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AN EXAMINATION OF FOCUS PROGRESS OF STUDIES ON MARPOL ANNEX IV AND ANNEX VI: A REVIEW

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ABSTRACT

International Convention for the Prevention of Pollution from Ships (MARPOL) is an international agreement, signed in 1973 and amended in 1978, to prevent pollution of seas from ship-based waste. In this review study, the Annex IV (Prevention of Pollution by Sewage from Ships) and Annex VI (Prevention of Air Pollution from Ships) contents of this agreement, which contains six annexes, are examined and changes in the focus of past studies and current studies are examined. Within the scope of Annex IV, the treatment procedures before the discharge of ship-based sewage wastes, special zones for wastewater discharge, and studies on the dilution of wastewater at sea after discharging to the sea were discussed. Within the scope of Annex VI, studies on emission inventory development, new technologies and alternative fuels have been examined. As a result of the review, the progress of the related studies has been evaluated and the future projections, which focused on the possible tendency of the studies, have been propounded.

Keywords: *MARPOL Annex IV, Sewage, MARPOL Annex VI, Ship exhaust emissions.*

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MARPOL EK IV VE EK VI ÜZERİNE YAPILAN ÇALIŞMALARIN ODAK İLERLEMESİNİN İNCELENMESİ

_ÖZ_

Denizlerin Gemilerden Kirlenmesini Önleme Uluslararası Sözleşmesi (MARPOL), denizlerin gemi kaynaklı atıklardan kirlenmesini önlemek için 1973 yılında imzalanan ve 1978'de değiştirilen uluslararası bir anlaşmadır. Bu inceleme çalışmasında, altı ek içeren bu sözleşmenin Ek IV (Gemi Pis Sularından Oluşan Kirlenmenin Kontrolü İçin Kurallar) ve Ek VI (Gemi Baca Gazlarından Kirlenmenin Önlenmesi İçin Kurallar) içeriği geçmiş çalışmalar ve mevcut çalışmalara odaklanmakta ve incelenmektedir. Ek IV kapsamında gemi bazlı kanalizasyon atıklarının deşarj edilmesinden önceki arıtma prosedürleri, atık su deşarjı için özel bölgeler ve denize boşaltıldıktan sonra denizde atık suyun seyreltilmesi üzerine çalışmalar tartışılmıştır. Ek VI kapsamında, emisyon envanterinin geliştirilmesi, yeni teknolojiler ve alternatif yakıtlar üzerine çalışmalar incelenmiştir. İnceleme sonucunda ilgili çalışmaların ilerlemesi değerlendirilmiş ve çalışmaların olası eğilimine odaklanan geleceğe yönelik tahminler ortaya konulmuştur.

Anahtar Kelimeler: *MARPOL Ek IV, Atık su, MARPOL Ek VI, Gemi baca gazı emisyonları*

1. INTRODUCTION

International Convention for the Prevention of Pollution from Ships (MARPOL) was adopted by International Maritime Organization (IMO) on 2 November 1973 and it covers all types of ship-related emissions to the environment. The main aim of MARPOL is to develop regulations in order to prevent the environmental pollution caused by shipping activities. While Annex IV, which entered into force on 27 September 2003, mainly focused on the requirements to control the pollution of the seas by sewage, Annex VI, which entered into force on 19 May 2005, sets limit on sulphur dioxide and nitrogen oxide emissions, mainly. The main aim of this review is to draw attention to the progress and change of the studies, which covers Annex IV and Annex VI.

2. MARPOL ANNEX IV

Annex IV includes a series of regulations on the discharge of sewage from ships to the sea, including equipment and systems for the control of sewage discharge of ships, provision of port reception facilities for sewage and research and certification requirements.

Ship-based wastewater is divided into blackwater and greywater. According to Annex IV; sewage is drainage and other wastes from any form of toilets, urinals, and WC scuppers; drainage from medical premises via wash basins, wash tubs and scuppers located in such premises; drainage from spaces containing living animals; or other waste waters when mixed with the drainages defined above (MARPOL Annex IV). Greywater, which has a lower pollutant concentration than sewage, means wastewater from sinks, bathrooms, showers, laundries and kitchens (U.S. Environmental Protection Agency, 2008). Sewage and greywater volumes are related to the number of passengers and crew and the time people spend on the ship. It is estimated that a person on a cruise ship produces 20-40 litres of sewage and 120-300 litres of greywater per day (Butt, 2007: 591-598).

