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APPLYING EMISSION CONTROL AREAS (ECA) IN MARITIME ZONES: ADOPTION AND COMPLIANCE

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ABSTRACT:

Establishing the Emission Control Area (ECA) constitutes a significant regulatory measure within the international maritime legal framework to mitigate air pollution from shipping activities. According to MARPOL Annex VI, the designation of an ECA requires a comprehensive, evidence-based proposal evaluated by the International Maritime Organization (IMO). Within these designated zones, ships must utilize low-sulfur fuel or adopt emission reduction technologies to comply with stringent emission standards. Implementing ECAs has significantly improved air quality in port cities and coastal regions. Compliance is ensured through a multi-level enforcement mechanism involving flag, port, and coastal States, supplemented by technological monitoring and regulatory infrastructure. This study adopts a normative legal methodology and a descriptive-analytical approach to examine ECA implementation's legal provisions, enforcement mechanisms, and practical implications in achieving sustainable environmental protection in the maritime sector.

Keywords: *Emission Control Area (ECA), MARPOL Annex VI, Maritime Air Pollution, Environmental Regulation, Compliance Monitoring*

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ABSTRAK:

Pembentukan Emission Control Area (ECA) merupakan langkah regulasi yang signifikan dalam kerangka hukum maritim internasional yang bertujuan untuk mengurangi polusi udara yang dihasilkan oleh aktivitas pelayaran. Berdasarkan MARPOL Annex VI, penetapan ECA memerlukan proposal yang komprehensif dan berbasis bukti yang dievaluasi oleh International Maritime Organization (IMO). Di dalam zona yang ditetapkan tersebut, kapal diwajibkan untuk menggunakan bahan bakar rendah sulfur atau mengadopsi teknologi pengurangan emisi guna mematuhi standar emisi yang ketat. Implementasi ECA terbukti berkontribusi pada peningkatan kualitas udara di kota pelabuhan dan wilayah pesisir. Kepatuhan terhadap peraturan ini dijamin melalui mekanisme penegakan hukum multi-level yang melibatkan flag States, port States, dan coastal States, yang didukung oleh pemantauan teknologi dan infrastruktur regulasi. Penelitian ini menggunakan metode penelitian hukum normatif yang dikombinasikan dengan pendekatan deskriptif-analitis untuk mengkaji ketentuan hukum, mekanisme penegakan, dan implikasi praktis dari implementasi ECA dalam mencapai perlindungan lingkungan berkelanjutan di sektor maritim.

***Kata Kunci**; Emission Control Area (ECA), MARPOL Annex VI, Polusi Udara Maritim, Regulasi Lingkungan, Pemantauan Kepatuhan.*

A. Introduction

In the modern industrial era, maritime transport plays a crucial role in global economic development, contributing approximately 80% of international trade volume.[1] This mode of transport is the primary choice for global trade due to its large capacity for transporting significant amounts of cargo at relatively economical costs. According to the Review of Maritime Transport 2023 released by the United Nations Conference on Trade and Development (UNCTAD), there are nearly 105,500 ships with a gross tonnage of more than 100 tons worldwide, with a total deadweight of approximately 2.3 billion tons.[2] This high trade volume makes maritime transport one of the world's busiest and most congested logistics routes.

Despite its significant contribution to economic growth, maritime transport also substantially negatively impacts the environment. Intensive shipping activities in international waters generate exhaust emissions from the combustion of marine fuels, which adversely affect air quality both at sea and in coastal regions. These emissions include major pollutants such as carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulate matter (PM). The presence of these pollutants not only exacerbates global warming but also disrupts marine ecosystems and endangers human health.

[1] UNCTAD, 2021, *Review of Maritime Report 2021*. UN Publications: New York.
[2] UNCTAD, 2023, *Review of Maritime Transport 2023: Towards a Green and Just Transition*. UN Publications: New York.

