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ENVIRONMENTAL FOOTPRINT ANALYSIS OF LARGE CRUISE SHIPS

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Contents

Table of Figures

List of Tables

ABSTRACT

There are many environmental and environmental impacts of cruise navigation. However, they are rarely evaluated collectively in scientific literature. This study provides a bibliographic overview of the pressures, management technologies and quantities of different waste categories produced by large cruise ships with a capacity of more than 3,000 passengers. The purpose of this work is to collate the different pressures and impacts of cruise ships on the marine environment and the affected coastal ecosystems and to identify areas for further future research. Numerous pressures on the environment and ecosystems are identified through the treatment of untreated sewage, solid waste generation and air pollutant emissions. Pressures that lead to the pollution of the marine environment by primary but emerging pollutants that require further study, impose large quantities of waste and the release of large quantities of gaseous pollutants into the atmosphere. Wastewater analysis studies were used to identify nutrients such as phosphates and nitrates, polycyclic aromatic hydrocarbons (PAHS) and other organic pollutants as well as the main gaseous pollutants (NOX, SOX, CO2 and PM) produced by cruise ships and solid waste quantification studies.

KEYWORDS: biological waste water treatment , gaseous pollutants, pollution , solid waste , nutrients

CHAPTER 1

1.1 Introduction

Shipping is a cyclical industry that meets the global supply and demand, is currently in a period of growth in various sectors. One area that has seen rapid growth in recent years is the cruise ship market. The cruise industry has seen significant growth in recent years in both the size of ships and the number of passengers carried. The number of vessels in the global fleet has also grown significantly with at least five new cruise ships being built each year over the last decade. At the end of 2004, there were 441 operational cruise ships, corresponding to 11.5 million gross tones, with an average age of 21 years.(Perucci et al.,2012.) In 2015, the total population of cruise ship passengers worldwide was estimated at 23 million, with an expected for growth 2020 to 28 million passengers (Cruise Market Watch, 2018).The largest ship in the world launched in 2016 is capable of carrying up to 8708 people between passengers and crew, which makes these types of ships real floating cities. Europe is currently the second largest market for cruise packages with the Mediterranean being the most popular destination for European travelers 2. In 2012 there were 207 cruise ships in the Mediterranean with a capacity of 249,000 passengers and a total annual amount of 5.7 million passengers and 28.7 million visits to the ports of Europe (Marusic et al.,2012 ; CLIA EUROPE , 2013). The European market grew by 162% during the ten years from 2002 to 2012 and despite the economic downturn, the European cruise is expected to reach 10 million passengers by 2020 (European Cruise Council, 2012). Indicatively, it is mentioned that worldwide the cruise passengers in 1990 were 3.8m, in 2004 more than 10m, in 2019 30m. and, for 2020, the estimates of the Cruise Lines International Association (CLIA,2016) referred to 32m. passengers - a size that the pandemic has dramatically reduced due to the Covid-19 virus. Between 2010 and 2019 the number of cruise passengers increased at an average annual rate of 5.4% and a total of 57% (19.1m passengers in 2010, about 30m in 2019). According to the same source, for the decade 2007-2017, land tourism worldwide increased by 47% to about 1.32 billion. tourists for 2017 (increase of 6.7% compared to 2016). Prior to the pandemic, the increase in cruise passengers was expected to continue at the same rate until 2022, 6% per year, and most of them would come from Europe. The Mediterranean and adjacent seas are one of the most dynamically growing cruise areas in the world. The employment of the total cruise ship fleet worldwide over the last 15 years shows that its share increased from 11.5% in 2003 to 12.9% in 2006 and to 15.8% in 2017, a year in which 250 European ports (including the European Atlantic Islands) 34cm. passenger visits (9.6% increase from 2015). For 2018 & 2019 its share was about 15%, maintaining 2nd place, with Asia following in 3rd place (10%). In terms of passenger traffic in the last 5 years there has been an increase of 11% in total visits to Mediterranean ports (30.2m in 2019, compared to 27.2m in 2015). The majority of cruise passengers in Europe have always been Europeans and, for 2018, their main destination remained the central and western Mediterranean, where there was an annual increase of 1.2% (2.27 million passengers). It was followed by Northern Europe with an annual increase of 4.8% (1.43 million passengers), while for the Eastern Mediterranean there was an increase of 8% (746 thousand passengers compared to 687 thousand in 2017, and 775 thousand in 2016), a figure that indicates regaining passenger confidence in the region, following the geopolitical instability of the first decade of the 21st century (Gulf Wars, Arab Spring, Turkish coup, Syrian war). The Mediterranean Sea offers some important advantages for companies as it enables them to diversify the services they provide, in contrast to the Caribbean region, where the cruise product concerns the triptych "fun-sun-sea". The Mediterranean region offers many additional alternatives for travelers, such as the iconic cultural and historical sites and cities of the great ancient civilizations. In addition, it has a significant geographical advantage as it is located at the crossroads of three continents (Europe, Africa and Asia), while the dense port system, as well as the dense land and air transport network, allow the organization of innovative routes in a relatively small area. Also, since 2001, there have been significant improvements in the security standards of Mediterranean port facilities, such as passenger terminals, and finally, the global cruise market is looking for a longer tourist / cruising season on offer in the region. On the other hand, multiple destinations create dynamic conditions in the use of ports, and consequently significant fluctuations in their use by companies. At the national level, in the period 2013-2018, the cruise passenger traffic followed the trend of the wider Mediterranean region: declining for the period 2014-2017, with the exception of 2016, which saw a temporary increase due to the failed coup and a series of illegal actions in Turkey. , due to which many companies were forced to cancel their approaches to the neighboring country and look for alternative ports of approach. Both in the Mediterranean and in Greece, from 2018 the trend was upward. Passenger traffic in the Mediterranean fluctuated from -7% (in 2014) to + 8% (in 2018), finally forming a positive average annual growth rate of 1%. For the eastern Mediterranean the average annual rate of change is estimated at -10% and for Piraeus -3%. Comparing passenger traffic in 2013 and 2018, in the Mediterranean there was an increase of 1%, in the eastern Mediterranean a decrease of 54% (the most significant decrease, of 33% compared to 10-15% in previous years, occurred in 2017) and in Greece a decrease of 12%. The Eastern Mediterranean absorbed an average of 10% of passenger traffic in the Mediterranean ports and Greece (taking into account the 8-10 ports that are members of Medcruise), despite the fluctuations, 8%, and 90 % of the eastern Mediterranean, which indicates the country's dominance in the region. Piraeus absorbed an average of 44% of passenger traffic in the eastern Mediterranean, and 4% of the Mediterranean. According to the data, 2019 was the first year in which there was an increase in passenger traffic in all three areas. On average, 611 ships approached 1,762 passengers annually in Piraeus, while the ports of the eastern Mediterranean received a total of 1,800 ships of 1,460 passengers. However, the rising climate in the Mediterranean in general in 2019 favored Piraeus in terms of homeporting, as -according to reports- was a homeport for 372 ships compared to 257 in 2018.

The activities carried out on these ships, i.e. mainly recreational activities, produce large amounts of solid, liquid and gaseous emissions, which are partially landed directly at sea or can also be processed at the port of destination. Environmental reports show that this wastewater is usually of a higher pollutant load than urban wastewater (USEPA, 2008). It is generally accepted that shipping provides the most efficient and environmentally friendly method of transporting goods worldwide compared to road, rail and air transport. The International Convention for the Prevention of Ship Pollution, 1973, as amended by the 1978 Protocol (MARPOL 73/78) and the International Safety Management Code (ISM), both under the auspices of the International Maritime Organization. Supports best practices for reducing pollution and generating harmful waste. Prohibits intentional dumping of certain waste at sea. Categorizes waste into black (forbidden) or gray (permission required). It contains six annexes that prohibit discharges, set construction standards, impose sanctions, allow enforcement and identify "Special Areas", which cover: oil, harmful liquids, harmful substances (packaged), sewage, waste, air pollution. The development of this particular market has introduced a unique set of environmental pressures that need to be addressed and investigated, in particular those related to waste management. The world's merchant fleet consists of about 46,222 vessels and it is estimated that a quarter of all waste is generated by less than 1% of this cruise ship fleet. (Perucci et al.,2012.). As the cruise market continues to grow, so will the amount of waste required rejection. There is also legislation through the European Parliament on port requirements and the provision of reception facilities for ship waste that cannot be disposed of at sea in accordance with MARPOL Directive 73/78. EU Directive 2000/59 (on ports) ship and waste cargo collection facilities) is based on the basic principles of EU land waste policy, with an emphasis on port and ship waste focusing on the concept of "polluter pays" and "producer responsibility", followed by prevention. Annex IV regulates the discharge of domestic waste water. however, there are no specific rules for cruise ships. In addition, ships can unload organic waste and treated waste at a minimum distance of more than three nautical miles from the nearest land or 12 nm from the nearest land without any treatment and always away from sensitive areas. Some of this waste and its effect on the oceans have been studied before, but without details about the pollutant load and without paying attention to emerging pollutants. In this regard, all ships must have on-board Sewage Treatment Equipment, either a traditional MSD (Marine Sanitation Device) that includes biological treatment that focuses on reducing Biologically Required Oxygen (BOD) and certain nutrients, clarification and filtration to remove solids, and finally a chlorine disinfection process to destroy pathogen (Koboević and Kurtela .,2011 ; USEPA, 2006). There are also advanced water treatment systems such as membrane bioreactors (MBR) or Mobile Bed Bioreactor (MBBR), followed by tertiary filtration and disinfection with ultraviolet radiation. These treatment systems are reliable enough to achieve high performance levels of wastewater treatment and disinfection as reported in sampling reports for various cruise ships (USEPA, 2006). Assessing and regulating the environmental footprint of cruise ships is not an easy task due to the inherent complexity and the fact that shipping has historically been absent from relevant mitigation policies

CHAPTER 2

2.1 INTERNATIONAL CONVENTION FOR THE PREVENTION OF MARINE POLLUTION FROM SHIPS (MARPOL 73/78)

In 1973 the IMO adopted the International Convention for the Prevention of Ship Pollution, known as MARPOL 73/78. The MARPOL Convention tackles pollution from oil, liquid harmful substances in bulk, harmful substances in packaged form, ship effluent, waste and air pollutants. MARPOL has helped to dramatically reduce shipping pollution. Statistics from reputable shipping companies and other independent bodies show that MARPOL, in combination with safety regulations such as the introduction of mandatory traffic separation systems and international standards for seafarers' training, have contributed to its continued decline. accidental and operational oil pollution for the last forty years. The Marine Environmental Protection Committee (MEPC) of the IMO reviews various provisions of MARPOL which either require clarification or present difficulties in their implementation.

The contract consists of the following parts:

• International Convention on the Prevention of Marine Pollution of 1973 and Protocol of 1978 on the International Convention on the Prevention of Marine Pollution of 1973.

• Protocol I: Predicting accident reports involving harmful substances.

• Protocol II: Arbitration.

• Six technical annexes:

1. Annex I: Regulations for the prevention of oil pollution. It entered into force on 2 October 1983.

2. Annex II: Regulations for the control of pollution by liquid noxious substances in bulk. It entered into force on 6 April 1987.

3. Annex III: Regulations for the prevention of pollution by harmful substances in packaged form. It entered into force on 1 July 1992.

4. Annex IV: Regulations for the prevention of pollution from ship sewage. It entered into force on 27 September 2003. The revised Annex IV was adopted in 2004.

5. Annex V: Regulations for the prevention of pollution from ship waste. It entered into force on 31 December 1988.

6. Annex VI: Regulations for the prevention of gaseous pollution from ships. It entered into force on 19 May 2005.The newest annex to the contract, Annex VI, will be developed in Chapter 6.

2.2 Annex I: Regulations for the prevention of oil pollution.

MARPOL Annex I concerns ships of all types. The responsibility for implementing Annex I regulations lies with governments and port authorities, shipowners, shippers, consignees, ship personnel and in particular the master and officers. The general rule in MARPOL Annex I is that Disposal of oil at sea is prohibited, unless certain conditions are met in relation to the following:

- Type and size of the ship.
- Characterization of a sea area.
- Distance from the shores.
- Ship equipment for pollution control.
- Types and origin of oily mixtures / residues.

• Oil content in oily mixtures / residues.

• Rate and quantity of waste oil.

• The instantaneous oil discharge rate does not exceed 30 liters per nautical mile (nm). "Instantaneous discharge rate" is the rate of oil discharge at a given point in time (in L / h) divided by the speed of the vessel at nodes (nm / h) at the same time. Studies have shown that oil discharged at a rate of 30 L / nm disperses quickly and leaves no residue.

The total amount of oil rejected does not exceed for the existing oil tankers (of the time) 1 / 15,000 and for the new oil tankers 1 / 30,000 of the cargo they carried on the last voyage. This requirement puts an upper limit on the amount of oil that can be discarded.

2.2.1 Special areas

A new and important feature of MARPOL 73/78 was the introduction of the concept of "special areas". Special areas are those marine areas in which, for recognized technical reasons, related to their oceanographic and ecological condition and the special nature of maritime traffic, the adoption of very strict measures to prevent their oil pollution is required. Specifically, Annex I specific areas include the Mediterranean Sea, the Baltic Sea, the Black Sea, the Red Sea, the Persian Gulf and the Gulf of Oman, the Gulf of Aden and the Antarctic region, northwestern European waters, the Oman region and the southern waters of South Africa. Within a designated area all runoff of oil, sludge, sewage and tank effluents should either be retained on board or delivered to ship reception facilities. Nevertheless, discharges from engine areas into special areas outside Antarctica are permitted when the oil content does not exceed 15 ppm.

2.2.2 Equipment of ships

The equipment includes:

• Automatic oil spill monitoring and control system: Provides continuous recording of oil spill rate in liters per nautical mile and the total quantity discarded.

• Oil separator.

• 15 ppm filtration machine.

• Other relevant equipment, such as oil meter, alarm system, recorder, etc.

Oil separators and filtration machines use similar mechanisms and include filters and / or separators, designed so that for oil separators the outflow has a maximum oil content of 100 ppm, while for filtration machines 15 ppm. Most oil separators are based on gravity and the density difference between oil and water for separation (ICS-OCIMF, 1994). It should be noted that a good oil / water separation takes time and depends on the movement of the ship as well as the type of oil. For example, under favorable conditions it may take 12 hours to separate the impure ballast, but in most cases more than 24 hours are required. It is worth noting that for discharges into special areas the ship must maintain a 15 ppm filtration machine with an automatic outflow switch.

2.2.3 Oil Record Book

According to Regulation 20, the "Oil Book" must be kept by:

• oil tankers of 150 gross weight and above,

• ships other than oil tankers of 400 gross tonnage or more.

The "Oil Book" has two parts:

• Part I: For all ships, including oil tankers, for engine room operations.

• Part II: For oil tankers only, for loading and unloading operations.

Each operation should be mentioned in the corresponding section of the "Oil Book" for IOPPC-certified vessels. Each "Oil Book" is kept for three years after the last registration.

2.3 Annex II: Regulations for the control of pollution by liquid noxious substances in bulk

Annex II to MARPOL 73/78 entered into force in 1987. At that time its forecasts had already been exceeded for the following reasons:

• Improvements to the pumps, which made possible much stricter limits on the quantities of substances that could be discharged into the sea.

• Improvements in the understanding of marine pollution, which brought about changes in the classification of chemicals.

• Change of public attitudes regarding:

1. environmental protection,

2. clean food,

3. clean seas for recreation.

Modifications were immediately proposed, which were adopted in 2004 and entered into force in 2007. Annex II to MARPOL 73/78 sets out in detail the disposal criteria and measures for the control of pollution by harmful liquid substances carried in bulk. These substances include any liquid transported in bulk that does not meet the definition of petroleum products listed in MARPOL Annex I. Therefore, Annex II does not include oil and its products, for which there are provisions in Annex I.