2.1. Wastewater Discharge Standards and Treatment Plants

Before the wastewater is discharged into the sea, standards determined by national and international authorities must be met in terms of pollution concentration. These standards have been tightened in recent years, especially with the increasing number of passenger ships. Passenger ships traveling specifically to Alaska waters are subject to stringent standards by the Environmental Protection Agency (EPA) and it is inevitable that these vessels use effective treatment systems. Sahin and Vardar (2015) compared the wastewater treatment standards of MARPOL and EPA, and mentioned the treatment procedures of Marine Sanitation Device (MSD) and Advanced Wastewater Treatment (AWT) treatment systems used in passenger ships. It has been stated that AWT systems perform better treatment than MSD systems and in the final disinfection stage of AWT systems, chlorine is less common in wastewater since the UV disinfection method is used instead of the chlorination method used in MSD systems (Sahin and Vardar, 2015a: 25-31; Sahin and Vardar, 2015b: 47-52). Koboević and Kurtela (2011) gave detailed information about the AWT systems used in passenger ships and mentioned the filtration and disinfection systems of several AWT models. In another study by Koboević et al. (2011) they provided a detailed information on national and international standards applied in various regions regarding ship-driven sewage discharge. In addition, information about the treatment capabilities of Type I, II and III MSD systems used in sewage treatment, which should be used in ships of various sizes, were given in the study. While the Type III MSD system consists only of the holding tank, the most effective MSD system is specified as Type II with the ability to perform more detailed treatment. MSD Type I system, which uses maceration and disinfection methods, is used on ships 19.7 meters and smaller. Table 1 shows the average wastewater concentrations of MSD and AWT treatment systems and international standards.

Table 1: Average Concentrations of Treatment Systems and International Standards

Analyte	AWT Effluent Concentration	Type II MSD Effluent Concentration	Annex IV Standards	EPA Standards
Fecal Coliform (CFU/100ml)	14.5	2040000	< 100	< 20
Total residual chlorine (mg/l)	338	1070	< 0,5	< 10
BOD (mg/l)	7.99	133	< 25	< 30
Total suspended solids (mg/l)	4.49	627	< 35	< 30
pH	6-9	6-9	6.0 – 8.5	6.0 – 9.0

Source: Sahin and Vardar 2015a, 2015b.

2.2. Special Zones for Discharging Wastewater

There are regions with stricter rules for discharges from ships. The water flow rate in the Baltic Sea is slow due to the low salinity of water, shallowness, lack of tides, and its location on the tectonic plate. The water in this area is in two layers due to the salinity difference and the oxygen level in the lower layer is low. Therefore, the pollutants discharged to this area remain for many years. For this reason, the Baltic Sea is defined as a sensitive area in MARPOL for sewage, garbage, oil and air pollution. Ship-generated discharges in this region are subject to stricter rules (Huhta et al. 2007: 3-58; Vaneeckhaute and Fazli, 2020: 12-20). The Baltic Sea has been designated by IMO as the world's first Annex IV sewage special area for cruise ships. These special area arrangements applied after 1 June 2019 for new cruise ships, and will be applied after 1 June 2021 for existing and IMO registered cruise ships. Extensions are made until 1 June 2023 for direct transitions between St. Petersburg and the North Sea. Before these dates, according to the Annex IV, it is forbidden to discharge the sewage that has not been comminuted and disinfected using the approved sewage treatment system within 12 nm from the nearest land and to discharge the sewage treated with approved treatment systems into the sea within 3 nm from the nearest land. According to Annex IV, discharge from the sewage holding tank should be at a moderate speed and the ship sailing at least 4 knots. In the Baltic Sea, ships with an AWT that reduces nitrogen and phosphorus levels to specified levels are permitted to discharge. Treatment systems suitable for these regions, which are designated as special areas according to Annex IV, have been approved by national administrations by taking into consideration the standards and test methods developed by IMO (HELCOM 2016; Wilewska-Bien and Anderberg, 2018: 207-213).

In his study, Backer (2018) examined the work of the IMO and regional organizations to reduce ship wastes in the Baltic Sea, which was designated as a special area within the scope of Annex IV. He noted that the Helsinki Commission's 'no special fee' approach aims to remove the remaining deterrence in the use of waste reception facilities in the region. Ytreberg et al. (2020) made environmental risk assessment of graywater discharge to the Baltic Sea. They stated that 90% of graywater discharges to the Baltic Sea originated from Ropax and cruise ships. It is stated that copper and zinc are the metals with the highest environmental risk factor among 44 different chemicals determined in graywater.