As the principal instrument in International Maritime Law, the United Nations Convention on the Law of the Sea (UNCLOS) plays a vital role in regulating the protection of the marine environment, including addressing air pollution stemming from shipping activities. Article 192 of UNCLOS establishes the obligation for states to "protect and preserve the marine environment," which includes preventive measures against pollution from various sources, including vessel emissions. This provision is further clarified in Article 194, which mandates each state to take the necessary measures to prevent, reduce, and control marine pollution. Furthermore, Article 212 explicitly addresses pollution from or through the atmosphere, requiring states to adopt appropriate regulations to mitigate the negative impacts of air pollution on the marine environment.

In its implementation, UNCLOS sets general obligations and encourages state parties to refer to more specific international standards and regulations. One of the primary instruments governing air pollution from ships is the International Convention for the Prevention of Pollution from Ships (MARPOL), adopted by the International Maritime Organization (IMO). Annex VI of MARPOL regulates explicitly the limits of ship emissions, including sulfur oxides (SOx), nitrogen oxides (NOx), and particulate matter (PM), which pose environmental and health risks.

As part of its mitigation efforts, MARPOL Annex VI introduced the concept of Emission Control Areas (ECA) maritime zones with stricter emissions aimed at reducing air pollution in designated sea areas. Within ECAs established by the IMO, the sulfur content in marine bunker fuel must not exceed 0.1%.[3] IMO has designated four ECAs: the Baltic Sea, the North Sea, North America, and the Caribbean Sea.[4]

The establishment of the Emission Control Area (ECA) presents significant challenges for foreign vessels navigating through these regions. These vessels must comply with stricter emission standards, necessitating low-sulfur fuel or implementing emission control technologies. According to IMO regulations, since 2015, operators of ships operating within ECAs must install exhaust gas cleaning systems such as scrubbers or switch to low-sulfur fuel to meet these standards.

[3] IMO, n.d., "IMO 2020 – Cutting Sulphur Oxide Emissions.", Available on Website: https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx, Accessed on May 7th, 2025.

[4] IMO, n.d., "Emission Control Areas (ECAs) Designated Under MARPOL Annex VI." Available on Website: https://www.imo.org/en/OurWork/Environment/Pages/Emission-Control-Areas-(ECAs)-designated-under-regulation-13-of-MARPOL-Annex-VI-(NOx-emission-control).aspx, Accessed on May 7th 2025.

The implementation of ECA is generally carried out in maritime areas with high shipping traffic or in coastal environments that are sensitive to air pollution. Notable examples include the Baltic and North Seas, designated as ECAs for SOx since the mid-2000s, and were later expanded to include NOx controls. The North American coastline and the Caribbean waters of the United States have also been designated as ECAs, considering the high shipping activity and its impact on air quality in those regions. The designation of these areas as ECAs aims to protect the marine environment and public health by requiring transiting vessels to use low-sulfur fuel or other emission control technologies.

This study examines how Emission Control Area (ECA) regulations are implemented and enforced within maritime zones used for international navigation, particularly in light of international legal frameworks such as UNCLOS and MARPOL Annex VI. It further explores how these regulations align with established international standards and the legal and practical challenges that may arise, especially for foreign vessels transiting through designated ECAs. By addressing these issues, the article seeks to provide a legal assessment and offer policy recommendations to enhance the effectiveness of emission control mechanisms from ships, thereby contributing to improved air quality in maritime regions and the advancement of sustainable environmental governance at sea.

B. Research Method

This journal's research approach adopts a normative legal research method to identify and analyze relevant principles or doctrines of positive law.[5] This research approach applies a statutory and a conceptual approach. The statutory approach examines relevant international maritime laws such as MARPOL 73/78, UNCLOS 1982, and the IMO Convention. The conceptual approach is carried out by studying studies legal principles and doctrines related to marine environmental protection and state responsibility. The legal material collection technique applied is library research, where various primary, secondary, and tertiary legal sources are thoroughly examined to gain a comprehensive understanding of the applicable legal aspects.