Environmental protection issues for harmful liquid substances transported in bulk are regulated by Annex II of MARPOL 73/78: • Substances are classified into categories according to the risk to the marine environment.

• Specifications are set for their discharges into the marine environment.

Safety issues for bulk harmful liquids are regulated by the IBC Code (International Code for the Construction and Equipment of Ships Carrying Dangerous Cargoes in Bulk) or the BCH (Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk) :

• Specifications are set for the design and construction of ships for each category of substances.

• Lists of substance names are classified, classified according to their risk.

2.3.1 Waste disposal requirements

Regarding the discharge of tank cargo residues, after they have been thoroughly drained according to the specifications mentioned earlier, Regulation 13.2 of Annex II of MARPOL applies and applies, which provides that no chemical, in any category () X, Y, G), cannot be discarded at sea, unless the following are met at the same time:

• The ship is in a speed of at least 7 knots for self-propelled ships or at least 4 knots for non-self-propelled ships.

Dispose of at least 12 nautical miles from the nearest land and in an area not less than 25 meters deep.

• Dispose of below the waterline.

The following also applies specifically to Category X substances:

• It is forbidden to dump cargo residues of category X substances directly into the sea.

• A tank from which Class X substance has been unloaded must be pre-washed before the ship leaves the port of unloading.

• The resulting residue must be delivered to a receiving facility until the concentration of the substance in the leachate is equal to or less than 0.1% by weight (based on analyzes of leachate samples taken by the inspector).

• When the desired concentration level (0.1% by weight) is reached, the leachate remaining in the tank must continue be discarded in the receiving facility until the tank is empty.

• Appropriate entries of these companies must be entered in the Cargo Book.

• Any quantity of water subsequently introduced into the tank may be discharged into the sea in accordance with the discharge standards of Regulation 13.2 (applies to substances of all categories).

For waste disposal procedures for substances in categories Y or Z, after draining in accordance with table 3.5, the disposal standards of Regulation 13.2 apply. That is, ship speed of at least 7 knots, discharge at a distance of at least 12 nautical miles from the nearest land, in an area with a depth of not less than 25 meters and below the waterline. Especially for high viscosity substances or solidifiers of category Y (concerns many vegetable oils that have high viscosity, ie high flow resistance), a pre-wash procedure must be applied after drainage. The residue / water mixture produced during prewash should be disposed of in a receiving facility until the tank is empty. Any quantity of water subsequently introduced into the tank may be discharged into the sea in accordance with the discharge standards of Regulation

13.2. A specific area for MARPOL Annex II is Antarctica, where no residual harmful liquid substances or mixtures containing such substances are permitted to be discharged into the sea (throughout the sea area south of 60 ° N).

2.4 Annex III: Regulations for the prevention of harmful pollutants in packaged form.

Annex III is the first optional annex to the contract. States ratifying the Convention are obliged to accept Annexes I and II, but may choose not to accept the other Annexes and therefore took much longer to enter into force.

Annex III is relatively small and contains detailed rules for packaging, marking, labeling, consignment notes, documentation, storage, quantity restrictions and exemptions to prevent harmful contamination in packaged form. , in containers, in containers, in portable tanks or in road and rail tankers. The so-called "harmful substances" are clarified in the International Maritime Dangerous Goods Code (IMDG Code).

2.5 Annex IV: Regulations for the Prevention of Ship Pollution

Annex IV is very important because both the passengers and the crew of a ship generate domestic sewage, in some cases in large quantities (e.g. cruise ships). According to the terms of Annex IV, sewage is defined as sewers and other wastes from all types of toilets, urinals and toilets, sewers from doctor's offices (pharmacies, hospitals) through sinks, baths and their sewers, sewers from spaces where there are live animals and any other waste containing any of the above sewers.

Problems caused by sewage discharges into the marine environment include:

• Health problems in humans due to the presence of pathogenic microorganisms in wastewater, as well as

• Depletion of marine oxygen and predominance of anaerobic conditions, resulting in the release of foul-smelling and dangerous gases (eg hydrogen sulfide - H_2S and ammonia - NH_3).

It is generally believed that in the high seas the wastewater is diluted to a sufficient degree and the bacteria aerobically break down the organic matter of the waste and eliminate it. This prohibits the discharge of sewage near land (3 or 12 nautical miles, depending on the treatment system available to the ship).

In accordance with Regulation 3 of Annex IV, ships are subject to inspections to verify that they comply with the provisions of the Annex. In particular, they are subject to an initial inspection before being put into service or before the issuance of the Certificate of Prevention of Sewage Pollution, which ensures that:

• When the ship has a sewage treatment plant, it meets the operational requirements based on the standards and test methods developed by the Agency.

• When the ship has a sewage mashing and disinfection system, this will be of a type approved by the Authority.

• When the ship has a holding tank, its capacity will be sufficient to hold all sewage, taking into account the operation of the ship, the number of people on board, etc. The holding tank must also have means of visually indicating the amount of its contents.

• The ship is equipped with a pipeline that ends abroad, suitable for the delivery of sewage to reception facilities and that this pipeline has a standard land connection, in accordance with Regulation 11 of the Annex.

Periodic inspections are also carried out at intervals not exceeding five years.

Regulation 8 stipulates that the discharge of sewage into the sea is prohibited, unless:

(a) The ship discharges pulp and disinfected effluent more than 3 nautical miles from the nearest land. The ship discharges wastewater that has not been mashed or disinfected more than 12 nautical miles from the nearest land. In any case, the effluent stored in holding tanks is not discharged all at once, but at a moderate rate of discharge, when the ship is on track and traveling at a speed of not less than 4 knots.

(b) The ship has an approved sewage treatment plant in operation; and

• The results of the installation tests are recorded in the International Certificate of Prevention of Pollution from the ship, while also

• Wastewater does not create visible floating solids or discolor the surrounding water.

(c) The ship is in waters under the jurisdiction of a country and discharges sewage according to less stringent requirements that may be imposed by it.

In other words, if the ship has a wastewater treatment plant that operates in accordance with MARPOL forecasts, then it can discharge its wastewater anywhere in the sea. Locally, in several states, legislation may prohibit discharges into ports.

If the ship has a sewage mashing and disinfection system that operates according to MARPOL forecasts, then it can discharge its sewage at a distance of more than 3 nautical miles from the nearest land. When the ship is less than 3 nm from land, it retains its wastewater in a holding tank and does not discharge it into the sea. If the ship has neither a treatment system nor a sewage mashing and disinfection system, it can discharge its sewage more than 12 nautical miles from the nearest land. When the ship is less than 12 nm from the nearest land, it shall hold them its wastewater into a holding tank and does not discharge it into the sea.

2.5.1 MARPOL forecasts for ship sewage treatment plants

For the purposes of Regulation 9.1 of Annex IV, a waste water treatment plant must meet the following discharge standards when tested for the type - approval certificate from the outset:

1 Heat Resistant Coliform Standard

The geometric mean of the number of heat-resistant coliforms of the effluent samples taken during the test period shall not exceed 100 thermo-molecular coliforms / 100 ml as determined by membrane filter, multi-tube fermentation or equivalent process.

2 Total Suspended solids (TSS)

The geometric mean of the total suspended solids content of the effluents taken during the test period shall not exceed 35 Qi / Qe mg / l. When the sewage treatment plant is inspected on board, the maximum total solids content of the waste samples taken during the test period can be adjusted to take into account the total solids suspension content in the flush water. By allowing this adjustment to the maximum TSS, ship-owners should ensure that adequate checks of the rinsing water TSSs are taken throughout the test period to accurately determine the geometric mean to be used as the adjustment number (defined as X).

Under no circumstances will the maximum permissible TSS be greater than (35 plus x) Qi / Qe mg / l. (Influent (Qi) - Liquid containing sewage, gray water or other liquid streams, to be, Effluent (Qe) - treated wastewater produced by the sewage treatment plant)

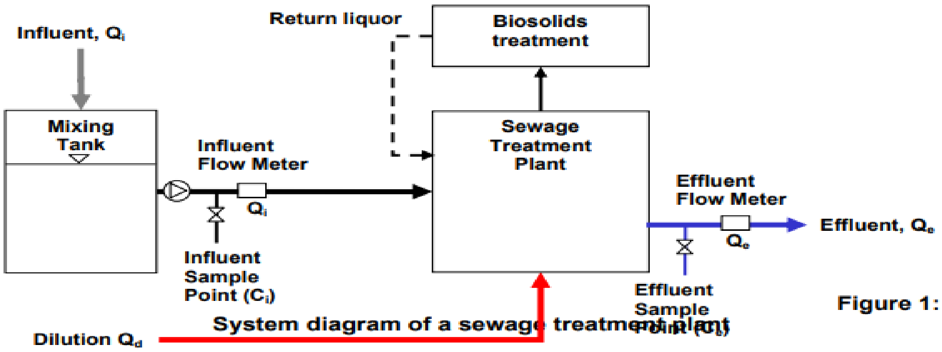


Figure 1 Typical Waste Treatment System.

The test method must be:

• filter a representative sample through a 0.45 μm membrane filter, dry at 105 ° C and weigh

• Centrifugation of a representative sample (for at least five minutes at an average acceleration of 2,800-3,200 g), drying at least 105 ° C and weighing; or

• Other internationally accepted equivalent test standards.1

3 Biochemical Oxygen Demand and Chemical Oxygen Demand (biochemically required oxygen)

• the geometric mean of the five-day biochemical oxygen demand (BOD5) of effluent samples taken during the test period does not exceed 25 mg / l and the chemical oxygen demand (COD) does not exceed 125 mg / l.

The standard test method should be

ISO 15705: 2002 for COD and

ISO 5815-1: 2003 for BOD5 or

• other internationally accepted equivalent test standards.

4 pH

• The pH of the effluent samples taken during the test period should be between 6 and 8.5.

5 Zero or undetectable values

For heat-resistant coliforms, the zero values should be replaced by a value of 1 heat-resistant coliform / 100 ml to allow the calculation of the geometric mean. For the total floats solids, biochemical oxygen demand and chemical oxygen demand, values below the detection limit should be replaced by half of the detection limit to allow the geometric mean to be calculated.

The current Annex IV to the MARPOL Convention allows the discharge of untreated sewage into the sea under certain conditions at a distance of more than 12 nautical miles from the nearest land. Sewage treated according to MEPC.2 (VI) or MEPC analysis standards. 159 (55) can be discarded anywhere. However, there is no requirement for the removal of nutrients, such as phosphorus (P) and nitrogen (N), from wastewater prior to discharge into the sea. In addition, nutrient processing standards are recommendations intended to be used only as target values, and under MARPOL Annex IV, nutrient standards, if adopted, will be fully and legally binding. (IMO MEPC.227(64) , 2012) ; IMO MEPC 1/Circ.834 ,2014).

2.5.2 Proposed outflow standards for Special Areas

Nutrients introduced into the marine environment through wastewater can cause algae overgrowth by reducing the level of oxygen in seawater and thus causing the destruction of fish, corals, marine and other marine organisms.9 For example in the Adriatic, the phytoplankton blooms and the production of large amounts of mucus, while not harmful to humans, their decomposition has adverse effects on marine organisms(Clark , 2006). This can be especially problematic during the summer months, when there is little water movement and the thermoclinic boundaries are mixed with the bottom layers. In the Baltic Sea, the problem of the introduction of nutrients into the sea by the discharge of sewage from land and from ships is becoming one of the most important problems of this sea. The agreement on appropriate limits for the discharge of nitrogen and phosphorus from passenger ships intending to dump sewage into designated areas should be based on a substantive assessment of both the scientifically generated release limits and the availability of relevant treatment technology. The proposed nutrient effluent standards were derived from the Baltic Sea Action Plan * (BSAP). In addition, nutrient processing standards are recommendations intended to be used only as target values, and under MARPOL Annex IV, nutrient standards, if adopted, will be fully and legally binding. For the purposes of Regulation 9.2.1 of Annex IV to MARPOL, a sewage treatment plant installed on a passenger ship intended to dump sewage into designated areas shall in addition meet the following discharge standards when testing the type-approval certificate from the principle.

Criteria for the disposal of nutrients in specific areas (Baltic Sea).

Passenger ships (over 12 passengers) sailing in special areas must be equipped with either:

1) type wastewater treatment plant (approved type) capable of reducing:

• N concentration at less than 20 mg / l or at least 70%, and -

• concentration P is less than 1.0 mg / l or at least 80% .

2) a sufficient quantity holding tank for the maintenance of all sewage, taking into account the operation of the ship, the number of people on board and other relevant factors.

The test method must be:

• ISO 29441: 2010 for total nitrogen. and

• ISO 6878: 2004 for total phosphorus. the

• other internationally accepted equivalent test standards.

However, none of the AWTS (Advanced water treatment system) currently used on cruise ships is expected to be able to meet the strictest of the two proposed nutritional standards, i.e. total nitrogen 20 mg / l or at least 70% reduction and total phosphorus 1.0 mg / l or at least 80% reduction. According to the BSAP, these limits generally correspond to a coastal community of 2,000 to 10,000 human equivalents. (CLIA , 2014 ; IMO MEPC.227(64) ,2012).

2.5.3 Sewage Disposal Rates

This standard does not incorporate dilution of wastewater with water or pale water in landing rate calculations. Therefore, the rate is a conservative estimate and it is recognized that effluents according to this standard will offer a higher level of protection to the marine environment due to mixing before actual landing.

The maximum permissible discharge rate is 1 / 200,000 (or a 200,000th part) scan volume as follows: DR max = 0.00926 V D B4

Where: DR max is the maximum allowable discharge rate (m3 / h)

V is the average speed (knots) of the ship during the period

D is length (m)

B width (breadth) (m)

2.6 Annex V: Regulations for the Prevention of Ship Pollution

Ship passengers and crews produce significant amounts of waste (solid waste) on a daily basis, such as food scraps, cans, bags, plastics, etc. Proper management of this waste so that it does not end up in the sea and on the shores is considered absolutely necessary for the protection of the coastal zone.

The waste must be grouped into categories for the purposes of the "Waste Book" (or the official deck logbook) as follows:

1. Plastics: Plastic waste of all kinds, including synthetic ropes and fishing nets, as well as plastic bags. It is forbidden to dump at sea all the waste of this category.

2. Food residues: Food residues can be disposed of at sea under special conditions (Table 3.6).

3. Household waste: Waste generated mainly at the ship's accommodation (eg bottles, papers, cardboard). Disposal of this category of waste into the sea is prohibited.

4. Cooking oils: Edible oils or animal fats used to prepare food. Disposal of this category of waste into the sea is prohibited.

5. Incinerators: Ashes and slag from ship incinerators used for incineration. Disposal of this category of waste into the sea is prohibited.

6. Operating waste: Solid waste (including sludge) collected during the normal operation or maintenance of a ship or used for handling and stowage of cargo. Functional waste also includes cleaners and additives contained in barns, as well as external washing water, which can be harmful to aquatic life.

7. Cargo residues: Residues of any cargo remaining on board or in the ship's hold after loading or unloading and not covered by other MARPOL annexes. Cargo residues can be disposed of at sea under special conditions.

8. Animal carcasses: The body of any animal carried as a consignment that dies or is killed during the journey. Animal carcasses can be disposed of at sea under special conditions (Table 3.6).

9. Fishing equipment: Any kind of equipment that can be used for fishing. Disposal of this category of waste into the sea is prohibited.

The specific areas for Annex V are the Mediterranean Sea, the Baltic Sea, the Black Sea, the Red Sea, the Gulf region (ie the Persian Gulf and the Gulf of Oman), the North Sea, the Antarctic region and the wider Caribbean region, including the Gulf of Mexico and the Caribbean Sea. In the special areas there are much stricter requirements.