Parks et al. (2019) drew attention to the increasing ship traffic in the Bering Sea and Bering Strait, and investigated the wastewater originating from these waters. In the study, the amount of oil discharged into these waters, sewage and graywater and the effect of these wastes on the region were discussed. In their work, Zhu and Zhuo (2017) also addressed regimes that focus on pollution prevention responsibilities for the parties involved in transport activities to ensure that ships used in Honkong waters comply with applicable rules and standards, under Annex IV.

In its detailed report, the Alaska Department of Environmental Conservation (ADEC) provided information on the number of passenger ships in the Alaska region, laws applied for wastewater management, wastewater treatment systems used in passenger ships, concentrations of pollutants contained in wastewater content, and their effects on the sea. In the report, the data of the wastewater samples taken from large and small passenger ships in various years are discussed in detail (Alaska Department of Environmental Conservation 2004).

In their study, McGee and Loehr (2003) gave information about the fecal coliform standards and calculations in the wastewater from the cruise ship to waters in Alaska through the studies conducted by Science Advisory Panel. They pointed out that the discharge of treated wastewater should be done 1 mile off the land and at a cruising speed of at least 6 knots, as the discharging of the vessels when stationary will increase the fecal coliform around the vessel and in the stream.

2.3. Secondary Natural Treatment System: 'Dilution Factor'

As can be seen in Table 1, AWT systems can perform much better treatment than MSD systems. In some cases, however, standards cannot be met, especially with regard to contaminant concentrations such as fecal coliform and total residual chlorine. The wastewater is able to meet the standards set by the authorities in a short period of time in the turbulence occurring in the wake of the ship, depending on the parameters of the ship, immediately after discharging into the sea. As a result of dilution studies, a simple formula has been developed and defined as 'dilution factor' in order to easily calculate the dilution amount. Since the increasing effect of the turbulence and mixing event occurring on the ship's wake will increase the dilution factor value, the concentration of the pollutant will reach the desired standard values in a shorter time and more effectively.

In the EPA's Cruise Ship Plume Tracking Survey Report, Rhodamine dye was first discharged to the ship's sewage tank and then to the sea. Before the discharge was realized, by adding dye to the waste water in the tank, the value of "dye concentration calculated in the tank" was obtained. The amount of dye discharged into the sea was calculated via the difference between the amount of dye added to the tank and the dye remaining in the tank after discharge. By calculating the amount of dye discharged to the volume of dye distribution (plume) on the way the ship takes along the discharge, the value of "dye concentration calculated in sea water" has been obtained. The ratio of the dye concentration calculated in the tank to the dye concentration calculated in the sea gave the "calculated dilution factor" value. In the "measured dilution factor" calculation, the dye concentrations added to the tank and determined in the ship wake dye distribution (plume) were monitored by making measurement instruments. The concentration of the dye distribution on the ship's wake was measured with the aid of a fluorometer. The ratio of dye concentrations measured in the tank and ship wake dye distribution gave the value of "dilution factor measured". The dilution factors calculated and estimated at the end of the study were compared (U.S. Environmental Protection Agency, 2002).

The EPA's Cruise Ship Discharge Assesment Report examined sewage and greywater discharges by passenger ships. This report provides detailed information on wastewater pollutant concentrations and standards of discharges from large and small passenger ships to Alaska waters. The pathogens in the wastewater and their damage to the sea are stated. In addition, the report gives detailed information about the working principles of MSD and AWT, and the pollutant concentrations of wastewater treated by these systems have been extensively studied. The report presents simple formulas used to calculate the dilution factor of large and small passenger ships (U.S. Environmental Protection Agency, 2008).

Heinen et al. (2003), reported how the formulations are used to estimate the dilution factor behind the moving cruise ships and the EPA paint studies on this subject. In this study, the dilution occurring behind the moving passenger ships has been calculated by formula and experimentally and it has been shown how much these values approached each other. In another study by Loehr et al. (2003), the versions of this dilution factor formula used by EPA are given for large and small passenger ships. The dilution factor values obtained from the formula and by experiment were compared. In their study, Sahin and Vardar (2018) examined the relationship between wastewater dilution at sea and the parameters of the ship in the scenario where 9 passenger ships operating in the Mediterranean discharge all of their wastewater into the sea. It is stated that, although the dilution factor is important, ships should be equipped with AWT systems.