Primary legal sources include international legal instruments such as the MARPOL 73/78 Convention, the United Nations Convention on the Law of the Sea (UNCLOS), and the International Maritime Organization (IMO) Convention. Secondary legal sources encompass scholarly journals, legal books, and research studies discussing the

[5] Bambang Sunggono, 2012, *Metodologi Penelitian Hukum 13th ed.*, Jakarta: Rajawali Press.

implementation of Emission Control Areas (ECA) in maritime areas. Tertiary sources include legal dictionaries and encyclopedias, which clarify relevant legal concepts.

The legal analysis is conducted using a descriptive-analytical method. The study first describes the relevant legal norms and regulatory frameworks. Then it analyzes their implementation, effectiveness, and potential gaps in ensuring compliance with emission standards for ships operating in designated ECA maritime zones.[6]

C. Discussion

1. Procedure for Proposing a Maritime Area for ECA Designation

The proposal to designate a maritime area as an Emission Control Area (ECA) by the International Maritime Organization (IMO) is a process strictly governed under Annex VI of the MARPOL Convention, particularly Regulation 13.6 concerning nitrogen oxides (NO_x), Regulation 14.3 concerning sulfur oxides (SO_x) and particulate matter (PM), and Appendix III, which outlines the relevant criteria and procedural requirements. The process begins with an initiative from one or more Party States with jurisdiction over the proposed maritime area. These States are responsible for preparing a formal and detailed proposal, supported by scientific, technical, and environmental policy data. The proposal must clearly define the geographical boundaries of the proposed area and specify the types of emissions to be regulated, whether NO_x, SO_x, PM, or a combination thereof.[7]

Scientific data, including emission measurement methodologies, must support this impact assessment. These meteorological conditions contribute to pollutant accumulation, and descriptions of geographical, oceanographic, or topographical features that exacerbate pollution effects. The proposed State(s) must also demonstrate the emission control measures undertaken on land-based sources, as evidence of a comprehensive emission reduction effort, not limited solely to the shipping sector. In addition, a cost-benefit analysis of the ECA implementation must be included, addressing its implications for the international shipping industry.[8]

Once the proposal is finalized, it is submitted to the IMO for evaluation by the Marine Environment Protection Committee (MEPC). The Committee will assess whether the

[6] Peter Mahmud Marzuki, 2011, *Penelitian Hukum 11th ed.*, Jakarta: Kencana.

[7] MARPOL Annex VI Appendix III, "*Criteria and Procedures for Designation of Emission Control Areas – Regulation 13.6 and regulation 14.3*"

[8] Bernard Wisniewski & Maciej Szymanski, "Navigation in Emission Control Area Zones." Scientific Journals of the Maritime University of Szczecin, Vol. 47, No.119, 2016, p.116.

proposal meets all the criteria outlined in Appendix III of MARPOL Annex VI. If deemed satisfactory, the Committee will amend Annex VI, designating the area as an ECA through the legal procedures established in Article 16 of the MARPOL Convention. This process includes an acceptance period and an entry-into-force phase, whereby the ECA designation becomes legally effective after a specified time frame, if Party States raise no substantial objections.

2. Implementation of ECAs in Maritime Areas

Emission Control Areas (ECAs) impose strict limits on the sulfur content of marine fuel, thereby reducing emissions of sulfur dioxide (SO_2) and fine particulate matter (PM), both of which pose serious risks to human health and the marine environment—a study by Anastasopolos et al.[9], focusing on Canadian port cities, demonstrated that following the enforcement of the North American ECA (NA-ECA), ambient SO_2 concentrations decreased significantly. The study analyzed air quality data from 2010 to 2016 across five major Canadian port cities: Halifax, Vancouver, Victoria, Montreal, and Quebec City, to assess the impact of the gradual implementation of low-sulfur fuel regulations culminating in a 0.1% sulfur content limit by 2015 on air pollutant concentrations.

