force on October 2, 1983. During the past years, the Convention has undergone many modifications and amendments Another characteristic of the Convention is that it gets upgraded according to each time's needs. The purpose of this Convention is to prevent and reduce pollution coming from ships, and therefore strict checks are systematically carried out to avoid any misconduct by the vessels concerned.

5.1.1 VESSEL WASTE

The main categories of vessel waste are the following:

a. Residues from cleaning cargo tanks (sludge)
b. Sewer and non- water (black – grey water)
c. Mixtures of the engine room (bilge, sludge)
d. Color coatings
e. Bunker residues (sludge)
f. Waste / Garbage
g. Air emissions garbage
h. Ballast water

5.1.2 MARPOL ANNEXES

According to the IMO, this Convention includes six (6) annexes which can be sorted by issuing date:

“Annex I Regulations for the Prevention of Pollution by Oil (entered into force on 2 October 1983)

Covers prevention of pollution by oil from operational measures as well as from accidental discharges; the 1992 amendments to Annex I made it mandatory for new oil tankers to have double hulls and brought in a phase-in schedule for existing tankers to fit double hulls, which was subsequently revised in 2001 and 2003.

Annex II Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk (entered into force on 2 October 1983)
Details the discharge criteria and measures for the control of pollution by noxious liquid substances carried in bulk; some 250 substances were evaluated and included in the list appended to the Convention; the discharge of their residues is allowed only to reception facilities until certain concentrations and conditions (which vary with the category of substances) are complied with.
In any case, no discharge of residues containing noxious substances is permitted within 12 miles of the nearest land.

Annex III Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form (entered into force on 1 July 1992)
Contains general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitations, exceptions and notifications.

For the purpose of this Annex, “harmful substances” are those substances which are identified as marine pollutants in the International Maritime Dangerous Goods Code (IMDG Code) or which meet the criteria in the Appendix of Annex III.

Annex IV Prevention of Pollution by Sewage from Ships (entered into force on 27 September 2003)
Contains requirements to control pollution of the sea by sewage; the discharge of sewage into the sea is prohibited, except when the ship has in operation an approved sewage treatment plant or when the ship is discharging comminuted and disinfected sewage using an approved system at a distance of more than three nautical miles from

the nearest land; sewage which is not comminuted or disinfected has to be discharged at a distance of more than 12 nautical miles from the nearest land.

Annex V Prevention of Pollution by Garbage from Ships (entered into force on 31 December 1988)

Deals with different types of garbage and specifies the distances from land and the manner in which they may be disposed of; the most important feature of the Annex is the complete ban imposed on the disposal into the sea of all forms of plastics.

Annex VI Prevention of Air Pollution from Ships (entered into force on 19 May 2005)

Sets limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibits deliberate emissions of ozone depleting substances; designated emission control areas set more stringent standards for SOx, NOx and particulate matter. A chapter adopted in 2011 covers mandatory technical and operational energy efficiency measures aimed at reducing greenhouse gas emissions from ships." (Source: IMO http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx)

For each of the fore-mentioned categories of waste, there is a gap of waste. This is defined as the difference between the waste generated onboard the vessel and the waste delivered to ports. The waste gap is a substitute for the quantity of waste that is illegally dumped. The following formulas are used in order to estimate the waste gap:

primary waste generated – (on-board treatment + legal discharges) = net waste generated net waste generated - waste delivered in ports = waste gap = potential illegal discharge

For the quantification of the waste gap, the impact assessment relies both on existing reports and literature, as well as the MARWAS model with waste delivery volumes for 29 large European ports. It should be noted that MARWAS has been used for Annex I (oily waste) and Annex IV (sewage waste).[2]

ANNEX I Oily Waste

Includes all oily residues and refining products except for petrochemical animal and vegetable oils as well as crude oil and fuel oil. They are also categorized into:

(i) Oily waste coming from vessels' engine rooms which are generated in any vessel type and include used mineral oils, fuel residues, oily bilge water and oily residues (sludge).

(ii) (ii) Oily tanker waste, including cargo residues, cargo tank washings, dirty ballast water etc. (EMSA, PRF, directive, 2016, p.27).

ANNEX II Hazardous and noxious liquid substances

These substances are categorized as followed:

Category X: Noxious liquid substances which if they enter the sea during tank cleaning and waste dumping, are considered to pose a significant danger to marine resources or human health and therefore, justify the prohibition of their dumping into the marine environment.

Category Y: The harmful liquid substances which if discharged into the sea from tank cleaning or ballast discharge processes, is considered to set marine resources or human health into danger or cause damage to property or other legitimate uses of the sea and therefore, justify the restriction of the quality and quantity of the dumping into the aquifer.

Category Z: Noxious liquid substances which if discharged into the sea from tank cleaning or ballast discharge processes is considered to pose a lower risk for marine resources or human health and therefore, justify less strict restrictions concerning the quality and quantity of the dumping into the marine environment.

Other substances: Substances that are indicated as OS (other substances) on the column of pollution category of chapter 18 of the international code of chemical bulk

[2] Supporting study for an Impact Assessment for the Revision of Directive 2000/59/EC on Port Reception Facilities for the European Comission Final Report, p. 10, 2017

substances (BCH), which have been evaluated and found not to fall in the category X, Y or Z above, as they are considered currently not to cause harm to marine resources, human health, amenities or other legitimate uses of the sea when discharged into the sea from tank cleaning or tanks discharging. The discharge of bilge water or ballast or other residues or mixtures that contain only substances, referred to as "other substances" is not subject to any requirements of the current Annex.