The government of each port state is obliged to ensure the existence of waste reception stations of sufficient capacity in ports and terminals, for the receipt of waste without causing undue delay to ships and according to their needs. The issue of landfills is also addressed in Directive 2000/59 / EC on port waste collection facilities and cargo residues, the provisions of which are set out in Chapter 7.

2.7 Annex VI to MARPOL

MARPOL Annex VI was adopted in 1997 and entered into force in 2005. Its provisions set limits on the emissions of the main pollutants in ships' exhaust gases, i.e. sulfur oxides (SOx) and nitrogen oxides (NOx), prohibiting intentional Emissions of Ozone Depleting Substances (ODS) and regulate onboard combustion and Emissions of Volatile Organic Compounds (VOCs) from tankers.

2.7.1 SO2 and NOx

Annex VI initially set an upper limit of 4.5% by weight. in the sulfur content of petroleum fuel used by ships. This limit has been reduced to 3.5% (2012) and is projected to decrease further to 0.5% by 2020 (Table 3, Figure 1).

Annex VI contains a provision for specific areas where SO2 Emission Control Areas (SECAs) will be stricter and specifically in these areas the sulfur content of the fuel should not initially exceed 1.5% by weight. This limit was reduced to 1% in 2010 and became 0.1% in 2015. An alternative is for ships to use high sulfur fuel and at the same time apply an exhaust gas cleaning system or use any other technology that will reduce emissions SO2 in the emission levels of low sulfur fuels.

Table 1 Sulfur content of fuels

Outside an ECA established to limit SOx and particulate matter emissions	Inside an ECA established to limit SOx and particulate matter emissions
4.50% m/m prior to 1 January 2012	1.50% m/m prior to 1 July 2010
3.50% m/m on and after 1 January 2012	1.00% m/m on and after 1 July 2010
0.50% m/m on and after 1 January 2020*	0.10% m/m on and after 1 January 2015

* MARPOL Annex VI Regulation 14 6, 11 Depending on the availability of light fuel (feasibility review to be completed in 2018), the date may be postponed to 1 January 2025.

Regulation 13 determines the quantities of NOx that a ship is allowed to emit per kWh. Quantities depend on the rated engine speed. There are three levels of emissions, Tier I-III. The younger a ship is, the stricter the boundaries. The Tier I forecasts (Table 6.5) apply to engines installed on ships built on or after 1/1/2000, while the Tier II emission limits apply to engines installed on ships built during or after after 1/1/2011. The limits of Level III (Tier III) are the strictest and will apply only in the Special Areas for NOx (NOx Emission Control Areas - NECAs), for engines on ships built on or after 1/1/2016. In particular, the Tier III limits are 80% stricter compared to the Tier I limits.

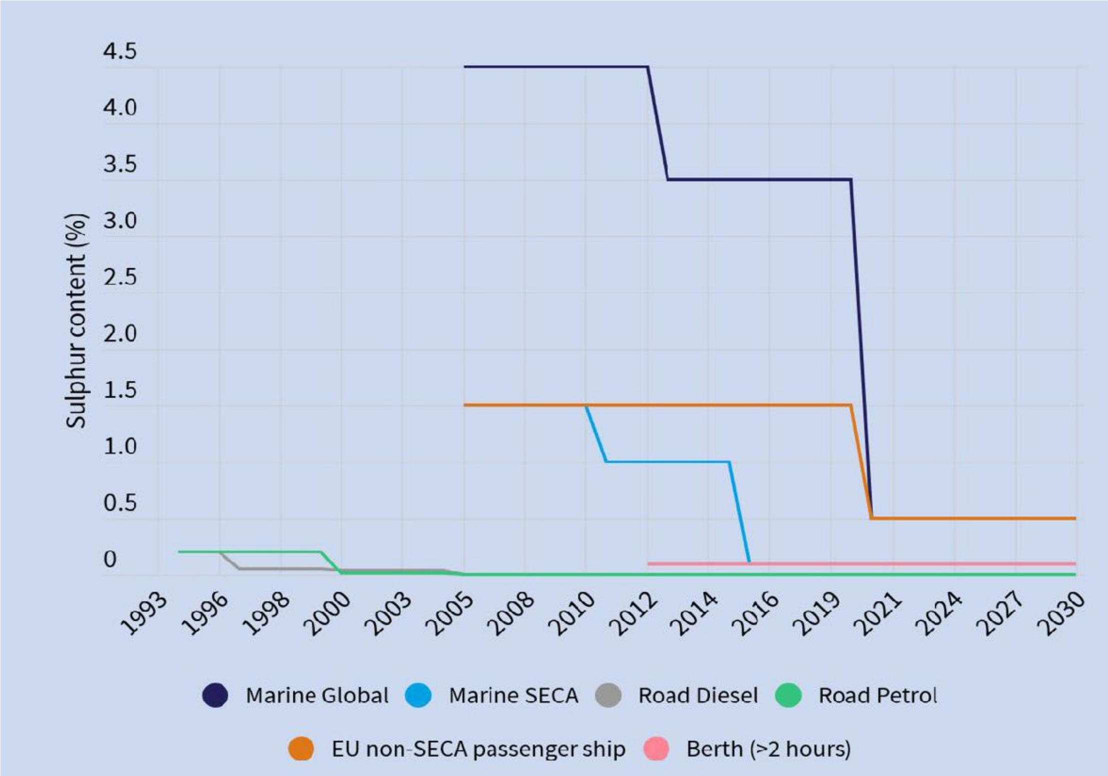


Figure 2 Limits on sulfur content of marine fuels under MARPOL Annex VI

2.7.2 Carbon dioxide (CO2)

On 1 January 2013, the provisions of the new Chapter 4 of Annex VI of MARPOL entered into force, which introduces measures aimed at improving the energy efficiency of shipping, in order to reduce fuel consumption and CO2 emissions. Regulation 21 of Chapter 4 introduces the Energy Efficiency Design Index (EEDI), which mainly concerns technical measures and is mandatory for new ships, while Regulation 22 introduces a mandatory management tool (Ship Energy Efficiency Management). Plan - SEEMP), which concerns mainly operational measures, for all ships (new and existing). In order for a ship to obtain the International Energy Efficiency Certificate (IEEC), it must meet the requirements for EEDI and SEEMP.

2.7.3 Description of the policy context and the EU regulatory framework for air pollution from ships

Shipping is an important transport sector relying on the use of fossil fuels as a source of energy. Unlike other transport modes, marine fuel is less refined and standards for emission of air pollutants are less strict. As a result, shipping is a source of considerable air pollution despite fewer number of operational vessels in the global fleet. Sulphur oxide (SOX) emissions form sulphate (SO4) aerosols that increase human health risks. SOX, fine particles (PM2.5) and nitrogen oxides (NOX) cause premature death, including from lung cancer and cardiovascular disease, and morbidity, e.g., childhood asthma. They also contribute to acidification in terrestrial and aquatic environments. NOX contribute to particle and ozone formation, in addition to causing acidification and eutrophication upon deposition on land, lakes and seas. It is moved long distances in air and is, therefore, often considered a 'regional' pollutant.

Over the past 10 years, governments acting locally, regionally and globally have commended efforts to reduce ship air pollution by setting SOX and NOX standards for marine fuels and engines. In addition, certain geographical areas in Europe and North America, and more recently in China (only local) have been designated emission control areas (ECA) for air pollutants.

Yet, shipping remains the least regulated transport sector as regards air pollution. The best marine Sulphur standard (0.1% | 1000 ppm) remains 100 times worse than Europe's Sulphur standard for road diesel/petrol (0.001% | 10 ppm) in place for the past 15 years. Recent studies have shown the staggering amount of air pollutants emitted by the global fleet and that increasingly large proportion of NOX and SOX depositions on land in coastal regions and port cities come from ships. But these studies have had a generic global and/or regional scope. Estimations of ship emissions have not been undertaken for individual countries with a coastline. Analysis of emissions from passenger ships, especially luxury cruise vessels, is also missing yet recent. The basic legislation for reducing sulfur dioxide emissions from shipping was Directive 1999/32 / EC on the reduction of the sulfur content of certain liquid fuels, which set the maximum permissible sulfur content of heavy fuel oil, domestic oil combustion and internal combustion oil of ships. This Directive was amended by Directive 2005/33 / EC, which brought the provisions of the EU into line with the IMO Framework and MARPOL Annex VI.

In addition, Directive 2005/33 / EC provided that from 1/1/2010 Member States should take all necessary measures to ensure that ships moored or anchored in EU ports do not use fuel containing in sulfur greater than 0.1% by weight By comparison, MARPOL Annex VI provides that ships within SECA (including specific areas) will use 0.1% by weight of fuel. in sulfur during and after July 1, 2015. This provision does not apply to ships that remain in ports for less than 2 hours, as well as to ships that turn off all engines and use energy from land. It applies to all boats regardless of flag, type, age or tonnage. It practically means that ships will have to change their fuel from heavy fuel (HFO - Heavy Fuel Oil) to light (MGO - Marine Gas Oil) in European ports. In the same context, the European Commission adopted Recommendation 2006/339 / EC, recommending that Member States consider establishing onshore energy supply for ships in ports, in particular where air quality limits are exceeded, or excessive noise and especially in ports located near residential areas. This recommendation is supported by Directive 2003/96 / EC on the taxation of electricity, which allows Member States to apply total or partial exemptions to the taxation of electricity under certain conditions, one of which may be considered to be the onshore energy for ships in ports.

In November 2012, Directive 2012/33 / EU was adopted, which again amended Directive 1992/32 / EC, further reducing the sulfur content of fuels inside and outside the SECAs, in line with MARPOL Annex VI regulations. , as follows:

Within SECAs

• 1.00% until 31/12/2014.

• 0.10% from 1/1/2015.

Except SECAs

• 3.50% from 6/18/2014.

• 0.50% from 1/1/2020.

Regarding CO2 emissions from shipping, in the White Paper on Transport, published in 2011, the European Commission stipulates that overall CO2 emissions from shipping should be reduced by 40% (and if possible by 50%) by 2050, compared to 2005 levels 16. Based on this objective, the European Commission proposes a new system for monitoring, reporting and verifying emissions (MRV) of carbon dioxide emissions for ships above of 5,000 daughters calling in EU ports. Based on MRV:

• Ships should monitor carbon dioxide emissions, distances traveled, and cargo carried.

• The above data should be confirmed by an independent body and sent annually to the ship's flag State and to the European Commission.

This expected reduction is very conservative in relation to the objectives of the White Paper on transport. Nevertheless, introducing the MRV and setting a reduction target could be the first step towards adopting a market-based emission reduction tool. The EU has so far excluded shipping from the emissions trading directive which raises the level of enforcement and compliance in different parts of the world can vary considerably. EU states have the advantage over the IMO that they have the power to enforce regulations as well as impose sanctions in the event of infringements. The increasing use by Member States of Port State Control (PSC) can be an effective tool in this area. The operating framework of the PSC in the EU is set by Directive 2009/16 / EC, as amended by Directive 2013/38 / EU.greenhouse effect (Directive 2003/87 / EC). It is estimated that it may integrate it in the future unilaterally, especially if the IMO does not proceed with the adoption of market-based tools.

A major challenge is the ability to enforce and control regulations. The IMO, which is a UN body, does not have such powers. Although in shipping especially the standards and regulations are (and should be) global.

Chapter 3 Liquid Waste from Cruise Ships

3.1 Introduction

Previous studies around the world have shown that liquid waste has a negative impact on the marine environment. The problem is most pronounced on large cruise ships where the total number of passengers and crew exceeds 8000 people (Eley et al., 2003) . Liquid waste from large cruise ships is produced in large quantities, so the methods of processing and managing them on board before dumping them at sea are very important. The liquid waste of a cruise ship can be divided into waste containing oil residues (oily bilge water) and sewage (sewage). Oily bilge water is a mixture of water, oil, lubricants, cleaning fluids and other similar waste generated by the ship's main and auxiliary engines, boilers and other engines. Oily water is treated as oil and is regulated by Annex I to the MARPOL Convention. Sanitary waste (sewage) for their most efficient treatment and subsequent disposal is divided into black water (black water) and gray water (gray water). Black water comes from discharges of all types of toilets, urinals, discharges from areas with animals and any other sewage which is mixed with the above and is regulated by Annex IV of MARPOL. Gray water, on the other hand, contains water from sinks, baths, showers, laundries, saunas, swimming pools, sinks, and water produced by shipwrecks and is not recognized as pollutant by the IMO (International Maritime Organization). This means that gray water is not recognized as a pollutant in the European Union either, since European legislation has adopted the IMO guidelines. A review of the literature has shown that pollution in ports and coastal areas does not come from black water but from gray water which is not recognized as a pollutant under the MARPOL Convention. Therefore, it is considered necessary to enact legislation restricting the discharge of raw gray water into ports and the sea area up to 3 M from the nearest land. In addition, research has shown that raw gray water contains bacteria and suspended solids equal to or greater than black water (Cohen, 2008) . By volume, the impact of wastewater from cruise ships is significant. On a large cruise ship, each passenger can use up to 40 liters of water through the "black water" system and 340 L "gray water" such as showers, washing machines and a pool on cruise ships with 2 000-3 000 passengers, during of a day about 550 000-800 000 liters of gray water are produced, 100 000-115 000 liters of black water.(Koboević.,2011).The quality of sanitary wastewater is determined by the quantity of certain characteristics contained in the wastewater. It should be noted that depending on their origin from the ship, wastewater contains different amounts and concentrations of waste and is characterized by its physical, chemical and microbiological properties. There are various indicators for the quality of liquid waste which are indicated by Annex IV of the IMO, the limits of which should not be exceeded by ship effluents after treatment. Indicators that have a significant impact on the marine environment and human health and are distinguished in the following: thermotolerant coliforms, total suspended solids (TSS), biochemical required oxygen for 5 days (5-day biochemical BOD), chemically required oxygen (COD), pH value, and chlorine residue. The concentration of these factors in the effluent depends directly on the effluent treatment system installed on the vessel. As the amount of waste generated by cruise ships is in this dimension, it is extremely important that they do not drain into the seas. Sewage discharges into the sea can pose a health risk, while in coastal areas, sewage can also lead to oxygen depletion and visible visual pollution - a major problem for countries with large tourism industries. In order to prevent marine environmental pollution, all ships must have on-board waste treatment systems or traditional marine treatment equipment which includes biological treatment with an emphasis on reducing biochemically required oxygen (BOD5) and some nutrients. for the destruction of solids and finally disinfection with chlorination for the destruction of pathogenic microorganisms (Tchobanoglous et al .,2003 ; Avellaneda et al .,2011). or advanced wastewater treatment systems such as membrane bioreactors (MBR) or mobile bed bioreactors followed by quaternary filtration and discharge Such systems can process 45-55 m3 / day of black water, 350-380 m3 / day of gray water, 100-125 m3 / day of water coming from washing machines, 175-200 m3 / day of water from cooking at a total flow rate of 550 -700 m3 / day. (Peric ,. 2016).Today, many of the top cruise lines have implemented practices and procedures to reduce environmental impact(Centre for Environmental Leadership in Business , 2003).

3.2 Black water (sewage or black water)

Sewage is discharged from all types of toilets and urinals, medical rooms, living areas, and any other wastewater if mixed with such discharges and regulated by Annex IV to the MARPOL Convention. Black water can harbor many pathogens that cause concern for human health, including salmonella, cinnamon, hepatitis A and E, and gastrointestinal viruses. Sewage contamination in bathing areas and shellfish breeding areas poses potential risks to human health and the environment by increasing the rate of aquatic diseases. 8 Average reported waste generation rates were 21,000 gallons / day / vessel and 8.4 gallons / day / person (EPA 2004). The capacity of the cruise ship to hold untreated (or treated) wastewater varies considerably. According to responses to the EPA Cruise Ship Survey for 2004, sewage storage capacity ranges from 0.5 to 170 hours, with an average stay capacity of 62 hours. Disposal of sewage into the sea is prohibited under the MARPOL IV Convention, unless the ship has an approved sewage treatment plant in operation or when the ship discharges crushed and disinfected wastewater using an approved system more than three nautical miles from the nearest land. Cruise ship drainage systems generally use fresh water to reduce corrosion of the piping system and vacuum flushing to reduce water transport and use. This gravity system uses 1 gallon of seawater per toilet wash compared to household toilets that use 1.3 gallons per wash

The main factors for the amount of wastewater are:

• the number of crew members and passengers;

• type of toilets: water toilets produce more drainage than vacuum toilets.