The findings indicated a statistically significant reduction in sulfur dioxide (SO_2) levels, a primary pollutant from the combustion of residual fuel oil (RFO) used by ships, across all cities studied. For instance, in Halifax, SO_2 concentrations fell by up to 73%, while Vancouver experienced reductions ranging from 66% to 83% following the second phase of ECA regulation. These reductions occurred primarily during the 2013–2016, coinciding with the transition from a 1% to a 0.1% sulfur limit, indicating that the regulatory measures directly impacted air quality in port areas.[10]

Additionally, concentrations of fine particulate components such as vanadium (V), nickel (Ni), and sulfates, distinct markers of RFO combustion, also declined significantly. This suggests a widespread shift among vessels to low-sulfur fuels that do not contain these heavy metals. These reductions were consistently observed across all studied port cities and were attributed directly to the decreased use of RFO.

[9] Angelos T. Anastasopolos, et al., "Air Quality in Canadian Port Cities after Regulation of Low-Sulphur Marine Fuel in the North American Emissions Control Area.", Science of The Total Environment, Vol. 791, 2021, p. 1.

[10] *Ibid.*, p. 5-6.

It is estimated that SO_x emissions from ships decreased by approximately 95–96% between 2010 and 2015, while PM emissions declined by 70–79%. These findings align with air quality monitoring data, reinforcing the conclusion that the observed reduction in air pollution was due to changes in fuel usage, rather than a decline in shipping activity or local industrial output.[11]

Furthermore, a study that conducted a global analysis of the impacts of Emission Control Areas (ECAs) using a spatial difference-in-differences methodology found that the implementation of ECAs successfully reduced SO_2 concentrations in coastal cities worldwide, with an average decrease ranging from 3.2% to 6.4%. Specifically, in North America, implementing ECAs with a sulfur content limit of 1.0% since 2012 and 0.1% since 2015 resulted in SO_2 concentration reductions of 4.8% and 4.4%, respectively.[12]

3. Adaptation of the Shipping Industry to ECA Regulations

The implementation of the Emission Control Area (ECA) under MARPOL Annex VI encourages the shipping industry to adapt in various ways to meet stricter emission standards. This policy establishes maximum sulfur content limits in marine fuel, specifically 0.1% m/m within ECA regions and 0.5% m/m globally since 2020.[13] To comply with the stringent requirements of Emission Control Area (ECA) regulations, the shipping industry has undertaken significant adaptations involving technological, operational, and investment aspects.

To meet these regulations, the shipping industry has adopted various strategies. One of the primary approaches is to switch from the use of Heavy Fuel Oil (HFO), which contains high levels of sulfur, to low-sulfur fuel alternatives such as Marine Gas Oil (MGO) and Very Low Sulfur Fuel Oil (VLSFO). Although this option increases operational costs due to the higher price of these cleaner fuels, the transition does not require significant modifications to ship engines, making it a practical solution for many ship operators. This shift is considered an efficient and relatively low-investment solution as vessels only require simple operational adjustments, and these fuels are widely available at many ports. Several

[11] *Ibid.,* p.7.

[12] Zheng Wan, et al., "Do Ship Emission Control Areas in China Reduce Sulfur Dioxide Concentrations in Local Air? A Study on Causal Effect Using the Difference-in-Difference Model.", Marine Pollution Bulletin, Vol. 149, 2019.

[13] Luis María Abadie, Nestor Goicoechea, and Ibon Galarraga, "Adapting the Shipping Sector to Stricter Emissions Regulations: Fuel Switching or Installing a Scrubber?", Transportation Research Part D: Transport and Enviroment, Vol. 57, 2017, p.239.

refineries have also begun to produce low-sulfur HFO and marine gas oil with sulfur content around 0.10%, which complies with IMO regulations in ECA zones.[14]

Another alternative is the installation of Scrubbers, or Exhaust Gas Cleaning Systems (EGCS), which are technologies used on ships to reduce exhaust gas emissions, particularly sulfur oxides (SOx), to meet the emission regulations established by the International Maritime Organization (IMO) under MARPOL Annex VI. This system enables ships to continue using high-sulfur fuel, such as Heavy Fuel Oil (HFO), by cleaning the exhaust gases before they are released into the atmosphere. Using scrubber systems has significantly reduced environmental pollution, particularly by cutting SOx emissions by at least 95% and Particulate Matter (PM) emissions by at least 60%.[15]