ANNEX III HARMFUL SUBSTANCES IN PACKAGED FORM

In this category the provision of host facilities is not required. On condition that the package gets destroyed, it is subject to a different category depending on the content and residues of package that can be categorized in appendix Annex V where the garbage is sorted.

ANNEX IV WASTE - BLACK WATERS

For the Greek ships, there is the Presidential Decree 400/96 (P.D) that has come into effect which sets regulations for the prevention of marine pollution from vessel sewage.

The waste produced onboard the vessels are considered as “sewage” or “black waters” and include drains from toilets, urinals, ship’s infirmary, as well as any other kind of waste mixed with the above. Other wastes generated onboard the vessels (e.g. from showers, kitchens, washing machines, etc.) are called "gray waters”. Usually there are separate piping for waste and grey waters, while different ways may be used to manage those wastes. Annex IV contains a series of regulations regarding the discharge of sewage into the sea from ships, including regulations about equipment and vessel systems to control sewage discharge, the provision of port reception facilities for waste - water and requirements for survey and certification.

In general, it is considered that at open sea, oceans are capable of assimilating and struggling with raw - unprocessed sewage through natural bacterial action. Consequently, the regulations of Annex IV of MARPOL Convention prohibit the discharge of sewage into the sea at a specific distance from the nearest land, unless otherwise specified. The Annex came into force on 27 September 2003. A revised Annex IV was approved on April 1, 2004 and entered into force on 1 August 2005. Existing ships shall comply with the provisions of the revised Annex IV five years after the entry into force date of Annex IV, which is from 27 September 2008. It shall apply to new ships engaged on international voyages with gross tonnage of 400 tons and more or ships certified to carry more than 15 people. Annex requires ships to have either an approved sewage treatment plant or an approved sewage and sanitation system or sewage storage tank. The sewage discharge into the sea is prohibited, unless the ship is operating an approved sewage treatment plant or when the ship evacuates sterilized and disinfected sewage using an approved system at a distance of more than three nautical miles from the nearest shore. The sewage effluent that has not crushed or disinfection can be disposed over a distance of 12 nautical miles from the nearest shore and the rate of discharge of untreated sewage must be approved by the Authority.

ANNEX V WASTE

The revised Annex V of MARPOL sets new regulatory requirements for waste discharge from ships and has entered into force since 1 January 2013. The new amendments prohibit the discharge of almost all kinds of waste into the sea with exemption of only under specific requirements for food, carcasses, cargo residues contained in the washing water and finally, environmentally friendly cleaning. As a result of all these regulations, more and more vessels have their waste disposed in reception facilities ashore. Annex V of MARPOL Convention applies to all ships. The regulation of prohibiting garbage disposal from the vessel do not apply when the garbage disposal from the ship is a necessary action to ensure the safety of the ship itself and the passenger onboard or for life rescuing at sea. In such cases, they should enter in the waste inventory or in the official vessel’s logbook for vessels with less than 400 gross tonnage.

According to the revised Annex V to MARPOL, the garbage produced onboard the ship shall be classified into the following categories:

A. Plastic - Litter which consist of or include plastic in any form. The garbage of this category is prohibited to be dumped into the aquifer.

B. Food waste - Sterile or unspoiled food substances. Food waste can be discharged into the sea under specific conditions / requirements.

C. Domestic waste - The garbage produced primarily in the accommodation spaces onboard the vessel (e.g. drinking bottles, paper, paperboard, etc.). The waste of this category is prohibited to be discharged into the aquifer.

D. Cooking Oil - Edible oil or animal fat used for the preparation or cooking of the food. The waste of this category is prohibited to be discharged into the aquifer.

E. Ashes coming from incinerators - Ash and clinker coming from incinerators used for waste incineration. The waste of this category is prohibited to be discharged into the aquifer.

F. Operating waste – Solid waste (including sludges) gathered on the vessel during the normal maintenance or operation of a vessel or used for loading and handling of the cargo. Operating waste also include detergents and additives contained in the cargo bin and external washing water that can be noxious to the aquatic environment. They do not contain gray water, bilge water or any similar discharges that are necessary for the operation of a vessel (boiler / econometer firing, water washing gas turbine, engines waste etc.). The waste of this category is prohibited to be discharged into the aquifer. Cargo residues - Residues of any cargo remaining on deck or after loading or discharging. This category does not include the cargo dust remaining on the deck after wiping or dust on external surfaces of the vessel. Such waste can be discharged under certain conditions / requirements. It is of high importance that in addition to other requirements (e.g. distance from the coast) cargo residues should not be harmful to the marine environment in order to be allowed for discharging at sea. Cargo residues which are considered as harmful to the marine environment are classified according to the criteria of the Global Harmonized System of Classification and Labeling of the UN Chemical Products (UN GHS), such as: acute toxicity for the marine environment of category 1, chronic category of toxicity into aquatic environment, carcinogenesis, mutagenesis, reproductive toxicity, etc.

G. Animal residues - Animal bodies transported onboard the ship as cargo and which are dying or have been euthanized during the voyage. Discharge of such waste that is allowed in the sea, under specific conditions / requirements. Fishing gear - Natural formation which can be put on water surface or the seabed so as to identify oceanic or fresh water. The waste of this category is prohibited to be discharged into the aquifer.