• duration of the trip.

• type of treatment: in the presence of a sewage treatment plant, or the crushing and disinfection system provides different amounts of waste.

• mode of operation of the ship

The ship at sea has 4 modes of operation due to sewage discharge:

• OPERATION 1: The ship's sewage is not discharged - it remains in the ship's liquid waste tanks

• OPERATION 2: The ship discharges wastewater treated by an advanced wastewater treatment plant installed on board

• OPERATION 3: The ship unloads partially treated wastewater (crushed and disinfected) and

• OPERATION 4: The ship discharges inappropriate wastewater directly into the sea.

Table 2 Comparison of the discharge standards of Annex IV of MARPOL according to the navigation sectors and the minimum appropriate mode of operation of the ship.

MARPOL'S Annex areas of navigation	Quality standards of sanitary wastewater effluent						Appropriate ship's operation mode
	Thermotolerant coliforms (in 100 ml)	TSS (mg/l)	BOD5 (mg/l)	COD (mg/l)	pH value	Cloral residual (mg/l)	
3 M area	100	35· Qi/Qe **	25· Qi/Qe **	125 Qi/Qe **	6 – 8.5	0.5	MODE 1 or MODE 2
3-12 M area	Ship is discharging comminuted and disinfected sewage						MODE 3
Area outside 12 M	Ship is discharging untreated sewage while en-route and proceeding at a speed not less than 4 knots. The maximum permissible discharge rate is given in *Equation 1*						MODE 4

* Applies to sewage treatment plants installed on board before 1 January 2010
** Where dilution is essential to a treatment process the effluent standards should be adjusted proportionally using dilution compensation factor Qi/Qe to take account of dilution Qd, where Qi is influent, liquid containing sewage and grey water to be processed by treatment plant, and Qe is effluent, treated wastewater produced by treatment plant.

3.3 Gray water (brown or gray water)

Gray water consists of discharges from the kitchen, bathroom and shower, as well as sewage from toilets, clothes and taps 27. The volume of heavy water produced depends to a large extent on the type of vessel and the number of passengers on board. Cruise ships, for example, produce more gray water than cargo ships, as they have more passengers and crew than other ships. Cruise ships also produce a higher volume of gray water per capita, because the passengers on these ships use kitchens and accommodation (sinks and showers) to a greater extent than the crew on cargo ships. EPA for 2004 show that about 52% of gray water comes from accommodation, 17% from washing machines, and 31 percent from kitchens. According to Eco-marine it appears that 52% comes from kitchens, 38% from food waste 8% of accommodation, and 2% of clothing (Hänninen and Rytkönen., 2004).Other regulations have extended the definition of calcareous water to include specific discharges from dishwashers. According to information obtained by the EPA during ship visits and through responses to the EPA survey of cruise ships operating in Alaska in 2004, the following waste streams were directed to the greywater system

1. Waste from bars and sinks.
2. Sewage from living room and day spa fountains and floor drains.
3. Waste from internal deck drains, shop sinks and deck drains in non-engine rooms.
4. condenser for refrigerator and air conditioner
5. Liquid waste from the laundry floor in passenger and crew laundry areas.
6. Dry cleaning concentrate.
7. Waste from garbage floor drains and sinks in restaurants and cafes.

8. Waste from hydromassage.

9. Liquid waste from medical facilities and medical tanks.

Gray water discharges may contain bacteria, pathogens, oils and fats, detergents and soaps, metals (e.g. cadmium, chromium, lead, copper, zinc, silver, nickel and mercury), solids and nutrients(USEPA, 2010 ; EMSA , 2016). Sewage from medical facility tanks and medical floor drains may contain components such as bacteria, nutrients and oxygen-destroying substances (e.g. BOD5), depending on the type of disease or treatment procedures performed. . It is common for cruise ships to have a separate tank for kitchen water, which is disposed of in accordance with food waste regulations. To validate the information gathered from the 2004 Cruise Ship Survey, USEPA reviewed the literature information on gray water production from other cruise ships. Estimated gray water production rates reported in response to the US EPA Cruise Ship Survey for 2004 ranged from 36 to 119 gallons / day / person, with an average of 67 gallons / day / person 28 for large cruise ships. According to a report by the Baltic Marine Environment Protection Committee, a cruise ship produces approximately 120 liters per person / day (32 gallons / day / person). day (30 to 85 gallons / day / person) (USEPA 2008b). As expected, the category of vessels currently covered by the 2008 VGP, which produces the largest volume of liquid water, are large cruise ships. Large cruise ships produce the largest volume of gray water mainly due to the large number of passengers and crew on these types of ships. Medium and small cruise ships also produce relatively large volumes of gray water, due to the relatively large number of passengers and crew. Surprising, however, is the relatively large volume of gray water produced by tugs and pressure vessels compared to other types of ships. In 2004, the EPA sampled wastewater from four large cruise ships operating in Alaska to characterize the gray water and sewage generated on board and to evaluate the performance of the advanced wastewater treatment systems (AWTS) Zenon, Hamworthy , Scanship ROCHEM.

The NRA announced to each ship separate untreated sources (accommodation, clothing, cooking and food waste) for over 400 analyzes, including pathogens, suspended and dissolved solids, BOD5, oils and fats, dissolved, and nutrients. In addition, sewage samples from washing machines for dioxins and furans were analyzed, and sewage samples from the kitchen were analyzed for organo-halide and organophosphate insecticides.

3.4 Sewage management and technology

Sewage is treated in various ways and if treated, can be disposed of at sea. The three main methods of wastewater treatment are 3: mechanical, chemical and biological. The amount of effluent produced depends, for example, on the number of people on board and the type of system used. The amount of liquid waste generated is estimated to be between 0.04 and 0.45 m3 per person per day. Of this amount, 0.01 to 0.06 m3 is probably black water, and the rest is gray or kitchen water. Sewage treatment is usually a combination of the three main methods such as mechanical-chemical, mechanical-biological and chemical-biological. The choice of method depends on the cleaning objectives and operating conditions of the ship (BMEPC , 1990 ; Kiukas.,2005). It should also work properly in all sewage streams and during maximum flow

Table 3 The reduction estimates for different treatment types (BMEPC, 1990).

	Reduction in BOD	Reduction in phosphorus
Biological plant	80–- 95%	20–- 40%
Chemical plant	50–- 70%	75–- 90%
Simultaneous thickening	90–- 98%	75 - 90%
Physical sedimentation	20 - 30%	5 – - 10%

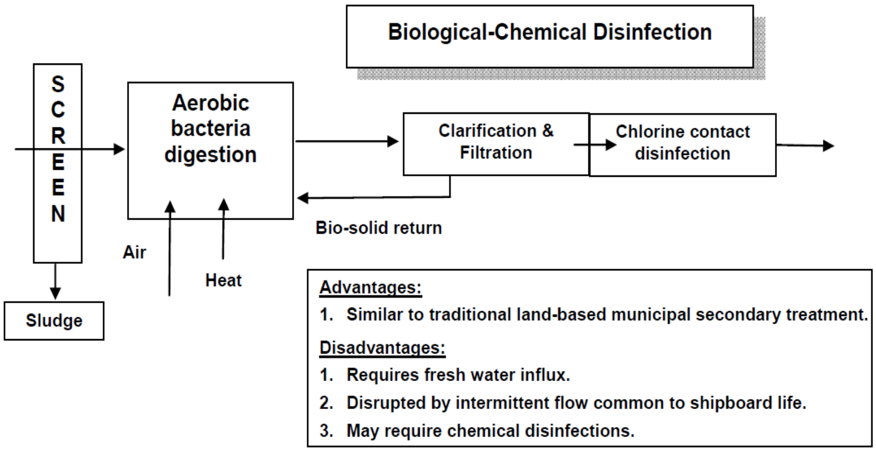


Figure 3 Simplified scheme of biological-chemical disinfection (Eley & Morehouse, 2003).

Sewage can either be collected in a holding tank, crushed and disinfected, or treated in a sewage treatment plant. Wastewater treatment plant waste is either discharged directly into the sea or stored in a holding tank. Sewage treatment includes the following stages:

1 Wastewater collection and management
2. Sewage pre-treatment
3. Sewage oxidation
4. Waste clarification and filtration
5. Waste disinfection
6. Sludge treatment

3.4.1 Sewage accumulation

At this stage the wastewater (black water, gray water and water from the kitchens is collected in containment tanks before going to the treatment plant. Ships that do not have a sewage treatment plant collect the black water in a containment tank. A holding tank is The size of the tank should take into account the capacity to hold all the sewage, the operation of the ship, the number of people on board and other relevant factors. The typical cruise ships with 2500 potential people can have tanks with a capacity of 1220-1800 m3 for untreated water, 900-1100 m3 for storage of treated water and a 3rd tank 15-150m3 for the collection of sludge (biosolids) produced by advanced water treatment systems) (Avellaneda et al.,2011). The holding tank must have a means of visually indicating the amount of its contents. The holding tank can also be used to collect gray water and / or kitchen water. However, gray water is not always directed to the storage tank and is sometimes stored in special containment tanks. Gray water can sometimes be discharged directly into the sea or mixed with wastewater to be treated. It can also be recycled in the toilet flush system.

3.4.2 Sewage pretreatment

Sewage pretreatment protects the other phases of the treatment process. Sewage contains a lot of solid waste and grease and can cause problems in the later stages of treatment. The pretreatment process reduces the amount of solids in the effluent. Effective pretreatment of the effluent also reduces the need for oxidation(Kiukas.,2005). The pretreatment is mechanical and consists of sieving and settling units. Also large particles pass through a shredding unit before being sieved.(Ionics Incorporated ,2005).

3.4.3 Sewage Oxidation

Sewage oxidation can be carried out either by physicochemical processes or by biological treatment.

3.4.3.1 Physico-chemical treatment

Physicochemical treatment technologies can be divided into two categories:

- electrochlorination
- coagulation / flocculation

Mechanical filtration leads to a reduction of 50% of the organic charge. The remaining organic compounds must be oxidized either chemically or biologically. During chemical oxidation, some chemicals such as ozone (O3), chlorine (Cl2) and hydrogen peroxide (H202) are added to the effluent. These chemicals oxidize the remaining organic compounds in the effluent. Chlorine is not environmentally friendly due to the carcinogenic compounds that develop as a by-product of the reaction. The added chemicals have an impact on the organic matter that has dissolved slightly and the reduction in BOD remains small. Through the chlorination system, the biological solids are reduced by oxidizing them, the total waste is diluted with seawater and the waste is discharged with the help of electrolysis. Operators add chlorine to tanks to ensure that the disinfection is complete. This hyperchlorination results in high levels of residual chlorine in the effluent which is deadly to marine organisms (Eley and Morehouse, 2003). Electrochlorination is a traditional technology that produces chlorine from seawater or a salt solution to disinfect wastewater. The technology requires high (and stable) salinity to operate efficiently. Electrochlorination is suitable for gravity flushing systems using seawater. With fresh water vacuum toilet systems, seawater flow is often introduced with multiple amounts of sewage flow. Some of these systems are approved in accordance with MEPC159 (55) adding a dechlorination step, much smaller than the equivalent biological treatment systems.

Coagulation / flocculation technology is also used to treat sewage on board. It uses chemicals to destabilize colloidal materials, which are then separated from the treated effluent by separation of dissolved air. Therefore, it is essential to have an appropriate chemical dosage as correction conditions within the dissolved air buoyancy chamber at all times to ensure compliant performance. However, some systems use flotation technology without the aid of any coagulant or flocculant. Instead, seawater is used to aid in the treatment process.

3.4.3.2 Biological treatment

Biological oxidation is controlled by biological growth, hydrolysis and decomposition processes. In biological growth, soluble organic matter is oxidized by microorganisms, mainly bacteria, fungi and protozoa, to carbon dioxide, water and new cells. The biological process is the heart of most processing systems. It is the most effective way to remove soluble organic matter from sewage. It is important that it is easy to maintain and operate as well as meet current cleaning requirements. The proper operation of the installation depends to a large extent on the technical staff and the condition of the wastewater.

In biological development, organisms use the organic load in wastewater as food. There are several types of biological treatment with the most common being the activated sludge treatment method where the effluent is mixed in a continuous action sludge aeration tank with active sludge. In activated sludge plants the sludge is continuously recycled to maintain the active biomass at a selected concentration in the tank. As the solids from the biological growth process and the inert solids from the incoming water gradually accumulate, some of them must be periodically removed from the recycling line to maintain a constant MLSS concentration. If the concentration rises too high, the solids can end up in the outflow line (Metcalf & Eddy,2003). Biological filters and bioengines are also used as biological treatment plants. Biological treatment systems are the most effective way to reduce the BOD load. The estimated reduction of BOD is 80-95% and the reduction of phosphorus ranges from 20-40%. The effectiveness of the method depends on the amount of active biomass and the living conditions of the microorganisms. No additives are needed in the biological treatment and the amount of sludge is small. The disadvantages of biological treatment are its long onset period and its sensitivity to external changes. The reasons for the malfunction of the biological system are the following:

1. Strong chemicals that have entered the unit destroy microorganisms.

1 Microorganisms die due to lack of oxygen when ventilation does not work properly or at all.

2 The active sludge return process is malfunctioning or not working at all. Compared to activated sludge filters, biofilters and bioengines are smaller in size and recover better from toxic effects. In addition, they have lower energy consumption, better sludge settling characteristics and stable loading variants(BMEPC,1990).

3.4.5 Phosphorus removal

Phosphorus is usually removed by chemical precipitation followed by retention or flotation. Phosphorus in wastewater is mainly in the form of ortho-phosphate ions (PO43-). Metal ions such as aluminum (Al3 +) or iron (Fe3 +) combine with soluble orthophosphate ions (PO43-) to form an insoluble precipitate (AlPO4 or FePO4) that can be removed from water by natural means. A variety of polymers can also be used to precipitate phosphorus (Metcalf & Eddy.,2003 ; van Haandel et al ., 2012).

3.4.6 Clarification and Filtering

After oxidation and biological treatment, the sludge is separated in the settling tank and returned to the aeration tank. Separation of active biomass of sediment particles and bacteria from water is a critical phase in the wastewater treatment process. The clearing and filtration processes used in ships are membrane filtration, Dissolved Air Floating (DAF). The DAF system is based on the injection of tiny air bubbles into the water stream supplied to the unit, causing the particles to float. on the surface of a basin with sloping sedimentary slabs from which they are continuously removed by sludge flow. The float separates the hydrophobic substances which have a greater tendency to be retained in the bubbles. Many times the formation of foam on the surface of the liquid is aided by the addition of a flocculant such as FeCl2, or AlSO4. The DAF treatment plant is very useful in the treatment of effluents with very high concentrations of suspended particles (TSS) or the highly variable content of suspended solids (CLIA, 2014).