Some ship operators consider using Liquefied Natural Gas (LNG) as an alternative fuel. LNG as a marine fuel contributed significantly to reducing pollutants emitted by ships. According to research, LNG has the potential to decrease sulfur oxide (SOx) emissions by nearly 100%, nitrogen oxide (NOx) emissions by up to 76.3%, particulate matter (PM) emissions by 92.9%, and carbon dioxide (CO_2) emissions by up to 25.7% when compared to the use of Heavy Fuel Oil (HFO).[16] This substantial reduction in emissions makes LNG one of the most environmentally friendly fuel options that align with the International Maritime Organization (IMO) regulations on air pollution control from ships.

Nevertheless, implementing LNG as a primary fuel is not without significant challenges, particularly concerning the high capital investment required. Applying LNG on ships demands structural modifications, including installing cryogenic storage tanks, fuel distribution systems, and additional safety equipment to ensure that LNG storage and distribution processes are safe and efficient.

With these various options, the shipping industry faces substantial investment, technology, and operational challenges, especially for developing countries with limited economic and technical capacities. The transition to cleaner energy sources in maritime operations requires the implementation of advancements in technology and infrastructure to comply with the IMO's environmental standards.

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[14] Sundaramurthy Vedachalam, Nathalie Baquerizo, and Ajay K. Dalai, "Review on Impacts of Low Sulfur Regulations on Marine Fuels and Compliance Options.", Fuel, Vol.310, Part A, 2020, p.5.

[15] Suganjar & Kundori, "Pengaruh Pemanfaatan Air Scrubber Dalam Mengurangi Pencemaran Udara Dari Kapal Sesuai Marpol 73/78 Annex VI.", Jurnal Manajemen Riset dan Teknologi Univeristas Karimun (Jurnal MARITIM), Vol. 4, No.1, 2022, p. 74.

[16] Styliani Livaniou, et al., "LNG vs. MDO in Marine Fuel Emissions Tracking." Sustainbility", Vol. 14, No. 7, 2022, p.3.

4. Analysis of Compliance with Maritime Vessel Navigation in ECA Waters

a. Mechanism for Reporting Compliance with ECA

Within the framework of MARPOL Annex VI, the implementation of Emission Control Areas (ECA) is closely linked to efforts to ensure maritime vessels comply with air emission standards, particularly concerning the control of sulfur content in ship fuels. State parties are responsible for establishing these standards, monitoring their implementation, and reporting compliance to the International Maritime Organization (IMO).

One crucial aspect of ECA implementation is the obligation to report compliance with air emission standards for ships.[17] State parties must gather data from inspections of vessels under their jurisdiction, including national-flagged ships and foreign vessels calling at their ports. These reports must include the number of boats inspected, the number of non-compliance cases identified, the types of non-compliance (such as the use of fuel exceeding the sulfur content limit), as well as enforcement actions taken, including administrative sanctions or required corrective measures. These reports must adhere to IMO guidelines, specifically the *Guidelines for Port State Control under MARPOL Annex VI* (MEPC.181(59)), which regulate the format and substance of the reports to ensure consistency across countries. This reporting mechanism aims to ensure transparency, accountability, and consistency in the global application of emission standards, while also providing an accurate overview of vessel compliance levels with regulations in ECA regions.

b. Enforcement of Maritime Vessel Compliance with ECA Regulations

Enforcement of regulations concerning reducing exhaust emissions from maritime vessels, particularly following the implementation of the IMO 2020 regulation, which establishes a maximum sulfur content of 0.50% m/m in ship fuel, is a complex process involving multiple actors within international and national legal systems. Enforcement does not rely on a single country or institution but is a collective responsibility shared between flag states, port states, coastal states, and recognized organizations designated to assist with technical inspections.[18]

[17] Dorota Pyć, "ECA Compliance and Enforcement – Legal Regime for Ships." SHS Web of Conferences, Vol. 58 (01026), 2018, p.3.

[18] Carsten Ørts Hansen, et. al., 2016, "*Navigating ECA-Zones Regulation and Decision-making*". Copenhangen: CBS Maritime, p. 57.