In EPA's Sampling Episode Report Cruise Ship Plume Dilution Study, six passenger ships were identified and details of the wastewater dilution studies of these ships were provided. The report includes detailed information about the treatment systems used by these ships, the wastewater discharge rate, the diameter of the pipe used for discharge and the side of the vessel where the discharge site is located and its height to the water surface. In the study, information about how the paint adds to the tanks and the sea and weather condition are also given (U.S. Environmental Protection Agency, 2009).

EPA and ADEC published the report on the wastewater discharge from stationary cruise ships. In this report, near field dilutions (0-15 meters) of discharges from stationary cruise ships are examined. Six cruise ships were used in the study and the dilution factors estimated by the dilution models created by computer programs CORMIX and PLUMES were compared with the dilution factors measured. Detailed information is given about the distances where the dilution factor measured by the model and the dilution factor values measured are consistent (Alaska Department of Environmental Conservation, 2009).

3. MARPOL ANNEX VI

Although ship-based air pollution does not pose a serious problem in itself, shipping activities contribute significantly to the global emissions. On the other hand, according to a previous study (Endresen et al., 2003: 17), nearly 70% of shipping emissions occur within 400 km of land. Thus, IMO have begun to study on the issue of shipping emissions. According to the latest report of IMO, shipping activities are estimated as responsible for 3.1%, 2.8%, 15% and 13% of all anthropogenic carbon dioxide (CO_2), carbon dioxide equivalent (CO_2e), nitrogen oxides (NO_x) and sulphur oxides (SO_x) (Smith et al., 2014: 327).

IMO has begun its studies on controlling and prevention of air pollution caused by shipping in 1973 with the first discussion on MARPOL. However, no action was taken until presentation of some papers, which indicated that shipping activities are responsible for 4%, 7% and 1-3% of SO_x, NO_x and chlorofluorocarbons, by Norway to Marine Environment Protection Committee in 1990. The works quickly gave fruit and made Annex VI prepared in 1997 and come into force in 19 May 2005 (IMO 2020a).

Because the main focus of Annex VI is for NO_x and SO_x emissions, strict limits for these emissions were settled, which are shown in Table 2 and Table 3.

Table 2: The Limits for No_x

Tier	**Ship Construction Date on or After**	**Total Weighted Cycle Emission Limit (g/kWh) n=Engine's Rated Speed (RPM)**		
		n<130	n=130-1999	n≥2000
Tier I	1 January 2000	17.0	$45 \times n^{-0.2}$	9.8
Tier II	1 January 2011	14.4	$44 \times n^{-0.2}$	7.7
Tier III	1 January 2016	3.4	$9 \times n^{-0.2}$	2.0

Source: IMO, 2020b.

Table 3: The Limits for So_x

Outside an Emission Control Area	**Inside an Emission Control Area**
4.50% prior to 1 January 2012	1.50% prior to 1 July 2010
3.50% on and after 1 January 2012	1.00% on and after 1 July 2010
0.50% on and after 1 January 2020	0.10% on and after 1 January 2015

Source: IMO, 2020c.

3.1. Determining Studies on MARPOL Annex –VI

Although the Annex did not come into force in 2002, the authors focused on the NO_x Technical Code and its requirements. The study mainly examined the emission inventories of ferries and automobiles. The authors concluded that ferries produce more NO_x, particulate matter (PM) and carbon monoxide (CO) (Corbett and Farrell, 2002: 197-211). Another study focused on discussing the qualification of Annex VI against other legislations prepared by EPA and European Union (EU). The study compared both opposite and supportive views against Annex VI. Although opposite views indicated that the requirements brought by Annex VI are already a part of EU policies, the other views expressed that MARPOL contributed to the development of new technologies even its preparation stage (Hyvättinen and Hildén, 2004: 491-502). A more recent study discussed whether Annex VI should be amended by adding CO_2 as a pollutant. It was indicated that some developing countries strongly opposed such an amendment because according to them, CO_2 is not a "pollutant" but a greenhouse gas. Besides, it was insisted that such amendments may cause "a tremendous domestic legal obstacles". Instead of adding new clauses to Annex VI, it was recommended to prepare a new and independent convention under the auspices of IMO (Shi, 2016: 187-192).