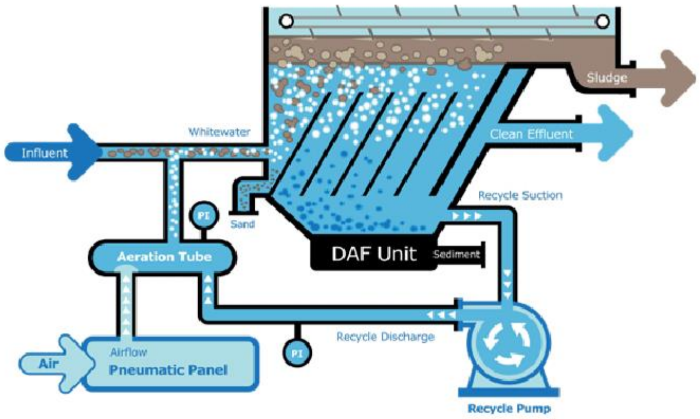


Figure 4: Dissolved air Flotation Unit (DAF)

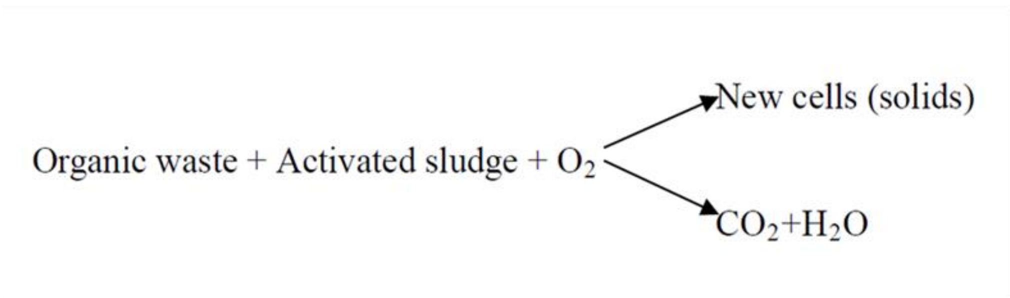
3.4.7 Disinfection

The last phase of the wastewater treatment process is disinfection. Disinfection improves the quality of the wastewater and is an essential part of the treatment process. When clarification and filtration is used, UV disinfection is performed. If the water is very cloudy, the UV light is not suitable for disinfection. The other possible disinfectants are, for example, chlorine, hydrogen peroxide and ozone. it is possible to further improve the purity and quality of water(Eley et al ,.2003).

Disinfection of effluents on modern cruise ships is most often treated with ultraviolet radiation to kill bacteria. The UV method does not require the addition of potentially environmentally toxic disinfectant chemicals, but consumes more energy.

3.5 Main types of wastewater treatment equipment on cruise ships

Since a cruise ship does not have the space to accommodate so many steps in the process, especially settling tanks or other solutions that require large areas, a ship's sewage treatment plant must be small, simple, reliable and have moderate operating costs. Many of the processes are grouped together, for example, the preliminary and main processing steps are usually integrated into a single filter (screeners) and the dispersed air distribution is usually used to save space instead of settling. In all pre-treatment systems, the effluent is mixed and sieved for large solids and plastics. Mixing can be done either before or after the sorting phase depending on the installation.



Treatment systems can be classified into 4 basic types in terms of their ability to reduce nutrients:

1) Electro-chlorination which disinfects wastewater (e.g. chlorine) but is not designed to remove any nutrients. US Coast Guard Recognizes and Approves 3 Types of Marine Hygiene Devices (MSD) Compliant with 33 CFR Part 1594
2) Type II MSD - are flow devices, which generally use biological treatment and disinfection. Some of these devices use disassembly and disinfection. Type II MSD can be used on boats of any size.
3) Type III MSD - tanks, where drains are stored until they can be properly discharged to a dry pump facility or out to sea (over 3 miles from shore). Type III MSD can be used on boats of any size. However, a Type II MSD may be equipped with installed holding tanks that can be used to store treated

effluent until it reaches a pump discharge facility from land or unloaded from the sea when the vessel is more than 3 miles away. miles from land.

4) Advanced wastewater treatment systems (AWP or AWTS), some of which are certified to meet the requirements of the IMO MARPOL Annex IV Baltic Sea Specific Area to reduce nitrogen by 20 mg / L or 70% and to reduce of phosphorus by 1 mg / L or by 80%. . These generally have a higher level of processing compared to MSD and in addition remove nutrients to varying degrees (depending on the equipment).

3.5.1 Conventional biological treatment systems (MSD II)

In the early stages of processing the system may include screening to remove sand and large agglomerates. The entire MSD II treatment system typically includes aerobic biological treatment to remove biochemical oxygen demand (BOD) and certain nutrients such as phosphorus (P) and nitrogen (N).

The unit is divided into three compartments, which are:

1) A ventilation compartment
2) arrangement apartment
3) processing compartment

In the processing compartment the liquid water is disinfected with chlorine or ultraviolet radiation to destroy the pathogens. Chlorination is well proven and effective. After chlorination, the water is discharged into the sea. The chlorination process is often performed with chlorine tablets.

Sludge ending up in the settling compartment is removed and stored in a storage tank and can be discharged to land installations.

Cruise ships usually install up to four systems, allowing one or two to be shut down for maintenance at any time. Cargo ships use only one unit.(Loehr et al., 2006). MSD systems treat only black water while gray water is discarded without treatment(Perucic., 2012).

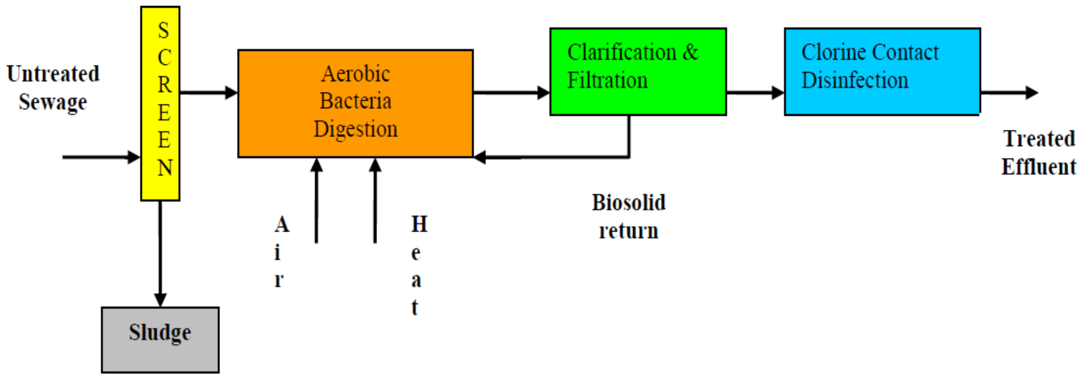


Figure 5 Simplified Scheme of Type II Marine Cleaning Device (MSD), Using Biological Treatment and Chlorine Disinfection

3.5.2 Advanced wastewater treatment technologies (AWP or AWTS)

To improve environmental performance, cruise ship companies test and install wastewater treatment systems using advanced technologies (AWP). These wastewater treatment systems are designed to result in high quality and clean waste effluents, for example, meeting or exceeding international standards for secondary and tertiary wastewater; and

recycled water.

Advanced water treatment technologies have been applied to these types of vessels since 2003(Oceana 2005). About a quarter of cruise ships had an advanced sewage treatment system (AWP) installed in 2013, which mixes and processes gray and black water to produce a residual biological sludge or sewage sludge that must be retained for landfill(HELCOM , 2013).

While only 31% of cruise ships worldwide (2015) were equipped with one of these advanced processing systems according to the year of construction of the various ships worldwide. Now in 2019 62% of the members of the Cruise Industry Association (CLIA) have AWP on board and all major cruise ships are now built with this type. AWP systems deal with both gray and black water at the same time while generally providing improved sorting , biological treatment, solids separation (using filtration or flotation) and disinfection (using ultraviolet radiation) compared to traditional Type II MSDs 39. In AWP systems the two main types of biological treatment processes currently used on ships are the bioreactor with (MBR) and the mobile bed biofilm reactor (MBBR).

3.5.2.1 Membrane Bioreactor (MBR)

Like conventional biological treatment systems, MBR also uses the "activated sludge" biological treatment process to remove dissolved and particulate organic pollutants, and also uses microfiltration or ultrafiltration membranes to separate pure water from biomass. The biggest advantage of membrane systems is their small size and good quality extracts with fewer processing steps than alternatives. The most important disadvantages are the higher cost and the sensitivity of the membranes, as they are prone to permanent pollution. The level of dissolved oxygen is particularly important as very low levels of carbon dioxide can cause sludge to build up and clog the membranes, as has been the case with some Royal Caribbean vessels using this technology (Metcalf and Eddy.,2003).

Membrane cartridges can either be immersed in the reactor or they can be in outdoor units which significantly increases the required pumping energy. The main advantage of having the membranes in an outer case is the ease with which they can be removed for inspection and cleaning. On the other hand, the advantage of submerged membranes is that the effluent (filtrate) can be absorbed by gravity or lightly pressurized, consuming less energy.

In a submerged installation the tank must be drained before inspection and cleaning. The membrane surfaces in a submerged configuration are kept clean by the turbulent movement of air bubbles, which are evacuated to the bottom of the membrane stacks. In an outdoor installation the membranes are kept clean from the high transverse flow inside the membrane unit. Frequent washing is also required(Sutton.,2006).

Performance is therefore more robust and reliable, provided that an MBR system is properly designed. In particular, measures must be taken to prevent the membranes from clogging or contaminating to ensure continuous membrane filtration performance. The need for a disinfection step depends on the specifications and properties of the membrane as well as the integrity of the membrane component assemblies.

3.5.2.2 MBBR technology (mobile bed biofilm reactor)

The Mobile Bed Biofilm Reactor (MBBR) was invented in Norway in the early 1990s. The process is based on providing a large area for germs to grow inside the reactor, increasing the amount of biomass in the tank without having to increase its size. pelvis. This is achieved by using vectors, an example of which is shown in Figure 4. They are usually made of plastic with complex structures that provide large surfaces, in which the bacterial mass grows to create a so-called bio-membrane 38.

Typically in embodiments, the MBBR is combined with a dissolved air flotation unit and a polishing filter to remove accumulated solids from the effluent prior to disinfection and discharge into the sea as shown in Figure 3 while the configuration has used successfully in many previous installations(Rusten et al., 1998 ;Jokela .,2012).

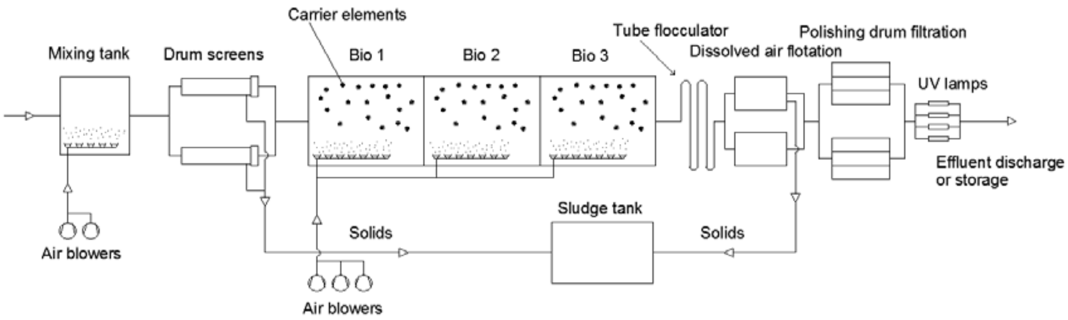


Figure 6 **MBBR processing unit.**

The carrier pieces are kept movable either by a mechanical mixer or by aerators. When considering the type of ventilation to be used in MBBRs it should be noted that the tank is not easy to empty due to the carrier elements mixed with the water. Thus, a coarse bubble ventilation system is a better choice due to the lower maintenance requirements and the blisters have a stronger buoyancy to keep the elements moving. As a result, more air is required to ventilate the tank, as the oxygen transfer efficiency of the larger bubbles is lower than that of the smaller ones. The maximum filling ratio or maximum fraction of the transport pieces in the tank is about 67% - 70%(Rusten et al., 1998). Higher percentages could lead to reduced efficiency due to limited movement of car components and oxygen transfer problems, causing unwanted anoxic zones in the tank. This was probably the initial cause of poor treatment performance at RCCL Sea OASIS, where the filling ratio increased without increasing the ventilation capacity. As a result, the movement of the carriers was hindered and unwanted dead spots formed in the reactor, causing the sludge to accumulate inside the reactor.

Another important design aspect is the organic charge per square meter of carrier surface. According to Rusten et al (1998), the average level must be maintained below 20 g BOD5 / m2 to achieve a sufficient reduction in organic matter. For the TUI NB project "BluMotion" the price is 8.7 g BOD5 / m2 with a load of BOD 1175 kg / d and a total area of 134400 m2. The carrier elements used by Scanship have a very large specific surface area of 800 m2 / m3.(Sutton., 2006 ; Jokela .,2012)

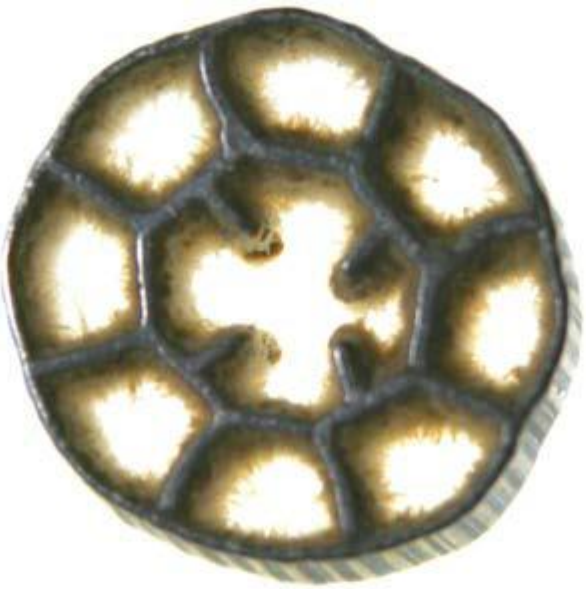


Figure 7 Biofilm vector element used by the heads with the bound bacterial mass visible. Source, Headworks USA

3.6 Chemicals in wastewater treatment

Chemical precipitation is used to remove fine particles and colloidal materials from wastewater by accumulating particles to create larger surfaces that can be removed by floating or precipitation. Their function is based on destabilizing colloidal particles, which are normally free-moving and introduce repulsive force towards other colloids. The chemicals destabilize the colloids, allowing the particles to aggregate into larger masses after collision(Koboevic ,2011) . In onshore treatment plants, flocculant chemicals are often used to improve the efficiency of a settling tank, but due to space constraints on ships, this phase is replaced by a dissolved air flotation unit. The clotted particles float on the surface of the unit with the buoyancy of air bubbles, which diffuse from the bottom of the tank. The floating solids are then naturally removed from a trash can and transported for further solid treatment. Common flocculants include minerals such as alum, iron sulfate and synthetic polymers such as polyacrylamide. These synthetic polymers are also commonly used in juicers to improve the dehydration process(Scanship , 2012). In the case of foaming in the bioreactor, the sprayers are initially used to spray purified effluents into the mixed liquid to keep the foam down. In case it is not effective, chemicals can be used to fight foaming before identifying and correcting the cause. Membrane filtration units should also be periodically cleaned by a cleaning system (CIP), which flushes the plates or membrane tubes by pumping sodium hypochlorite (bleach) through them in the opposite direction(Jokela, 2012) Sodium hydroxide (NaOH) is used to maintain the pH of the biological process around neutral (pH 7). Especially nitrification reactions and food waste (especially citrus fruits) tend to lower the pH of the bioreactor, causing less optimal conditions for germs and processing disturbances(Henze et al., 2002 ; Ceraa., 2019).