According to Article 217 of the United Nations Convention on the Law of the Sea (UNCLOS), flag states must ensure compliance by vessels under their flag with international regulations set by competent international organizations such as IMO. As such, flag states must ensure that ships under their flag adhere to MARPOL Annex VI's provisions, which focus on preventing air pollution from ships. To fulfill this responsibility, flag states must conduct inspections and surveys of these vessels—when they begin operations and periodically thereafter. The results of these inspections are documented in an official certificate known as the International Air Pollution Prevention Certificate (IAPP Certificate), which proves that the ship complies with the prescribed standards.[19] However, due to resource constraints and the need for specialized expertise, flag states typically delegate these technical tasks to classification societies, which act as recognized organizations. While these tasks can be delegated, the legal responsibility for compliance remains with the flag state. Therefore, the state must also oversee the activities of the recognized organizations through guidelines set out in the IMO Instruments Implementation Code (III Code) and the Code for Recognized Organizations (RO Code).

In addition to the flag state, port states play a vital role in enforcing these regulations. Under Article 218 of UNCLOS, if there is suspicion that a vessel has violated international environmental protection regulations, the port state has the authority to investigate pollutant discharges within its internal waters, territorial sea, or exclusive economic zone (EEZ). Thus, when a foreign vessel docks at a port, the port state authorities have the right and–are encouraged to conduct inspections through the Port State Control (PSC) mechanism. These inspections include verifying the IAPP certificate, checking bunker delivery notes (BDN) to confirm the origin and sulfur content of the fuel used, and documenting the use of scrubber systems if the vessel employs this method to reduce emissions. In some cases, inspections may involve collecting fuel samples for sulfur content testing in a laboratory. Port states may also employ remote sensing technologies, such as sniffers or differential optical absorption spectroscopy (DOAS) sensors mounted on bridges, aircraft, or drones, to detect vessels potentially violating emission limits even before they enter port.[20] If a violation is suspected, the port state may detain the vessel, impose fines, or take legal action following its national regulations.

[19] Leo Čampara, Nermin Hasanspahić, and Srđan Vujičić, "Overview of MARPOL ANNEX VI Regulations for Prevention of Air Pollution from Marine Diesel Engines.", SHS Web Conf, Vol. 58, 2018, p. 3.

[20] Denise Bell Knudsen, 2021, "Is the Shipping Industry Still Sulfuring? A Study of Compliance Factors from the IMO 2020 Sulfur Cap Spring 2021.", Thesis: Departement of Business Law LUND University.

Article 220 of UNCLOS, concerning Enforcement by Coastal States, grants coastal states the authority to monitor vessel compliance with regulations. This article allows coastal states to inspect vessels passing through their territorial waters or exclusive economic zone (EEZ) if there is clear evidence to suspect that the vessel is not complying with international regulations. This applies even if the principle of innocent passage, as defined in Part II, Section 3 of UNCLOS, would generally apply, since this principle can be overridden if there is evidence to support the suspicion of a violation of pollution prevention or reduction regulations.

Enforcement also depends on the availability of low-sulfur fuel (VLSFO) on the market. Port states and fuel suppliers must ensure that the fuel sold to vessels complies with IMO 2020 regulations. In practice, vessels must retain BDN documents for at least three years and perform fuel testing to confirm that the sulfur content and other properties meet safety and environmental standards.

On the other hand, using scrubbers as emission cleaning devices also entails specific legal and technical consequences. Closed-loop scrubbers produce wastewater that must be disposed of safely in port. Therefore, ports must provide adequate reception facilities to accept and treat the wastewater from vessels using scrubbers.

c. Compliance with ECA Regulations at Regional and National Levels

The enforcement of compliance with Emission Control Area (ECA) regulations in maritime regions is governed by an international regulatory framework, which is further strengthened by regional and national laws. At the regional level, the European Union plays a central role in ensuring that emission standards in ECAs, such as in the Baltic Sea and the North Sea, are adhered to by all vessels operating in these areas. This is regulated under Directive (EU) 2016/802, which adopted a maximum sulfur emission limit of 0.10% m/m in the ECA and 0.50% m/m outside the ECA as of January 1, 2020.