H. Electronic waste

These new categories represent categories that will be used for recording at the garbage inventory. The replaced MARPOL Annex V sets six categories, while the revised Annex sets nine. Each ship with tonnage of 100 and more (instead of the 400 GT required by the replaced Annex V of MARPOL) and every ship certified to carry 15 or more people must carry waste management plan even at the labor language of the crew that contains procedures for:

- Waste Minimization
- Waste collection
- Storing waste
- Garbage processing
- Gear used onboard for waste management
- Person responsible or persons responsible for the implementation of Garbage Management plan

In addition to the Waste Management Plan, each vessel of 400 and more passengers and every ship certified to carry 15 or more people and performs itineraries in ports under the jurisdiction of another party, should keep a Waste Inventory. The form that is set out in the appendix of the revised Annex where waste discharges are recorded, is different from the replaced. In order to enhance the implementation of the waste management plan onboard the ship and to better implement the garbage management procedures, crews and ships officers may use the standard form (see. Annex I) of the IMO for the beforehand notification of waste delivery at port reception facilities, as defined in the newsletter. (IMO, MEPC.1 / Circ.644, 1 July 2013).

ANNEX

STANDARD FORMAT OF THE ADVANCE NOTIFICATION FORM FOR WASTE DELIVERY TO PORT RECEPTION FACILITIES

Notification of the Delivery of Waste to: .... *(enter name of port or terminal)*

The master of a ship should forward the information below to the designated authority at least 24 hours in advance of arrival or upon departure of the previous port if the voyage is less than 24 hours.
This form shall be retained on board the vessel along with the appropriate Oil RB, Cargo RB or Garbage RB.

DELIVERY FROM SHIPS (ANF)

1. SHIP PARTICULARS

1.1	Name of ship:	1.5	Owner or operator:
1.2	IMO number:	1.6	Distinctive number or letters:
1.3	Gross tonnage:	1.7	Flag State:
1.4	Type of ship: ☐ Oil tanker ☐ Other cargo ship		☐ Chemical tanker ☐ Passenger ship ☐ Bulk carrier ☐ Ro-ro ☐ Container ☐ Other (specify)

2. PORT AND VOYAGE PARTICULARS

2.1	Location/Terminal name and POC:	2.6	Last Port where waste was delivered:
2.2	Arrival Date and Time:	2.7	Date of Last Delivery:
2.3	Departure Date and Time:	2.8	Next Port of Delivery (if known):
2.4	Last Port and Country:	2.9	Person submitting this form is (if other than the master):
2.5	Next Port and Country (if known):		

3. TYPE AND AMOUNT OF WASTE FOR DISCHARGE TO FACILITY

MARPOL Annex I – Oil	**Quantity (m^3)**
Oily bilge water	
Oily residues (sludge)	
Oily tank washings	
Dirty ballast water	
Scale and sludge from tank cleaning	
Other (please specify)	
MARPOL Annex II – NLS	**Quantity (m^3)/Name[1]**
Category X substance	
Category Y substance	
Category Z substance	
OS – other substances	
MARPOL Annex IV – Sewage	**Quantity (m^3)**

MARPOL Annex V – Garbage	**Quantity (m^3)**
A. Plastics	
B. Food wastes	
C. Domestic wastes (e.g. paper products, rags, glass, metal, bottles, crockery, etc.)	
D. Cooking oil	
E. Incinerator ashes	
F. Operational wastes	
G. Cargo residues[2]	
H. Animal carcass(es)	
I. Fishing gear	
MARPOL Annex VI – Air pollution	**Quantity (m^3)**
Ozone-depleting substances and equipment containing such substances	
Exhaust gas-cleaning residues	

[1] Indicate the proper shipping name of the NLS involved.

[2] Indicate the proper shipping name of the dry cargo.

Name of ship:	IMO Number:

Please state below the approximate amount of waste and residues remaining on board and the percentage of maximum storage capacity. If delivering all waste on board at this port please strike through this table and tick the box below. If delivering some or no waste, please complete all columns.

I confirm that I am delivering all the waste held on board this vessel (as shown on page 1) at this port ☐

Type	Maximum dedicated storage capacity (m^3)	Amount of waste retained on board (m^3)	Port at which remaining waste will be delivered (if known)	Estimate amount of waste to be generated between notification and next port of call (m^3)
MARPOL Annex I – Oil				
Oily bilge water				
Oily residues (sludges)				
Oily tank washings				
Dirty ballast water				
Scale and sludge from tank cleaning				
Other (please specify)				
MARPOL Annex II – NLS[3]				
Category X substance				
Category Y substance				
Category Z substance				
OS – other substances				
MARPOL Annex IV – Sewage				
Sewage				
MARPOL Annex V – Garbage				
A. Plastics				
B. Food wastes				
C. Domestic wastes (e.g. paper products, rags, glass, metal, bottles, crockery, etc.)				
D. Cooking oil				
E. Incinerator ashes				
F. Operational wastes				
G. Cargo residues[4]				
H. Animal carcass(es)				
I. Fishing gear				

Date: .... Name and Position: ....

Time: .... Signature: ....

[3] Indicate the proper shipping name of the NLS involved.
[4] Indicate the proper shipping name of the dry cargo.