CHAPTER 4 SOLID WASTE

4.1. Introduction

The amount of solid waste generated by cruise ships varies from ship to ship, depending on the size of the ship, the number of passengers and crew, and material consumption. Compared to other types of ships, cruise ships produce large volumes of solid waste. Environmental Resources Limited (1991) estimates that a cruise ship produces 70 times more solid waste per day than a typical cargo ship. In determining the amount of waste generated on a boat, the National Research Council (1995) indicates that "the amount of rubbish is commensurate with the standard of living of the community. The higher the standard, the more likely sailors are to use packaged food, supplies and disposable items rather than provisions requiring additional preparation and cleaning. "It is also estimated that 24% of solid waste generated by ships worldwide (by weight) comes from cruise ships (National Research Council, 1995). With large cruise ships carrying many thousands of passengers, the amount of waste generated in a given day can be significant. A large cruise ship with 2,500 passengers and 800 crew (a total of 3,300 people on board) can produce 1 ton of garbage from the normal operations in one day (National Research Council, 1995) It turns out that the amount of waste generated in a given day is much larger with an average of 7.5 m3 of garbage per day. This average is diversified as the number of passengers and crew increases. On average, each cruise ship passenger produces at least two kilograms of non-hazardous solid waste per day. In addition, each cruise ship passenger has two bottles and two cans (both of which are recyclable) per day. The data show that the range of garbage production per passenger per day on a cruise ship ranges from 0.0075-0.068 cubic meters. Separation is performed to calculate what percentage of the total is plastic, cooking oils, food scraps paper, glass functional waste and incineration ash.

4.2 PLASTICS

Plastic waste typically includes sheets, wrappers, bottles, drums, synthetic ropes, synthetic fishing nets, plastic garbage bags and empty chemical containers. In some cases, ships and waste handlers distinguish between plastics that come in contact with food ("contaminated" or "dirty") and "clean" plastics. The two are stored separately for hygiene reasons and because dirty plastics (and other food waste) may contain pathogens and may need to be disposed of separately from the door. There are two ways to manage plastics on board, either they are kept separate (compressed or otherwise) and delivered to the PRF or they can be incinerated, while the ashes are treated as incinerators. Incineration is restricted by Regulation 16 of MARPOL VI, which prohibits the incineration of polyvinyl chloride (PVC) on ships, except for one incinerator for which an IMO type-approval certificate has been issued in accordance with MEPC.244 (66) (MEPC, 2014). Combustion of plastics with PCB is always prohibited. Ships with large amounts of plastic, such as cruise ships, can use a shredder or compressor to minimize the volume of waste, as delivery to the PRF is often based on volume. Plastics are most often produced in the hotel condition of the cruise ship. Plastics are collected in bags or bins. Sometimes clean and dirty plastics are collected separately, especially when they are to be delivered in different PRFs. They can be incinerated when the ship incinerator is certified for that use. Although most waste management plans aim to prevent plastic waste when supplies are received, they are often not carried out for practical reasons, e.g. because the plastics are part of the supplies and the supplies are unpacked well after delivery so that the plastics cannot be returned to the supplier. The production of rubbish, including plastics, on ships depends on a number of factors. The amount of hotel waste is based on the number of passengers and crew and the consumption of material and is proportional to the standard of living (HELCOM,2015). In practice, supplies, packaging and kitchen waste lead mainly to the production of plastics. Plastic waste from the movement of goods is limited to the general cargo and depends entirely on the type and packaging of the cargo.

In addition, reducing pre-loading waste can affect the amount of plastic waste production on board, for example, plastic packaging is removed before being loaded on board. There is very little information on the actual volume of plastic waste generated on ships and is often provided as garbage or solid waste numbers. According to the literature, each person produces 1 kg of solid waste daily and other sources provide an estimate of 3 kg / day per crew member (EMSA , 2008). Maintenance-related solid waste is 11 kg / day ship for all ships (NEA , PM Group, 2009). These estimates are not specific to plastic waste but provide an area of 0.06 to 0.2 m3 per person per day 67. Amounts per day of crew member ranged from 0.001 to 0.016 m3. For the calculation of plastics data were used for 2 ships with 4 years data and another two ships with 5 years data and 1 with 3 years data. From the study of the data it was found that the quantities of plastics produced on average one year by a medium-sized cruise ship range from 671000-1301000 (lt) of plastic waste while the production of plastics per passenger per day can range from 3-4 (lt)). According to the literature and studies conducted by the European Maritime Safety Agency (EMSA). Most ships generate between 1 and 8 (lt) plastics per person per day, although in some cases quantities of up to 25 (lt) per person per day have been reported. Plastics produced on the cruise ship account for 25% of all waste.

4.3 Household Waste (papers, boxes, glass)

Household waste is all household waste that is not food waste, cooking oil or plastic. Household waste does not contain gray water. Therefore, household waste usually includes paper, cardboard, fluorescent lamps, synthetics, sheets, cans, lids, glass, canteen packaging waste, etc. Household waste is generated on board as a result of the hotel equipment of the crew and passengers and are produced on all types of ships. The treatment of household waste varies depending on the types produced and the amount of waste generated. The production of this type of waste can vary every month. From the literature such as (EPA, 2008) we find that on average, each passenger on cruise ships produces at least 2 pounds (900 grams) of non-hazardous solid waste per day. In addition, each cruise ship passenger has two bottles and two containers (both recyclable) per day 67. For passenger ships, the average household waste production is 3 kg / person / day (NEA, PM Group, 2009). Assuming an average density of 75 kg / m3, this translates to 0.04 m3 / person / day or 4 (lt) per person / day. The literature shows that it ranges from 0.001 to 0.08 m3. In our study for cruise ships the range of production of household waste per passenger per day ranges from 33-94 (lt), while per ship can be produced on average per year from 1403000 -2450000 (lt).

4.4 Food Residues

Organic food waste can be dumped directly into the sea 12 nm from the nearest land or shredded and then dumped into the sea 3 nm from the nearest land (12 m in special areas). Alternatively, food waste may be stored separately in separate vessels for later disposal at sea or delivered to PRF in case disposal at sea is not permitted due to regulation. Guidelines for the application of Annex V describe that care must be taken to ensure that plastics contaminated with food waste (eg plastic food wrappers) and other waste are not dumped at sea with other food waste. The regulation stipulates that in all cases, waste must be stored in a way that avoids risks to health and safety. The quantities of food residues produced on average one year by a medium-sized cruise ship range from 225-1623 m3 with an average of 347-885 m3 per year per ship, according to the literature and studies conducted by European

Maritime Safety Agency (EMSA) show that the quantities of food waste produced vary from 0.001 to 0.003 m3 per person per day while in our study according to available data production per passenger per day can be increased from 0.001-0.008 m^3 leftovers.

4.5 Cooking Oil

Cooking oil waste is generated on board during food preparation and is produced on most types of boats. Cooking oil in most cases is collected and delivered to the PRF. In some cases, it burns. On some ships, it was customary to mix cooking oil with mud and treat it as mud. Large cruises tend to have a separate tank for storing cooking oils with large capacities (up to 1,000 m3). During ship inspections and interviews by EMSA, information was collected on the cooking oil waste of 8 ships (MEPC,2011-2012). Only a few ships process cooking oil, with the majority storing it and delivering it to the PRF. The amounts recorded in the garbage inventory on these 8 ships ranged from 0.004 to 0.14 m3 per day. The latter is extremely high and may be due to incorrect reporting (eg recording liters instead of m^3). For passenger ships, this number increases to 0.01 liters per person per day, however during the study there are not many observations for this type of ship. In our study the production of cooking oils ranges from 0.028-0.094 m3 per day per passenger. The large price increase is due to high consumption in a few days of operation of the ship or incorrect data. On an annual basis, an average cruise ship can produce from 8-11 m^3 of cooking oil waste per year. This amount changes on ships with a larger capacity.

4.6 Incineration ashes

Ships can be equipped with incinerators for the incineration of sludge, household, operational waste and other types of waste. The resulting incinerators are listed separately in the waste inventory. The waste is generated in the incinerator, collected in bags and delivered to the PRF. There is no further treatment of this waste. Sacks or bins are often dedicated to incinerators that can be classified as hazardous waste. The guide for incineration production is the amount of combustion of oily sludge (including the oily part of the collector), plastic, household waste, and functional waste including oily carpets on board. While some ships incinerate most of their sludge and household waste, others have a waste management plan that prohibits the use of an incinerator. If a ship has an incinerator installed, it is common practice to use it to treat oily sludge. The choice of installing an incinerator depends on the ship's journey, the duration of the voyage, the on-board waste storage capacity or the general on-board waste management policies. During ship inspections and interviews, information on incinerators produced by 4 ships (EMSA) was collected. The type of waste and the amount of waste incinerated differ between the ships visited. The quantities produced per month vary from 0.004 to 0.06 m3 per month, although this depends entirely on the frequency of use of the incineration plant.

4.7 Operating waste

"Operating waste" means all solid waste (including sludge) not covered by other annexes collected on board during the normal maintenance or operation of a ship or used for the storage and handling of cargo. This includes cleaning agents and additives contained in cargo cargo and external wash water, but not in gray water, catchment water or other similar discharges necessary for the operation of a ship, taking into account the guidelines(Smith et al.,2014). The quantities produced per month vary from 0.02 to 18.6 m^3. Amounts per day of crew member ranged from 0.001 to 0.1 m^3. Other estimates range from 0.001 m^3 per person per day to 0.5 m^3 per person per day, depending on the size of the ship and the itineraries carried out. Many ships do not report waste in this category. The quantities produced per month vary from 0.02 to 18.6 $m^{3.}$ Amounts per day of crew member ranged from 0.001 to 0.1 m^3. Other estimates range from 0.001 m^3 per person per day to 0.5 m^3 per person per day, depending on the size of the ship and the routes carried out.

4.8 Carcasses of animals

Animal carcasses are the remains of a dead animal. Disposal of animal carcases is permitted only outside designated areas and as close as possible to the nearest land and on the road. Thus, the option for disposing of animal carcasses is either dumping at sea or delivery to a PRF. When the ship has adequate storage space, limited quantities of carcases can be stored for short periods before unloading. If there are health and safety threats, discharge into the sea is recommended, however, more than 12 nm from the nearest land. Prior to discharge into the sea, carcases must be subdivided or treated to facilitate the sinking or dispersal of the carcases (Viana et al., 2014). We have not identified any vessels producing animal carcasses and therefore this type of waste has not been analyzed.

CHAPTER 5 GASEOUS POLLUTANTS

5.1 Introduction

About 70% of ship emissions occur 400 km offshore and typically contribute 1-7% to annual average PM10 levels, with 1-20% to PM2.5 and 8-11% to PM1 in coastal areas.

In general, all ship activities are responsible for air emissions and in particular:

i. The voyage,

ii. Traffic within the port,

iii. Functions during the stay at the anchorage such as lighting, heating, cooling, ventilation, etc.), loading and unloading tankers.

iv. Ship maintenance / construction / dismantling operations, which take place in creeks often located near many ports, are also responsible for emissions of air pollutants, mainly dust, particles, gases (e.g. from welds), aerosols.

v. The main problem is the emissions of volatile organic compounds from metal degreasing and paints. In terms of boat surface cleaning, paint removal, zinc anode changes, and paints, the main emissions are dust (from sandblasting, grinding, etc.) and solvents, which contain volatile organic compounds (Volatile Organic). Compounds) and Hazardous Air Pollutants.

vi. Finally, basic ship modifications produce asbestos, heavy metals, hydrocarbons and ozone-depleting substances.

vii. Emissions can also come from the incineration of waste on board. In this case, dioxins and other heavy metals are released into the atmosphere. Focusing on the emissions of ships that consume fuel, we find that for economic reasons, many ships use heavy fuel oil, which has a very high content of sulfur (90% higher than gasoline or conventional oil).

The same pollutants, in different amounts, are emitted by all types of ships that run on conventional fossil fuel (diesel) engines. The amount of gases emitted by ship engines into the atmosphere is directly related to the total oil consumption, which depends on various factors, such as:

• the shape of the ship

•cargo,

• the roughness of the hull,

• engine condition,

• maneuvering time and

• the stay of the ship at the berth.

Auxiliary engines also contribute to total exhaust emissions. Emissions from cruise ship auxiliary engines are particularly important because they have a constant need for energy from auxiliary engines to meet the demands of hospitality both at sea. The impact of ship emissions is global and local. The first concerns mainly emissions during the navigation phase. For the year 2008-2009 NOX emissions were found to be dominant throughout the year, followed by those of SO_2 and third the $PM_{2.5}$ Emissions. For the passenger port of Piraeus during a twelve-month period 2008-2009 it appears that the activity of ships on cruise ships and coastal passenger ships produced 2610 tons of major pollutants (NOX, S02 and PM2.5 combined) (Figure 10). Emissions in summer were almost twice as high when auxiliary engine power was needed for hotel services, and minimal in winter. During the fall and spring the ratio of emissions during maneuvers to berth emissions was almost equal to the annual average. On average, activity within port facilities of coastal passenger transport produced almost twice as many emissions as cruise ships (Figure 5), although significant seasonal fluctuations were observed. . During the summer, increased demand for shipping services (increased maritime port traffic) inevitably leads to increased land traffic and congestion. Exhaust emissions of various road vehicles (trucks, buses, private cars) moving in and out of and around the port of

Piraeus are added to the exhaust emissions of the ship maximizing the harmful effects on the city air. Throughout the year, the emissions of the ships at berth were between three and five times higher than those produced during the ship's maneuvers. Of the cruise ships operating in the port of Piraeus, 56.5% were found to be driven mechanically by diesel engines (47.6% and 8.9% by 4-year and 2-year, respectively). 34.7% used the engine layout diesel-electric (MSD generators) and 8.8% used a steam or gas turbine, as well as combined electric oil and gas turbines. In the case of diesel-powered cruise ships as a whole the production of electricity is divided between propulsive and auxiliary purposes according to demand and the auxiliary engine data are not presented as a separate scheme. However, the size of the auxiliary engine is supposed to be based on an auxiliary propulsion ratio of 0.278, as suggested by recent estimates of the auxiliary engine power of some of the cruise ships arriving in Piraeus, as well as some of their sister ships (Starcrest , 2005 ; Tzanatos , 2010a and 2010b)

All MSD (Middle Speed Diesel) powered cruise ships use 1.5% by weight of low sulfur fuel (HSD) and HSD diesel engines use MDO1.0% by weight sulfur content. (tzannatos, syrakos). About 65% of the auxiliary engines of coastal passenger ships and cruise ships use MDO (with 1% S), while the remaining 35% burn LSFO. In general, it has been observed that most of the older ships require MDO in their auxiliary engines, while the newer ships can tolerate heavier oils. The MSD generators of the diesel and steam turbines of the cruise ships that use steam with electricity use LSFO, while the ships that run on gas turbines operate with MDO (1% S). Ship diesel (distillate) is defined according to the percentage of sulfur content:

- Marine Diesel Oil (MDO): Ship diesel oil (distillate) is a mixture of kerosene, light and heavy fractions of internal combustion oil to which is added up to 10-15%, residual fuel, i.e. crude oil.
- Low Sulfur Fuel Oil (LSFO): The percentage of sulfur content should not exceed 3.5% by weight

- Ultra low sulfur fuel oil (ULSFO): The percentage of sulfur content should not exceed 0.1%

More specifically, during the summer and spring the ratio of the cruise to the emissions of the coastal ships was about 0.5. Despite the fact that cruise ships operate their auxiliary engines at high loads during their stay at the pier, the overwhelming presence of coastal shipping companies during the summer keeps the relative contribution of the cruise low. As expected, the cruise contribution was minimal (about 5% of this coastal shipping) in the winter and cruise ship and coastal emissions came very close to the autumn, when cruise ships produced about 80% of the ship). NOX emissions were found to be 1790 tonnes, while SO2 and PM2.5 emissions were estimated at 722 and 99 tonnes, respectively 86. The total stock of cruise ships in the study ports of Greece in 2013 amounted to 2742.7 tons: with NOx predominant (1887.5 tons), followed by SO2 and PM2.5 (760.9 and 94.3 tons respectively).