3.2. Studies on Developing Emission Inventories

Developing emission inventories is an essential first step to understand the real impacts of shipping emissions. Thus, various studies were realized to measure emission amounts in trading routes and some ports. In order to develop regulations and prepare legislations for measuring emissions, first, the extent of these pollutant should be understood well. Saxe and Larsen (2004) investigated the air pollution caused by shipping activities in three Danish ports: Copenhagen, Elsinore and Køge. It was concluded that while shipping activities in the Port of Copenhagen and the Port of Elsinore may cause health problems to people because the NO_x amounts are higher than the EU's standards. In a further study, a national emission inventory of maritime fleet was developed for Denmark. The study focused on the contribution of fuel consumption and emissions of sea transportation to the Danish inventory and the author also investigated the impact of Annex VI to the total inventory. According to the results, the contribution of sea transportation to total fuel consumption (and CO_2), NO_x and SO_2 emissions are 5%, 34% and 167%, respectively. Besides, the fuel consumption, NO_x and SO_2 emissions decreased by 45%, 45% and 81% between 1990-2005 (Winther, 2008: 4632-55). Two studies were conducted for emission inventories of Belgium. First study focused on the annual CO_2, SO_2 and NO_x emissions of four Belgian ports. The estimations showed that 1880, 31 and 39 kton of CO_2, SO_2 and NO_x were emitted respectively between April 2003-March 2004. It was also concluded that these emissions correspond 1.5%, 30% and 22% of total CO_2, SO_2 and NO_x emissions (De Meyer et al. 2008: 196-206). The other study focused on the decreases in emissions due to IMO and EU regulations. While CO_2 and NO_x emissions are expected to increase by 2-9% and 1-8% for 2004-2010 period, respectively, it was estimated that SO_2 emissions would decrease by at least 50% in the same period. On the other hand, if the auxiliary engines' fuel switch from heavy fuel oil to diesel oil, a great reduction would be expected for PM (33%) and small reductions for CO_2, NO_x, CO and hydrocarbons (HC) (4-5%) (Schrooten et al. 2008: 667-76). Another study on developing inventory was conducted for the Marmara Sea Region of Turkey including Turkish Straits. According to the results, the total annual emissions were estimated as 5,451,224, 111,039, 87,168, 20,281, 5801 and 4762 t for CO_2, NO_x, SO_2, CO, volatile organic compounds and PM, respectively (Deniz and Durmuşoğlu, 2008: 255-61). In 2008, the total emission inventory of shipping activities of Greek fleet was estimated as 12.9 million tons. It was also concluded that the ship emission inventory of Greece had an almost fourfold increase during 1984-2008 (Tzannatos Ernestos, 2010: 2194-2202). Similarly, the shipping emissions of the Port of Las Palmas were calculated in a study published in 2015. The total CO_2, NO_x, SO_x, CO and $PM_{2.5}$ emission amounts were 208,697, 4237, 1420, 497 and 338 tons. The majority of these emissions occurred during hoteling and produced by passenger ferries and container ships (Tichavska and Tovar, 2015: 347-60). A more recent study focused on the emission inventory of Port of Samsun during 2010-2015 period. The estimations showed that NO_x, SO_2, HC and PM_{10} emissions were 728, 574, 32 and 64 tons, respectively. The majority of these emissions were produced by Ro-Ro ships in cruising mode (Alver et al. 2018: 822-28). In a more comprehensive study, the total emission inventory for EU countries were calculated for 2005 and the future estimations were conducted until 2030 (Schrooten et al. 2009: 318-23).