Annex 1: Notification form of waste delivered to port reception facilities.

5.2 POLLUTION DURING SHIPBREAKING

One of the most distinct characteristics of shipping industry is the so-called "Shipping Cycle", where the evolution of prices and values of the vessels follows a cyclic pattern. The global shipping vessels with an average age of 25 years are ready to be scrapped since their operating costs increase as time goes by, making thus the operation economically unviable.

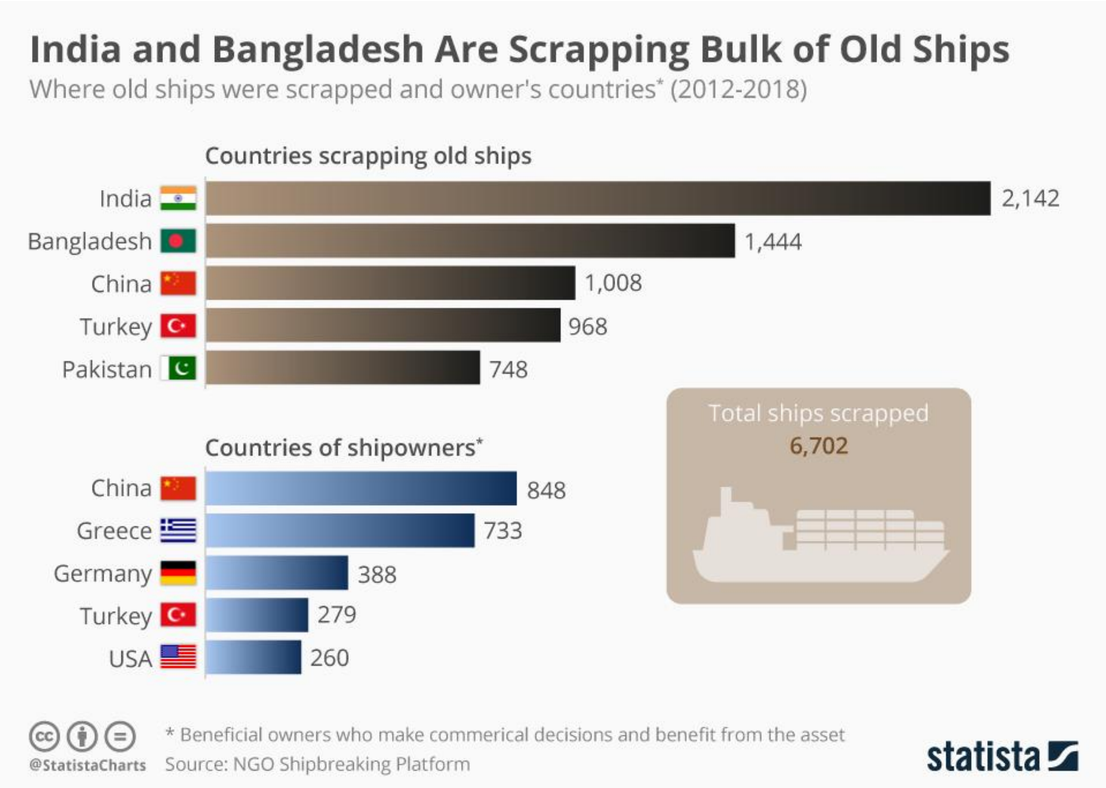

Table 2: Countries of Shipowners and countries of Shipbreaking

The process of shipbreaking cannot be described as environmentally friendly at all. It results in contamination coming from solid, liquid and gaseous waste. The waste arises mainly from the accumulation of rust, sludge, iron filings as well as wooden and plastic ones. At this point, it should be mentioned that both the pollution originating from solid and liquid waste is largely dependent on the size of the vessel that is going to be dissolved and the level of residual cleanliness as well as the conduct of business. Still, one of the major risks in the shipbreaking process is the disposal of heavy metals and polychlorinated biphenyls (PCB) - belonging to the chlorinated aromatic hydrocarbons - at sea. (Κουλογιάννη, 2009). Prior to cutting the vessel, the process preceding is that of the washing of its parts. Liquid waste can be considered as products from the washing process; the latter is performed in order to get rid of oil residues, slags and other ingredients with high concentration of biochemical oxygen demand (BOD). Moreover, liquid waste coming not only from the fire extinguishing vessel systems but also from the washing water of the shipbreaking unit itself. The ship dismantling procedures result in the appearance of dust and smoke that contribute to air pollution, while many metal parts end up in the sea. Vessels that have completed their economic life and led to the scrap yards, usually have metal parts with high rust rate and hazardous substances. The outcome of that was the strong opposition of European and American facilities which led scrap yards to the territories of developing countries, mainly India and Pakistan and to a lesser extent in Bangladesh, Turkey, Netherlands, USA and China. The increased labor costs, the cost of compliance with the existing regulations as well as the absence or the laxity of applying safety regulations at the developing countries in conjunction with the absence of a legal framework and adaptable workforce, leading to the conclusion that the risk of environmental pollution is even greater. Therefore, the need to adopt anti-pollution measures in the coastal zone against such practices is now more urgent than ever. These measures must concern both the legislative level and the level of labor and facilities as well as the proper training of the labor force.