Emissions during the hoteling operation corresponded to 88.5% of the total and significantly exceed those produced during maneuvering activities (11.5% of the total) 87. For Piraeus, in 2007 the total amount of NOx and SO2 from cruise ships were 597 and 241 tons respectively (Tzanatos , 2010a), which contributed by 0.4% and 0.83% to the total national inventory respectively (markogianni, 2015). For 2013 the contribution was found be similar, 0.49% for NOx and 0.74% for SO2(Starcrest , 2007) . In the same study, air emissions from cruise ships traveling at sea (ie approaching and departing from study ports have also been estimated to assess their potential magnitude compared to air pollution in the area. For the year 2019, 829 arrivals from 115 different cruise ships of all sizes took place in the port of Piraeus. The process of calculating gaseous pollutants was done through fuel consumption. The carbon content of the fuel is about 84.9 to 87.412, while the sulfur content of the fuel depends on the type of fuel. Marine engines emit mainly nitrogen, oxygen, water in the form of water vapor and carbon dioxide, while to a much lesser extent they will also emit nitrogen oxides, sulfur oxides, carbon monoxide, non-combustible hydrocarbons and particulate matter, as shown in Figure 2 below. Briefly mention that the production of CO2 in ideal conditions is due to perfect combustion of carbon contained in the fuel, but in a marine engine the conditions are vague with the consequence that combustion is incomplete and produce further soot, carbon monoxide and unburned hydrocarbons(CLIA , 2014). SOx emissions from marine engines are due to the sulfur content of the fuel. Due to the oxidation of sulfur during the combustion of the engine, sulfur oxides are produced. One of its oxides produced SO3 reacts with water which is in the form of water vapor and sulfuric acid particles are produced. NOx emission is created due to the nitrogen content of the ambient air. Although chemically inert under normal conditions, nitrogen in marine engines at very high temperatures reacts with atmospheric oxygen to produce nitrogen oxides. Finally, PMs are characterized by the synthesis of a mixture of organic and inorganic substances, where their components are atomic carbon, ash, soot, non-combustible fuel particles and lubricating oils, sulfates and moisture(IMO, 2014). The atomic mass of carbon is 12 amu and the atomic mass of oxygen is 16 amu. Assuming that all the carbon in the fuel is converted to carbon dioxide (CO2) we have the following:

$$C \rightarrow CO_2 \tag{17}$$

$$12g\ C \rightarrow * \ 12 + (16 * 2))\ g\ CO_2 = 44\ g\ CO_2 \tag{18}$$

If we now assume that x is the amount of fuel containing 12g of carbon, then 100g of fuel will contain 86.7g of carbon. So we have:

$$\frac{x}{100} = \frac{12}{86,7} \rightarrow x = \frac{12 * 100}{86,7} \; g \; \kappa\alpha\upsilon\sigma\acute{\iota}\mu o\upsilon \tag{19}$$

Since 44g CO2 are produced per 12g C contained in the fuel (equation (18)) and also the 12 g C are assumed to be contained in x g of fuel, then it is valid that 44g CO2 are produced per 1200 / 86.7 g. Fuel. So the carbon dioxide emission factor is calculated as follows

$$EF_{CO_2} = \frac{44 \; g \; CO_2}{\frac{12 \; g \; C * 100 \; g \; \kappa\alpha\upsilon\sigma\acute{\iota}\mu o\upsilon}{86,7 \; g \; C}} \rightarrow EF_{CO_2} = 3,179 \; \frac{g \; CO_2}{g \; \kappa\alpha\upsilon\sigma\acute{\iota}\mu o\upsilon * \frac{Kg}{1000 \; g}} \rightarrow EF_{CO_2} = 3179 \; \frac{g \; CO_2}{Kg \; \kappa\alpha\upsilon\sigma\acute{\iota}\mu o\upsilon} \tag{20}$$

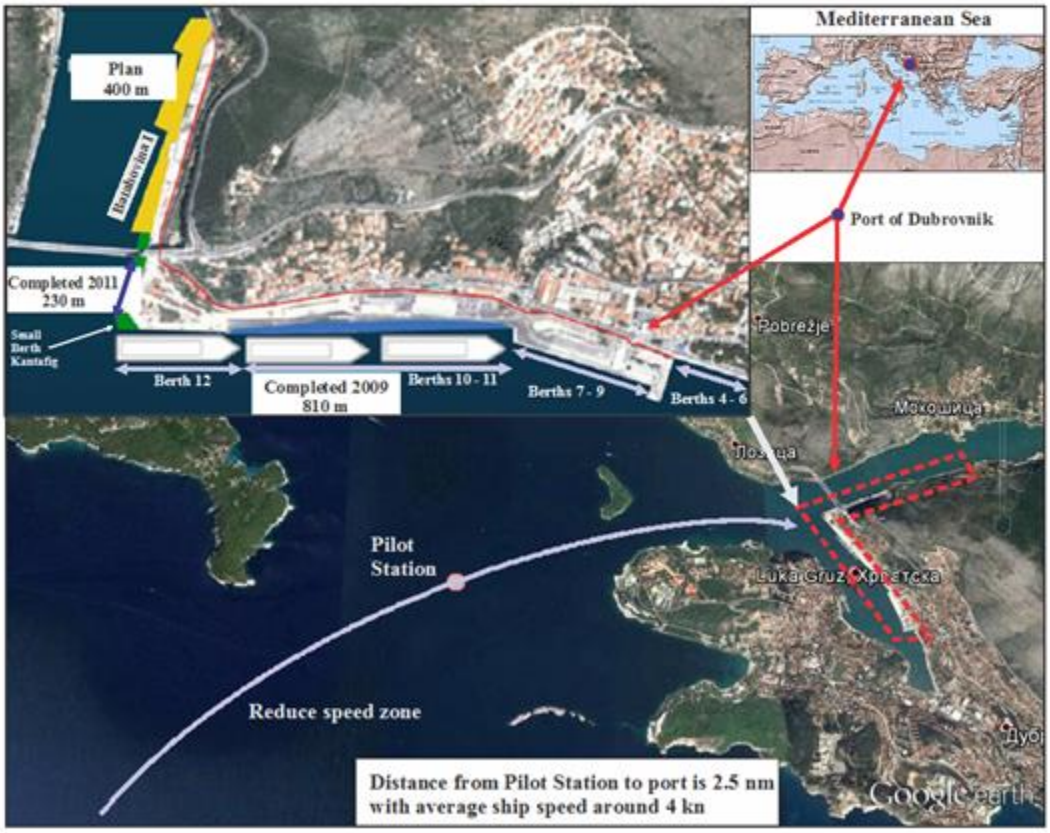
The total emissions fluctuate depending on the days of operation of the ship while they range from 26,500 tons to 58 thousand tons of CO2 per year. On newer ships such as ships C1 and C2 the average emission is about 32,000 tonnes per year. For one passenger, emissions range from 102 kg to 222 kg of CO2 per day with an average of 140 kg per day.

CHAPTER 6 – SHIP EMMISSIONS AND THEIR EXTERNALITIES IN CRUIZE PORTS – THE CASE FOR DUBROVNIK AND KOTOR PORTS

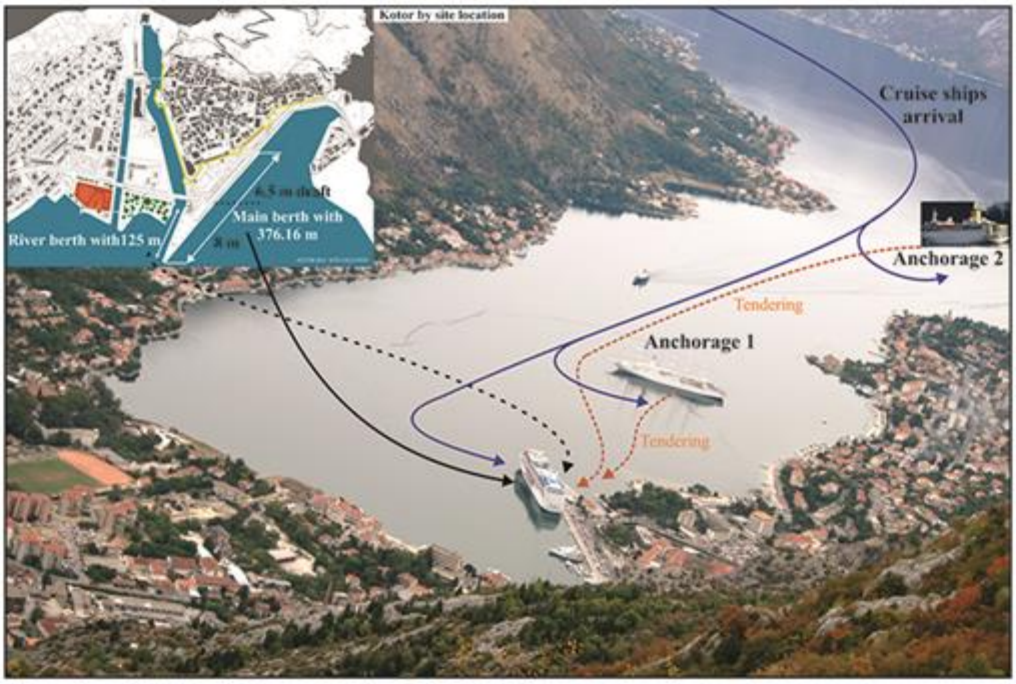
Within the general challenge of controlling the exhaust emissions produced by ships, navigation in bays and ports has attracted over the last decade increasing attention due to the significance of air pollution on the natural and built environment of coastal regions. For the navigation in ports, the structure of the emission modeling methodology relies on the distinction of the various activity phases performed by each port-calling ship and the emission estimation utilizes real and empirical data with regard to the operating characteristics of each ship during its approach, stay and departure from the port. Furthermore, the in-port ship activity constitutes the basis for modeling the evaluation of the air pollution damage caused by ships in ports, as applied by Tzannatos (2010a) for the passenger and cruise terminal of the port of Piraeus in Greece. Taking into account that cruise vessels because of their high propulsion and hoteling energy requirements are the most fuel demanding amongst all ship types and cruise destinations by virtue of their natural and cultural attractiveness are highly sensitive to air pollution, the assessment of ship emissions produced in ports of high cruise activity has attracted particular attention. More specifically, cruise ship emissions in ports has been the focus of the work by Maragkogianni and Papaefthimiou (2015) for five Greek ports evaluating the external costs of air pollution. Finally Tzannatos (2010a; 2010b) has worked on the emission inventories, externalities and control options associated with the cruise and ferry operations within the main port of Piraeus.

It is within this background of research interest, regulations and practices for controlling the ship emissions in ports that Dubrovnik and Kotor are considered to be a suitable reference for conducting a ship activity-based research on ship emissions in an effort to enrich the relevant knowledge and experience beyond the issues addressed by the currently available research literature. More specifically, in the current case, the ship activity-based approach is utilized to capture and analyze on a comparative basis the influence of the ship operational factors in the two ports. In terms of the port importance, the Adriatic hosts currently the second (after the West Med.) cruise market within the Mediterranean, accounting for nearly 22% of all port calls (MedCruise 2015). Dubrovnik is the third Mediterranean cruise port in terms of calls (following Civitavecchia and Barcelona) and Kotor occupies the 13th place, whereas they are the first and fourth busiest ports of call within the Adriatic-Ionian region, respectively.

The ports Studied



Layout of the port of Dubrovnik



Layout of the port of Kotor

Cruise ships at the port of Kotor are served at two berth locations (Main Berth and River Berth) and at two anchorages (Anchorage 1 and Anchorage 2) given in Fig. 2. At the Main Berth is possible to service a ship with average draft of 8 m. Sometimes, this berth is available to receive two smaller cruise ships simultaneously. Also, a river berth is used for servicing ships up to 4.5 m draft and 125 m length. The anchorages are at distances of 0.28 and 1.1 nautical mile from the location of the berths. Both anchorage areas are highly accessible and do not have ship length or draft limitations within the range of dimensions for all cruise ships calling at Kotor. In this case, passengers are embarking and disembarking to and from the ship by tendering service. Prior to berthing, ships normally perform a maneuver and approach the berth by bow. Anchoring in the port of Kotor involves dynamic position adjustment for safety reasons due to the narrowness of the inner bay basin. Ships are not allowed to move freely at the anchorage because of the danger of collision with the local traffic and/or grounding at the shallow waters near the shore. Smaller cruise ships are served by the River Berth, while larger vessels use the Main Berth or anchorages, with those of higher gross tonnage being exclusively anchored due to the Main Berth limitations.

A ship activity-based approach for the estimation of ship emissions requires the integration of traffic data (vessel movements, port calls) and technical characteristics of vessels. The detailed information of cruise ship and passenger traffic data during 2012-2014 at Dubrovnik and Kotor was obtained by the port authorities, whereas the gross tonnage (GT) as well as engine details of the cruise ships was obtained from the ship register of the IHS Fairplay Sea-web on line service. For the electrically driven ships, which on average constituted around 85% of all the (individual) ships involved in the port traffic data and almost exclusively in the larger vessel size range, it was assumed that the ratio of auxiliary to propulsion power stands on average at 0.278 (ISF 2009).

With regard to the annual cruise ship traffic in both ports, Table 1 presents the number of (individual) ships which called at the ports and their average gross tonnage (GT/ship), as well as the total number of port calls including those which involved the use of anchorage, as well as the total gross tonnage (Called GT), total number of passengers (Called PAX) and their weighted value per call. Furthermore, the total time and the average time per call spent in each of the ship activity phases (i.e.in maneuvering, at berth and anchorage) is included (DPA 2014; MONSTAT 2015; PKAD 2014). Dubrovnik has higher values for most of the presented parameters during the whole period under consideration. For example, Dubrovnik has been visited by more individual ships exempt in 2014 during which both ports recorded the same number of ships, whilst the size of the ships which called at Dubrovnik is generally higher than those at Kotor by 46.6% on average. Dubrovnik has 32.3%, 142.5%, 149%, 83.3% and 88.1% higher values for port calls, Called GT, Called PAX, Called GT per call and Called PAX per call, respectively. For 2014, these differences are the lowest between the two ports, being even higher in 2012 and 2013. Despite the fact that the number of port calls does not show a monotonically increasing trend for both ports during the period under consideration, it should be noticed that the parameters of Called GT per call and Called PAX per call are monotonically increasing. This indicates that with the passage of time ships of higher GT and passenger carrying capacity are calling in both ports. Despite the higher number of port calls at the port of Dubrovnik the use of anchorage was negligible (with a maximum of five anchored calls in 2014), whereas the anchorages of the port of Kotor were used for an annual average of 37.1% of the calls, rising from 29.6 in 2012 to over 41% in 2014.