The European Union, through Implementing Act 2015/253, establishes an inspection mechanism, which includes verifying fuel delivery documents, testing fuel samples taken from the ship's circulation system, and checking records in the oil record book.[21] Member states must also report inspection results and compliance levels annually to the European Commission, evaluating whether further regulatory tightening is necessary. At the operational level, the European Union emphasizes transparency among fuel suppliers by

[21] Dorota Pyć, *op. cit.,* p.5.

requiring member states to maintain a public register of maritime fuel suppliers and to report the quantity and type of fuel distributed annually. Suppliers who do not meet the sulfur content standards may face administrative penalties.

At the national level, Poland has adopted European Union regulations through the Polish Act on Prevention of Pollution from Ships, first introduced in 1995 and amended several times to align with MARPOL Annex VI and Directive (EU) 2016/802. This law stipulates that both Polish-flagged and foreign ships operating in Polish maritime waters must use fuel with sulfur content that complies with international standards. Alternatively, ships can use emission abatement methods, such as scrubbers or alternative fuels, which produce emissions equivalent to low-sulfur fuels.

Compliance monitoring is carried out by the Director of the Maritime Office, who is authorized to inspect ships. This includes checking fuel delivery documents, taking samples from the ship's fuel circulation system, and verifying fuel changeover operation records. At least 40% of the vessels inspected will have fuel samples taken for sulfur content testing. Additionally, fuel suppliers in Poland must register and report their distribution activities to the Maritime Office annually, including information on the quantity of fuel supplied and its sulfur content.

Poland imposes strict penalties in cases of non-compliance. Shipowners who fail to meet emission standards may be fined up to 1,000,000 SDR (Special Drawing Rights) for pollution in Polish waters and 600,000 SDR for using emission reduction methods without authorization. Fuel suppliers who do not meet the standards may also be fined up to 50,000 SDR. Furthermore, inspection results are reported annually to the President of the Office of Competition and Consumer Protection and the European Commission as part of the annual reporting obligations.

D. Conclusion

Implementing the Emission Control Area (ECA) is a crucial part of global efforts to reduce the harmful effects of air emissions from the maritime sector on human health and the marine environment. The designation of ECA is governed by strict procedures under Annex VI of the MARPOL Convention, which requires comprehensive scientific, technical, environmental, and economic assessments. The application of ECA in regions such as North

America and Europe has proven effective in reducing sulfur dioxide and particulate matter emissions, significantly improving air quality in port cities.

The success of ECA implementation depends not only on regulatory designation but also on the maritime industry's ability to adapt through fuel switching, installation of exhaust gas cleaning systems (scrubbers), and the use of alternative fuels such as Liquefied Natural Gas (LNG), which substantially reduce emissions. However, these technological changes require significant investment and infrastructure development, particularly in developing countries.

Effective enforcement is key to success, with active roles played by flag, port, and coastal states through vessel inspections, document verification, fuel testing, and remote monitoring technologies. Additionally, compliant fuels and adequate port facilities must be ensured to manage waste from scrubber use. National and regional regulatory support, as seen in the European Union and Poland, highlights the importance of legal harmonization and institutional capacity building at the domestic level.

Therefore, strengthening the governance of ECA implementation through regulatory harmonization, infrastructure readiness, and consistent law enforcement is essential to achieving sustainable maritime environmental standards and protecting public health.

E. Suggestion

States are urged to enhance port infrastructure by ensuring consistent availability of low-sulfur fuels and adequate facilities for the management of scrubber waste, thereby facilitating compliance with Emission Control Area (ECA) regulations. In addition, it is imperative to strengthen monitoring and enforcement mechanisms through systematic inspections, rigorous document verification, and regular fuel testing, conducted consistently by flag states, port states, and coastal states. Such measures are vital to guarantee the effective and sustainable implementation of ECAs, ultimately safeguarding environmental integrity and public health.

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