Image 3: Bangladesh 2009[3]

Seagoing vessels during the dismantling procedure produce various kinds of hazardous waste. Therefore, the shipbreaking industry is considered such harmful to the environment, human health and local biodiversity. During the shipbreaking process, all kinds of dangerous solid, liquid and gaseous waste are produced. Soluble and insoluble materials accumulate in the ground and by means of the tide, dispersed in a wide range of the coastal zone. Regarding the waste, it is mainly composed of heavy metals (mercury, lead, arsenic, chromium, cadmium, zinc, etc.), oily residues, and bacteria (Islam and Hossain, 1986). Compared to all produced waste, heavy metals and oily by-products are considered the most severe because of their toxicity and the long-term stay into the aquifer (Forstner and Wittmann, 1981; Sinex and Wright, 1988).

The environmental impact of scrapping ships is caused mainly due to the following factors:

- Metal objects originating from the dissolution and disposed into the sea.

- Possible leaks of oil and oily residues, flammables or explosive materials.

- Residual leakage (slops) derived from the washing of the cargo tanks, bilge water and the ballast water leakages from the vessels' ballast tanks.

- Garbage dumping and other solid waste disposal (Neser et al, 2008).

Taking all the fore-mentioned data into consideration, geographical distribution of scrap and recycling market of ships has been accumulated in Southeast Asia countries. The largest amount of ships to be dissolved is mostly spread over three countries, Bangladesh, Pakistan and India.

[3] Mikelis, 2009

Image 4: Bangladesh 2009

5.2.1 SOLID WASTE

The waste produced by scrapping can be divided into 16 categories according to their composition, as following: metal, paper, glass and ceramic, plastic, leather, fabrics, wood, rubbers, food residues, chemicals, paints, insulation materials, materials fused with oil products and other flammable materials or non. Ships produce solid waste as up to 10-15% of the Light Displacement (LDT). On numerous occasions, vessels carry even cargo residues in their tanks whose composition is difficult to determine. Materials such as asbestos which exist in large quantities especially in old ships, are considered as extremely hazardous to both workers' health and marine environment (Islam and Hossain, 2006).

5.2.2 GASEOUS WASTE

Asbestos is one of the most important waste released into the atmosphere during the dismantling of ships. Asbestos can be found as heat-insulation material in many places inside the ships' engine rooms. In addition, it is widely used in construction of interior rooms in passenger and cruise ships (asbestos panels). The asbestos fibers are invisible to the naked eye, odorless and tasteless, not dissolved in water and is highly resistant to chemical and biological degradation. If this material is not removed by taking all the prescribed security measures, gets divided into very thin fibers which are hovered in the atmosphere for long periods. From the moment fibers enter the body, they remain and accumulate in the lungs. The high levels of asbestos can lead to lung cancer, mesothelioma cancer and asbestosis. Unfortunately, the symptoms of these diseases are presented after a long period since the original exposure of the patient. In Europe, since 1991, the majority of types of asbestos has been forbidden to be used. In the years that followed up and specifically in 2003, a total ban took place not only in Europe but in most countries of the world, as well. (http://en.wikipedia.org/wiki/Asbestos).

Another major sources of air pollution are the chlorocarbon compounds (freon) existing onboard the vessels within the refrigeration systems and some other fire extinguishing systems containing fire retardants (halon). Although they are not toxic or flammable materials, they contribute to the destruction of the ozone layer. Polyvinyl chloride (PVC), which is used in many different applications onboard, such as cables, pipes, etc. Burning of the cables constitutes the usual practice followed for the recovery of copper, burning the insulation surrounding them, produces large quantities of hydrogen chloride gas. If inhaled together with water vapor and moisture it can generate hydrochloric acid in the lungs, causing asthma, Raynaud's syndrome, liver cancer, brain cancer, reproductive problems, etc. (Islam and Hossain, 2006). Furthermore, the burning of PVC products produces carbon monoxide, dioxins and chlorinated furans. Dioxins and furans are highly toxic and are directly linked to cancer as well as birth abnormalities. These substances are either directly inhaled or settle in soil and water, inserted into the food chain (http://en.wikipedia.org/wiki/PVC). Extensive activities of such kind to coastal zones contribute to consistency loss of the soil itself. This event accelerates the soil erosion rate and increases the turbidity of the seawater, which in turn leads to lower oxygen levels inside the water. This series of effects results in reducing the marine life throughout the whole region (Islam and Hossain, 1986).

5.3 BASEL CONVENTION ON HAZARDOUS WASTES

The United Nations Environmental Programme (UNEP) held the convention of Basel on March 22, 1989 and led to the creation of the "Basel Convention" as a result of the continuous illegal discharge of toxic waste from the developed countries in Africa. Its main objective is to control the transportations of hazardous waste as well as the methods of disposal. This Convention has been signed by 178 States and eventually entered into force in 1992. It is the first to deal with toxic and hazardous waste, recognizing thus, the danger of these substances that pose a significant threat to both the environment and human health. The main goal of the Convention is to reduce hazardous waste generation and promoting their environmentally correct management. The Convention also prohibits the transboundary movement of hazardous waste on condition that environmentally correct management is not ensured and their aim is to implement a cross-border waste transport control system where and when allowed.