3.3. Studies on New Technologies

New and approved technologies are required to reduce emissions. Although there are various techniques, only some of them are approved and examined well in the literature. A recent study compared these technologies in terms of reduction ratio and installation and operating costs. The results showed that internal engine modifications, continuous water injection, fuel water emulsions, direct water injection, humid air motor and selective catalytic reduction (SCR) have 25%, 70%, 50%, 50%, 70% and 95% reduction impact on NO_x emissions (Yang et al. 2012: 478-86). One of the experimental studies was conducted in 2007 by using SCR to reduce NO_x emissions and it was indicated that NO_x emissions reduced by 95% (Komar et al. 2007: 305-9). Another study focused on improving scrubber efficiency and it was indicated that under the optimized conditions the desulphurization efficiency may exceed 90% (Tang et al. 2014: 98-104). In a more recent study, the cost-benefit analysis of utilizing scrubber and marine gas oil (MGO) was realized. According to the results, first, it was indicated that scrubber have no effect on reduction CO_2 and NO_x but $PM_{2.5}$ and SO_2. Second, while the SO_2 and $PM_{2.5}$ productions during base case, in which no scrubber has installed, were estimated as 4533 and 556 tons. Scrubber utilization may cause a 98% and 55% for SO_2 and $PM_{2.5}$, respectively. On the other hand, MGO utilization cause approximately 91% and 39% reduction for both (Jiang et al. 2014). Boscarato et al. (2015) studied on a combined system of SCR and scrubber and they concluded that the presence of SCR located before the scrubber may reduce NO_x emissions significantly as well as SO_x. One of the latest studies focused on the maximum removal ratio of NO_x and SO_2 by utilizing wet scrubber based on seawater electrolysis technology. The results showed that NO_x and SO_2 could be removed by 92% and 100% in optimum conditions (Yang et al. 2018: 8-15). Exhaust gas recirculation (EGR) system is utilized to reduce NO_x emissions, mainly and in a recent study, it was concluded that EGR may reduce NO_x formation rate by 90% in Tier III engines and in 75% load (Raptotasios et al. 2015). Kökkülünk et al. (2014) experimentally and theoretically investigated the decreasing impacts of EGR and concluded that NO emissions reduce with raising EGR ratio. Waste heat recovery system (WHRS) is another technology for reducing NO_x and CO_2 emissions and it was concluded that WHRS may reduce these gases by approximately 36% and 17% (Senary et al. 2016: 1951-60).

3.4. Studies on Alternative Fuels

Utilizing alternative fuels instead of fossil fuels is another field of study. For it is estimated that distilling the fuel and using organic origin fuels cause less emissions, the studies on these types of fuels increased, recently. Jiménez Espadafor et al. (2009) studied on pure vegetable oils as fuel and concluded that utilizing these oil may reduce NO_x, SO_2 and PM emissions to zero and cause a significant reduction in CO_2 and CO emissions. In another study it was proved that waste-oil based fuels meet the standards of IMO in terms of NO_x emissions, which means using waste-oil based fuels does not increase NO_x emissions (Gabiña et al. 2016: 28-36). A more recent study focused on waste oil utilization and it was concluded that in case of using waste oil as fuel, NO_x emissions decrease significantly (Wei et al. 2018: 73-80). On the other hand, another study resulted that waste-oils decrease NO_x and CO_2 emissions while it was observed a slight increase in CO emissions (Gabiña et al. 2019: 259-68). Liquefied natural gas (LNG) is another common alternative fuel and it is estimated that using

LNG may reduce NO_x, SO_2, PM and CO_2 emissions (Burel et al. 2013: 312-20). It was also indicated that LNG may reduce PM emissions, as well (Thomson et al. 2015: 153-67). Two recent studies focused on the impact of V on engine performance and emissions (Chu-Van et al. 2020: 116437) and the removal of V, Ni and S on emissions (Garcia-Montoto et al. 2020: 106341).

4. CONCLUSIONS

Studies conducted in the literature within the scope of Annex IV and national organizations show how important the effective disposal of ship-based wastewater is for the seas. As the number of people carrying ships increases, the amount of wastewater produced by ships will increase in direct proportion, so wastewater treatment and disposal is especially important for passenger ships. Studies in recent years have shown that even if wastewater is treated in treatment systems, it may not meet the standards set by the authorities in terms of some important pollutants. Studies by EPA and ADEC have shown that wastewater can be diluted in the turbulence and mixture occurring on the ship's trail shortly after being discharged into the sea and can meet the specified standards. As a result of the dilution studies that EPA has carried out important studies, a simple formula has been developed and defined as the 'dilution factor' in order to easily calculate the dilution amount. Since the increasing effect of the turbulence and mixing event occurring on the ship's trail will increase the dilution factor value, the concentration of the pollutant will reach the desired standard values in a shorter time and more effectively.

When the studies related to Annex VI are examined, it is seen that the first studies after the announcement of Annex VI are generally focused towards emission inventory. It is clear that this first process is where a problem is tried to be presented regionally and globally. Studies in various regions of the world have shown that ship emissions pose a serious threat to the environment and future potential impacts should be taken into account. When the studies after 2010 are analyzed, it is seen that efforts to create emission inventory have been replaced by innovative technologies and alternative fuels. Especially in recent years, studies have focused on examining even minor effects. For this reason, it can be concluded that the studies on MARPOL focus on the examination of various effects of innovative technologies and future studies are expected to cover the details of these issues and it is obvious that these kind of studies will be expected and accepted widely.

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