Estimation of pollution loads

According to Tzannatos 2010, the following formulae were used :

The emission estimation model relies on the distinction of the various activity phases performed by each cruise ship calling at the ports of Dubrovnik or Kotor. According to the EU regulation, passenger ships burn fuel oil with maximum 1.5% sulphur during sailing and maneuvering, while at berth the use of distillates is limited to maximum 0.1% sulphur. In developing an activity-based emissions inventory for ships, emissions are estimated as a function of energy consumption during each activity (expressed in terms of engine power usage and time) multiplied by an emission factor expressed in terms of grams per kilowatt-hour (g/kWh). The ship emission inventory is composed of the NO_x, SO_2 and PM emissions produced during each call i at the ports of Dubrovnik and Kotor in the period from 1st April to 30th November, whereas the emissions produced during each port call is the sum of the emissions in each ship activity phase (of maneuvering, E_{MAN} and at berth or at anchorage, $E_{A/B}$), according to the expression:

$E_i = E_{MAN} + E_{A/B}$ (tons)
(4.1)

where,

$E_{MAN} = [T_{MAN} \cdot [(P_{ME} \cdot LF_{ME} \cdot \sum EF_{ME_e}) + (P_{AE} \cdot LF_{AE} \cdot \sum EF_{AE_e})]_{MAN}] \cdot 10^{-6}$
(4.2)

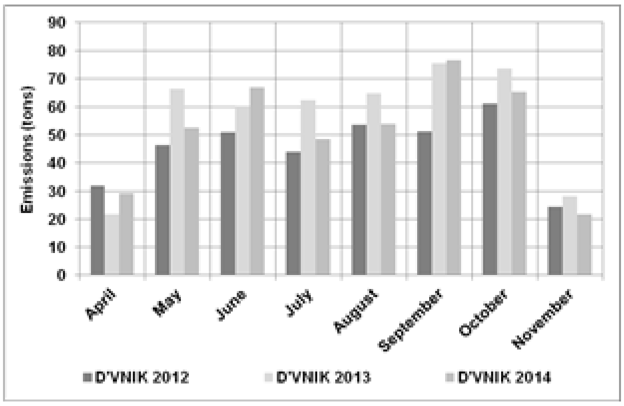
and

$E_{A/B} = [T_{A/B} \cdot [(P_{ME} \cdot LF_{ME} \cdot \sum EF_{ME_e}) + (P_{AE} \cdot LF_{AE} \cdot \sum EF_{AE_e})]_{A/B}] \cdot 10^{-6}$
(4.3)

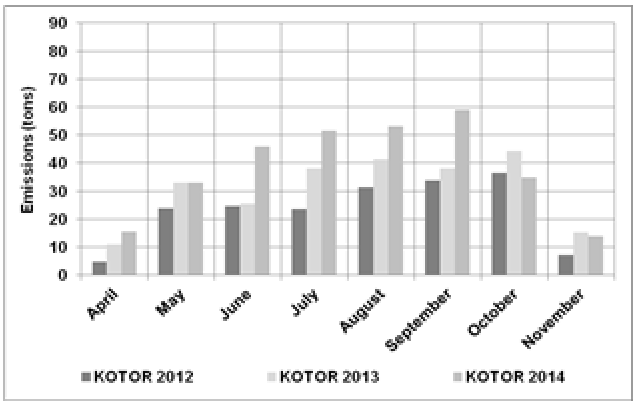
where,

T_{MAN} and $T_{A/B}$ = time spent in maneuvering and at berth or anchorage (h),
P_{ME} and P_{AE} = ship's main engine (*ME*) and auxiliary engine (*AE*) allocation of power (kW),
LF_{ME} and LF_{AE} = load factors of main and auxiliary engines and
EF_{ME} and EF_{AE} = emission factors of emission e for the main and auxiliary engines (g/kWh).

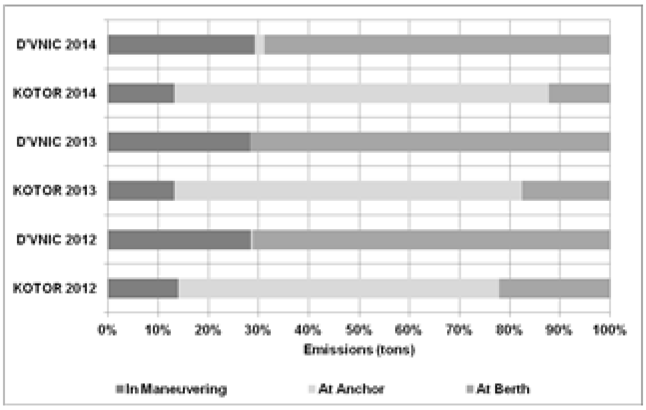
The following results were obtained :



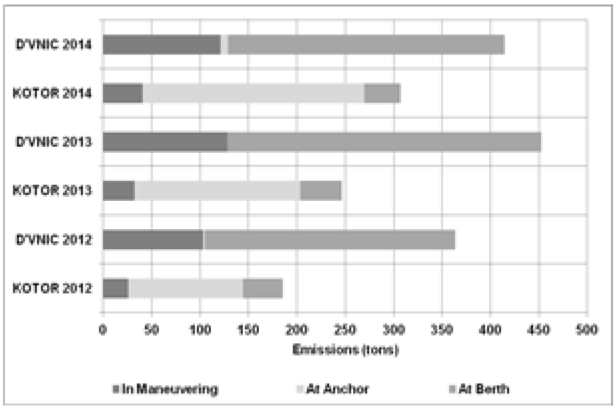
Monthly distribution of emissions – Dubrovnik



Monthly distribution of emissions - Kotor



Distribution of emissions relative to ship activity phase



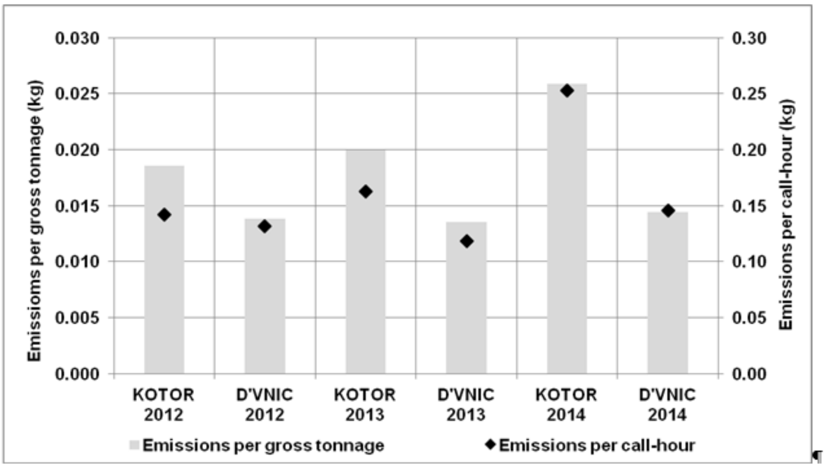
Distribution of emissions relative to ship activity phase

Externality results

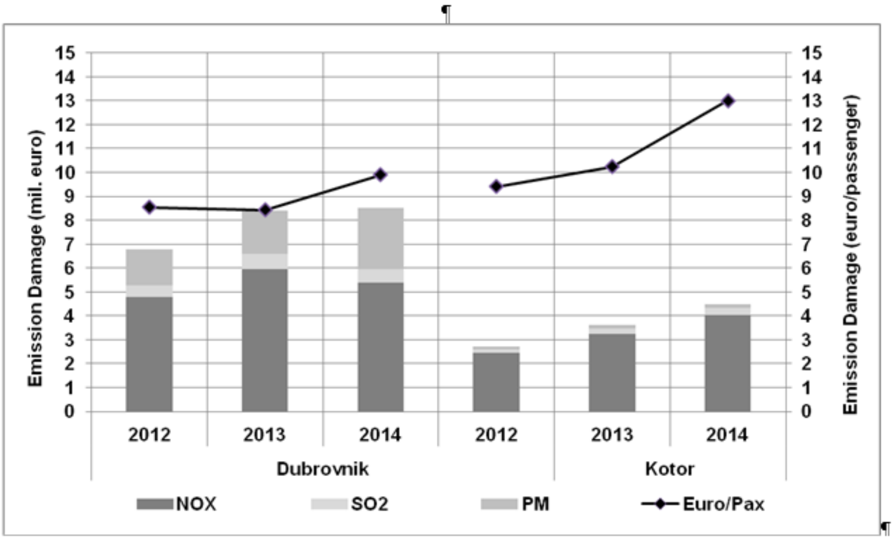
The analysis of the damage costs of the air pollution produced by the ships calling at the port of Dubrovnik and Kotor is presented below. Damage costs were generally found to be in proportion to the emissions produced in each port, i.e. they are higher in Dubrovnik than those in Kotor. In this study, the pollution of NO_x is the most damaging primarily due to its higher emitted quantities, as its unit costs are generally significantly lower than those of PM emissions. The share of PM damage is significantly higher for Dubrovnik because of its urban characteristics as opposed to the rural population density of Kotor, thus following the general pattern.

The air pollution damage at the port of Kotor was found to be higher in terms of the port calling cruise passengers, ranging between 9 and 13 euro per passenger for the port of Kotor as opposed to 8.5 to around 10 euro per passenger for the port of Dubrovnik.

Furthermore, the port of Dubrovnik was generally found to bear higher damage costs per call and per hour spent in port, whilst in contrast to the observed higher emission levels per GT at Kotor, the damage per GT was found to be generally comparable between the two ports because of the lower impact of PM unit cost at Kotor in comparison to that at Dubrovnik. However, with the exemption of 2012, the air pollution damage per call-hour at the port of Dubrovnik was higher than that at Kotor, following the trend observed for the corresponding emission parameter.



Comparison of gross tonnage and call-hour weighted emissions.



Analysis of damage costs of air pollutants.

Conclusions

The analysis of emission levels and associated damages in the cruise ports of Kotor and Dubrovnik indicates that for a given regulatory framework for the control of air pollution from ships and for a given port calling demand, the available port infrastructure in terms of its complexity and adequacy constitutes a decisive factor.

The port of Kotor was found to suffer under the influence of the low availability of berth space which dictates the use of the anchorages especially during the busy summer season, whilst the port of Dubrovnik imposes upon ship operators a complex maneuvering procedure which inevitably leads to increased emissions and even higher air pollution damages due to its urban characteristics.

The provision of port facilities for the improvement of the local air quality requires investments which can be realized through the internalization of the damage costs associated with the in-port ship emissions. According to the “polluter pays principle”, it is proposed that pricing policies for the provision of cruise port services should incorporate the damage of air pollution from ships for facilitating the financing of appropriate remedial projects, such as the supply of adequate and easily accessible berths.

In an attempt to recover the damage costs of air pollution from ships, port management should consider the enforcement of port dues which incorporate the associated costs. The aforementioned analysis offers the ability to choose from a range of port pricing policies amongst which the damage cost per port calling passenger appears to be the most appropriate, as cruise passengers are the ultimate users of the shipping services

CHAPTER 7 CONCLUSIONS

Cruise ships generate large amounts of waste that need to be disposed of responsibly. While MARPOL 73/78 allows the disposal of various types of treated waste at sea when a boat is 12 miles offshore in Greece they dump the waste at a distance of more than 6 nautical miles and the speed exceeds 6 nautical knots. There is a need to encourage further action in order to achieve a more sustainable approach to ship waste management, rather than dumping it at sea, especially for solid waste. More sustainable cruise practices, based on integration with the local economy and community, be supported by discouraging and preventing short-term and opportunistic exploitation. Further research on practices, emissions and technology development in the industry. closer analysis of other existing initiatives from around the world (US Ships Act). Cruise ships and operators should be encouraged to explore environmentally friendly packaging and minimize waste production by ensuring, where possible, local store suppliers use the least amount of packaging to reduce waste. Further research into alternative methods of waste disposal and on-board waste management systems should be carried out, encouraging investment in new technology. Garbage should be sorted by category for further treatment, such as recycling. Hazardous material must not be mixed with other waste and must be sent to suitable receiving and treatment facilities. To achieve this, there is a need for all inland and port ports to address their waste management plans and environmental commitment and to carefully consider their responsibility to provide adequate recycling, reduction and reuse. There is also a need for local authorities to work with ports and port operators to ensure that environmental best practice is undertaken and achieved. Analysis shows that even a relatively small number of cruise ships emit vast amounts of air pollution. High emissions are due to insufficient stringency of the marine fuel quality and engine emissions standards. These are further compounded by the large size of marine engines and longer operational times of cruise vessels in ports and closer to the coasts. The evidence shows that even SECA ports are still exposed to high amounts of SOX and PM from ships. Emissions at berth are of a special concern given that main cruise passenger terminals are very close to densely populated cities. This is despite the 0.1% standard in place for all European ports for passenger ships with port calls longer than 2 hours. In 2020, marine sulphur standard for ships sailing in the EU EEZ outside the SECAs and outside the (berths in) European ports will improve from 1.5% to 0.5%. This will have considerable impact on ship air pollution. However, emissions from cruise ships will still remain considerably large compared to the emissions from the European passenger car fleet. As table A.3.1 demonstrates, even after the 2020 standard, a handful of cruise ships will still emit about 18, 10 and 41 times more SOX than all of the passenger vehicles respectively in Spain, Italy and Greece – top cruise ship polluted countries in Europe. Also, 2020 standard will have no impact on emissions in ports and in SECAs, because the standard in SECAs and in European ports is more stringent than the upcoming global standard (0.1% vs. 0.5%). Cruise pollution must be dramatically reduced to protect health and the environment and to become a branch of a more sustainable form of transport. Fortunately, there are technologies available to eliminate all ship emissions at berth and at sea. Notably, shore-side electricity (SSE), the possibility for ships at berth to connect to the local electricity grid and power their on-board equipment, is a proven and mature technology which can greatly reduce the local air pollution generated by docked vessels in ports. The European Alternative Fuels Infrastructure Directive

a study by 15

requires SSE in major European ports, but only if it is cost-beneficial; as a result, there is little uptake so far by ships and ports.

A 10% reduction in speed is equivalent to a reduction in fuel consumption of about 20% per unit distance while also resulting in a significant reduction in CO_2, SO_2 and

PM emissions. Improved voyage planning, includes the selection of optimal routes based on weather conditions and currents to reduce energy consumption. Emission reduction up to 2-4%. Exact arrival time: takes into account tides, congestion and arrival to avoid waiting times at the port. Offers the possibility of reducing emissions by 1 - 5%. Computer software (for use while a boat is at sea): finds the optimal route. Saves emissions up to 5%. Reducing SO_2 emissions by various methods such as an exhaust gas cleaning system (eg scrubbers) ˝ Cruise ships can also run on liquefied natural gas (LNG) Results: Reduces SO_2 emissions to almost zero (no S in LNG) Significant NO_x and PM emission reductions (> 80%). Cold ironing SO_2, NO_x and PM emissions can be reduced by 90% or more.

Two main issues are hindering the widespread adoption of SSE:

1. A "chicken-and-egg" problem, whereby owners of the vessels do not invest in ships to make them SSE-compatible because of limited connections available in ports, while at the same time ports do not invest in SSE connections because few ships can use them.

2. There is also a market distortion because of taxation. Shore-side electricity is taxed under the 2003 EU Energy Tax Directive, while fossil marine fuels are tax exempt. Such an uneven playing field creates a disincentive for ship owners to use SSE in ports wherever these technologies are available. This situation further disincentivises ports interested in SSE capacity.

Recommendation 1: In order to create a level playing field between SSE and fossil fuels used on-board, the EU should exempt by default SSE from electricity taxation for a transitional period of time, and/or tax at an equivalent rate fossil fuels used on board.

Recommendation 2: The EU should mandate zero emission berth standard in European ports, hence requiring ships to use SSE or implement alternative measures to achieve equivalent results. This would help ports that have invested in SSE avoid stranded assets.

Recommendation 3: Extend SECA standards to the rest of the EU seas and further tighten the SECA standard, notably, in favour of 10ppm sulphur standard (0.001%) currently applicable to road transport.

Recommendation 4: Given that NOX from existing and new ships is of great concern and that upcoming Baltic and North Sea and English Channel nitrogen emissions control areas (NECAs) will only address emissions from new ships built after 2021 alone, there is a need to tackle NOX from existing ships in all European waters (outside ports). For this reason, we recommend for a stand-alone EU measure, including possibly a financial mechanism similar to the Norwegian NOX Fund. Ships can use SCR systems and diesel particulate filters (DPF) to reduce their NOX and PM.

Recommendation 5: Consider zero emission control areas, as an extension of zero emission berth standard, in European territorial waters, especially in the major touristic destinations.

Ship sourced air pollution is a huge problem in many parts of the world. Even though the scope of this analysis was limited to continental Europe and surrounding islands only, one could expect similar levels of ship pollution elsewhere, too. For this reason, the recommendations of this report can be valid for countries as well.

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