Regarding the management of waste, the following principles were introduced:

• Principle of waste reduction and cross-border transport

• Principle of self-sufficiency and proximity

• Principle of rational management. (EU, 1989)

According to the general obligations of the Basel Convention the import or export of hazardous waste or other wastes from a non-contracting state is prohibited. Also, no waste can be exported if the importing country has not given its consent in written form for this specific movement. Information disclosure through a particular document regarding the proposed cross-border movements in the countries concerned is prescribed, so that they can assess the effects of movements on human health and the environment. Another requirement of the Convention is that cross-border movement of waste should be permitted only if there is a risk that is associated with both their transfer and their disposal. Moreover, waste subject to cross-border movement must be packaged, labeled and transported in accordance with international standards, whereas they should always be accompanied by a document of transport that follows them from the starting point to the disposal point. Finally, contracting states are given the capability to impose additional requirements which must always be consistent with the provisions of the Convention, though. Then, according to the Basel Convention, the emphasis is given to the use of clean production methods and indicates that trade taking place, requires the prior consent of the sending country as well as the briefing for the consent of the importing country. Basel's Convention weak spots are that only substances which are or will be available, while it only covers domestic and hazardous waste and "excludes" the radioactive ones. The Convention does not prohibit any cross-border movement of waste but in fact permits it, under certain strict conditions. (EU, 1989) On October 17-21, 2011 in Cartagena, Colombia, the 10th Meeting of the Parties of the Convention with some main goals:

I. The prevention, minimization and recovery of waste.
II. The better cooperation between state members of the Convention to achieve a more effective cross-border waste transport control.
III. A better partnership of the Convention with other international agreements such as the Stockholm Convention, the Rotterdam's and Hong Kong's.
IV. The immediate implementation of the BAN Amendment regarding hazardous waste export ban to countries out of the Organisation for Economic Co-operation and Development (OECD).

5.3.1 INDUSTRIAL, URBAN AND SOLID WASTE

Usually, waste from industries as well as cities which are discharged without any process into the sea contain hazardous and toxic substances such as heavy metals, non-degradable organic compounds, nitrates, phosphates and germs that greatly overburden the environment. This situation is getting even worse if consider the micro-tidal nature of closed seas such as the Mediterranean. The absence of tidal activity contributes to the non-dilution and dispersion of soluble and particulate wastes (EEA-UNEP / MAP, 2014, p.39).

Solid waste from urban centers are concentrated along the coastline are also a danger not only to public health but to marine environment, too. The careless discharge of garbage in landfills without preserving the basic sanitary measures and piling them in places near the sea or the city boundaries turns themselves into being sources of pollution for the surrounding areas with serious consequences such as contamination of groundwater, diseases spreading and pollution of the coastal environment. Fires which may be caused by an accident, release particulate matter, polycyclic aromatic hydrocarbons and dioxins that are harmful to the health of neighboring populations (EEA, 2006). Moreover, the garbage concentration on the coasts is interrelated with the cascade of floating solid waste at sea and the seabed. Plastics are primarily responsible for the death of thousands of mammals and sea turtles each year. Plastic garbage remains for decades in the marine environment or in small pieces - which are quite noxious to marine creatures as they feed on them - or in larger pieces which entrap fish, marine mammals and birds. Recent surveys have shown that many species of marine animals are prone to be trapped in garbage floating on sea surface, while even more refuse have been found dead with garbage in their stomach.[4]

6 PLASTICS

It is widely accepted that 20th century has been the golden age on whatever is related to discoveries of chemical substances, major political, social and financial developments as well as environmental breakdowns. Regarding the section of substances, **plastic** could not have been omitted. Plastic is a material consisting of a wide range of organic polymers and other synthetic compounds of high molecular mass which is malleable and so can be molded into solid objects. Due to their low cost, ease of manufacture, moisture – barrier properties, versatility, and imperviousness to water, plastics are used in a multitude of products of different scale (https://en.wikipedia.org/wiki/Plastic), with commercial, medicinal and industrial applications. The annual global demand for plastics has consistently increased over the recent years and presently stands at about 245 million tons. Since World War II, coasts and aquifers are the receivers of plastic waste which end up there through accidental releases and indiscriminate discards. The percentage of plastic debris ending into the aquifer is by 80% due to land – based sources and 18% due to the fishing industry. Due to its lightweight, durable nature, plastic has become a prevalent, widespread element of marine litter (Moore, 2008; Thompson et al., 2009). Production of organic polymers is focused on polypropylene (PP), polyvinylchloride

[4] Τσελέντης Β., (2008), Διαχείριση Θαλάσσιου Περιβάλλοντος και Ναυτιλία, εκδ. Σταμούλη, Αθήνα, σελ. 39

(PVC) and polyethylene (PE) which according to 2007 data composed 24%, 19% and 21% of plastic production in a global scale (Andrady, 2011).

Diagram 2: Distribution of global plastics production

6.1 DEFINITION OF MICROPLASTICS

A term was created in order to describe the microscopic plastic particles found into the marine environment; they are known as “microplastics”. Microplastics have a size of less than 5mm and can be of primary (manufactured by default) or secondary (fragments of microplastic objects) origin. They are most likely to be accumulated on coasts / beaches, within the benthos, ocean surface and outfalls. The case of Mediterranean Sea is of interest as plastic objects of larger sizes accumulate with a higher proportion, probably due to the peculiar hydrodynamic characteristics of this semi-enclosed basin.

The rapid increase in the abundance of microplastics in the marine environment can be easily observed. Plastic fishing nets can be left or lost in the ocean by fishermen. Known as ghost nets, these entangle fish, dolphins, sea turtles, sharks, dugongs, crocodiles, seabirds, crabs, and other creatures, restricting movement, ultimately causing starvation, laceration and infection. On condition that any creature needs to return to the surface to breathe, it eventually dies out of suffocation.

6.2 DEGRADATION

Degradation of macroplastic items increases the possibilities that organisms will eventually ingest small microplastic particles. In fact, fragmented microplastics have been shown to be more harmful than virgin microplastics.

At this point, a closer look to degradation procedure shall be made. Degradation is generally classified according to the agency causing it:

a. Photodegradation – action of light (usually sunlight in outdoor exposure).
b. Biodegradation – action of living organisms usually microbes.
c. Thermooxidative degradation – slow oxidative breakdown at moderate temperatures.
d. Thermal degradation – action of high temperatures (not environmental).
e. Hydrolysis – reaction with water (Andrady, 2011).

6.2.1 SIZE OF MICROPLASTICS

Moreover, bioavailability of microplastics is affected by their size. In other words, their tiny size could easily be misleading by larger planktivore organisms which would result in ingesting them by mistake instead of ingesting their natural prey. Not to mention any larger organisms such as marine mammals and turtles which feed or inhale microplastic in quite respectable quantities. Such a distinct example is that of the fin whale *Balaenoptera physalus* that lives and reproduces inside the Mediterranean. B. physalus is one of the largest filter feeders in the world, engulfing around 70,000 liters of seawater at once, increasing thus chances to inhale microplastics and get immediately contaminated (Fossi et al. 2012).

Image 5: Plastic bag in the ocean (Google)

6.2.2 DENSITY

At the same level, density of microplastics is also a critical factor. For instance, low-density polyethylene (PE) plastic (super-market) food bags periodically obtain neutral buoyancy, forcing them to sink underwater as biofouling accumulates upon them (Lobelle and Cunliffe, 2011). In addition, the benthos is likely to be a sink for high density microplastics.

6.2.3 COLOUR

Colour of microplastics may also contribute to the likelihood of ingestion, due to prey item resemblance. Especially white items have the tendency to be extremely popular to fish and their larvae as they resemble zooplankton or jellyfish; as a result, the fore-mentioned visual predators get confused and feed on microplastic items. Another distinct instance is the omnivorous amphipod *Orchestia gammarellus* which directly mistakes microplastics as a natural food source and can therefore be considered as their primary consumer (Murray and Cowie, 2011). On the contrary, scavenger species have adopted a non-selective feeding behavior, feeding thus on larger particles of sediments.

6.2.4 ABSORPTION AS WAY OF ENTRY

Finally, microplastics may not only enter the food chain via ingestion, as they can possibly be absorbed to organisms. A typical sample are the freshwater marine algal cells *Chlorella* and *Scenedesmus* which absorb charged microplastics, perhaps due to the electrostatic attraction between the beads and cellulose constituent of the living cells.

6.3 ORIGINS OF MICROPLASTICS

Microplastics usually originate from two sources: a) weathering breakdown of meso- and macroplastics debris and b) direct runoff into the oceans (from industrial products and smaller particles in consumer goods). What is more, plastic litter occurs in the coasts, surface water and deep water environments but the rates of weathering in these fore-mentioned sites vary between each other; for instance, degradation of plastics floating on sea surface compared to the one of plastics exposed on a beach surface is significantly more retarded owing to lower temperatures and lower oxygen concentration in the water. The very high temperature that plastics lying on the coast are subjected to accelerate the degradation process.

6.3.1 FOULING

Fouling is also a critical factor for the development of plastic debris. Their sequence strongly depends on water conditions as well as the season of exposure. Namely, plastic debris obtain an extra layer of foulants, increasing their density as the fouling process progresses. Then, it reaches a point where once the plastic density exceeds that of the sea water it can sink well below the water surface and eventually is deposited on the seabed. (Railkin, 2003).

7 TRANSFER TO FOOD CHAIN

Given that lower trophic organisms, specifically invertebrates, can ingest and accumulate microplastic particles, it is likely that microplastics will be introduced to the food web. Smaller invertebrates consume plankton which has previously ingested microplastics or have ingested them passively. A potential outcome would be to accumulate plastic which in turn will block the normal feeding activity. Furthermore, microplastics represent a long – term threat due to the toxicity of Persistent Organic Pollutants (POPs) which are integrated into microplastics. As the chain goes by, microplastics obtain new routes of entry to higher levels of trophic pyramid.

The transfer of ingested microplastics from digestive system to circulatory system of marine organisms can damage important organs as the heart or the liver, besides the potential toxic effects (Endo et al, 2005). Contaminants are being transferred to marine organisms through direct exposure, with POPs attaching to the external surface (skeleton, skin) or the internal one (gill walls, guts, tissues) of the organism. Plastic pellets found in debris also pick up metals from the water which may too be transported and ingested. Another way of transference is via the indirect exposure to microplastics, with organisms getting in contact with contaminants existing into the aquifer (external exposure) or organismal fluids (internal exposure).

Ingestion of microplastics through different mechanisms has been demonstrated in more than one hundred aquatic species, from zooplankton to whales, from mussels to sharks, from crabs to seagulls. As stated before, organisms ingest microplastics either unintentionally during their feeding or by preying on smaller organisms who contain microplastics [(trophic transfer), (Gesamp, 2016)]. Especially in cases that marine organisms live and feed in common / under a formation of a hive, there was reported an ingestion in over 80% of individuals. Similarly, planktonic colonies gather an amount that in some cases exceeds 50% of their own population.

Image 6: A decaying sea bird carcass with plastic debris in its stomach.[5]

7.1 CHEMICALS

Aside from the physiological effects to aquatic organisms originating from the ingestion, microplastics are linked to releasing detrimental chemicals to the marine environment; videlicet, the level of hazard increases with contaminants or additives containing endocrine (e.g. phthalate, plastic monomers) which disrupt chemicals' function. Based on samples taken, these compounds have been measured at high concentrations in plastic fragments at urban and remote beaches. The scientific community has already gathered several reports on their behavior and sorted them according to their origin:

- Chemicals originating from the recycling procedure of plastic waste.
- Chemicals intentionally added during the production processes such as plasticizers, pigments, flame retardants and ultraviolet stabilizers (all of them additive substances).

[5] Credit: Chris Jordan

- Chemicals unintentionally added during the production processes such as monomers and catalysts which may also come from ultraviolet radiation onto plastic waste.
- Chemicals with hydrophobic properties (with environmental origins) that are transferred to the plastics.

According to researches that have taken place, endocrine chemicals cause disruptions to the synthesis of endogenous hormones, leading thus to impaired reproduction and low birth rates, feminization or demasculinization of male species, decrease of biodiversity, loss of metabolism and thyroid issues. In both fish and mussels, pathological alterations on tissues were associated with infiltration of immune cells, suggesting inflammatory processes. Unfortunately, most of the health impacts mentioned above concerning the aquatic organisms are currently limited to lower trophic levels like zooplanktons. The exact extent of this harm cannot be defined and the reason for that is that necropsies on such small organisms are too time- and fund consuming.

7.2 TOXICITY

At this point, a special reference to the element of toxicity shall be made. Ingestion by microbiota may potentially deliver concentrated and already dissolved POPs to marine organisms. In general, according to Andrady, toxicity is attributed to one or more of the below presented factors:

i. "Residual monomers from manufacture present in the plastic or toxic additives used in compounding of plastic may leach out of the ingested plastic. The potential toxicity of phthalate plasticizers used in PVC has been widely discussed in the literature
ii. Toxicity of some intermediates from partial degradation of plastics. For instance, burning polystyrene can yield styrene and other aromatics and a partially burnt plastic may contain significant levels of styrene and other aromatics.
iii. The POPs present in sea water are slowly absorbed and concentrated in the microplastic fragments. Plastics debris does 'clean' the sea water of the

> dissolved pollutant chemicals. On being ingested, however, these can become bioavailable to the organisms."

7.3 POTENTIAL IMPACTS ON FOOD SAFETY

As stated above, Endocrine Disrupting Chemicals (EDCs) introduced through microplastics have already raised several concerns about food safety. Perhaps, the most significant source of dietary exposure of humans to microplastics is via filter – feeding shellfish. Bivalves are a typical example of such species, sold in Chinese fishing markets. More specifically, they are directly exposed to microplastics in the ocean and thus become contaminated. As a result, Chinese consumers could come into contact with hundreds of thousands of hazardous microplastics annually. In case any other larger edible fish species get contaminated, it is of high importance that prior to consumption, the gut is removed so there are less chances of exposure from microplastics.

At present, as there is a number of reports stating that POPs are transferred within marine food webs such as PCBs and dioxins, there is limited information regarding the impacts of microplastics on food webs and no associated laboratory experiments have been conducted.

The Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted at a Conference of Plenipotentiaries on 22 May 2001 in Stockholm, Sweden. The Convention finally entered into force on 17 May 2004. In relation to the Convention, humans should consider the introduction of measures which will work towards the reduction of marine plastic litter. Firstly, not only shall plastic litter prevention be encouraged, but also fund, develop and implement safer alternatives to restrict them. Secondly, recycling should be further forwarded and scientific community must support any research on environmental and health impacts of microplastics and POPs. Last but not least, is to encourage the industries as well as authorities to enforce a rational collection and management of waste and promote environmentally friendly behavior.

8. CONCLUSION

To sum up, plastic pollution in the marine environment is now recognized as a real and constantly growing threat with a global-scale distribution and adverse effects spanning from molecular level, physiological performance and organisms' health, up to the loss of ecosystemic services. In this respect, it is imperative that severe measures are taken to address the problem at both international and national levels. Aside from the current use of pollution treatment methods either it is performed with the aid of chemicals or via natural procedures there is much that has to be done towards a viable situation.

At the same time, the rise of public awareness on environmental microplastics should also stimulate technological innovation to reduce the use and consumption of plastics, stimulate a new approach toward collection, minimize their input into the environment and re-use of stranded materials. As plankton species constitute the very foundation of the marine food web, any threat to these can have serious and far-reaching effects in the world oceans. The distortion of the food chain could be imminent unless interventions are made.

Therefore, to predict the fate and impact of plastic in the whole ocean environment, it is of high importance for citizens to understand the multiple interactions between weathering and biofilm growth and composition, and their joint effects on sinking rate, plastic density and the consumption of plastic by filter-, suspension-, and deposit-feeding organisms. With regard to the chemical transfer of chemicals from plastics, there is still need of more researches for reliable estimates to be made as to the impacts that microplastics have both to human and to marine organisms.

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