ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2523-5664 (Print)
ISSN: 2523-5672 (Online)
CODEN: WCMABD

Water Conservation & Management (WCM)

DOI: http://doi.org/10.26480/wcm.02.2021.114.120

CrossMark

RESEARCH ARTICLE

A STUDY ON LEGAL POLICIES AND SOLUTIONS FOR SHIP BALLAST WATER TREATMENT

Nguyen Viet Linh Le[a], Dinh Tuyen Nguyen[b,*], Abdel Rahman M. Al-Tawaha[c], Dinh Tung Vo[d,*]

[a] Faculty of Automobile Technology, Van Lang University, Ho Chi Minh City, Vietnam.
[b] PATET Research Group, Ho Chi Minh City University of Transport, Ho Chi Minh city, Vietnam.
[c] Department of Biological Sciences, Al-Hussein Bin Talal University, Maan, Jordan.
[d] Institute of Engineering, HUTECH University, Ho Chi Minh city, Vietnam.
**Corresponding author email: dinhtuyen.nguyen@ut.edu.vn; vd.tung@hutech.edu.vn*

ARTICLE DETAILS

Article History:

Received 02 October 2021
Accepted 20 November 2021
Available online 30 November 2021

ABSTRACT

Shipping plays a very important role in the movement of most goods in the world. Ships are a means of transport used to transport goods at sea. Every day, there are many ships moving back and forth between different seas at a high frequency. Each ship's voyage can be full, low-load, or no-load. Using ballast water is a long-standing solution used to balance and stabilize ships during voyages. Ballast water is taken into the ship and discharged anywhere in the sea. This means that the organisms in the ballast water can also migrate to any part of the sea. There are beneficial organisms and harmful organisms for the ecosystem in the waters they are brought in. Organisms that grow unprofitably will destroy the stable ecology of the seas they reach. To solve this problem, it is necessary to have appropriate legal policies and solutions to treat ballast water. This short review presents current regulatory policies and solutions for ballast water treatment. Some challenges and prospects for future regulatory policies and solutions for ballast water treatment are also outlined.

KEYWORDS

Ballast water, treatment, IMO policy, sea enviroment

1. INTRODUCTION

Nowadays, marine transportation plays an important role in the global goods trade (Suarez-Aleman, 2015; Park et al., 2021; Ghaderi, 2019). Global freight activities is witnessing a bustling and development, especially, 80% of the all goods trade is conducted by maritime transport. In order to serve this development, there have been numerous shipping companies and fleets of countries around the world to be established. Therefore, the demand for fuel is strongly rising. The emission from the diesel engines is usually released directly into the air or water consequently causing environmental pollution (Pham, 2018; Chau et al., 2020; Cao et al., 2020; Pham et al., 2018; Tabatabaei and Aghbashlo, 2020; Hoang, 2018; Duoang and Huynh, 2021; Hoang et al., 2017; Truong and Le, 2021; Nizetic and Rowinski, 2021). Many studies carried out to find the solution for this problem can be mentioned as seeking for a potential alternative fuel, upgrading the productivity of diesel engines by different methods, solutions for sustainable emission reduction, advanced technology applications, and theoretical study solutions on fluid flows related to vessel movement (Hoang, 2021; Atarod, 2021; Nguyen and Duong, 2020; Nguyen and Hoang, 2020; Le et al., 2020; Hoang, 2021; Olcer et al., 2021; Hoang, 2018; Ganesana et al., 2022; Hoang and Pham, 2021; Bui et al., 2021; Pham, 2020; Pham, 2019; Le et al., 2020; Nayak et al., 2022; Hoang, 2020; Hoang and Pham, 2020; Do and Nguyen, 2020; Do et al., 2020; Nguyen, 2020). Parallel with that, many giant cargo ships have been designing to adapt the great demand for global trade (Peters, 2001; Prokopowicz and Berg-Andreassen, 2016; Tillig and Ringsberg, 2020).

However, unsustainability, imbalance and direct negative impact on the maritime environment are its consequence. The pollution of the marine environment is increasing and the major emission at sea is come from marine transport. Emissions, oil spills, heavy metals and cargo are sources of pollution from ships. This issue also poses great challenges to the safety of the environment. Exhaust gases such as CO2, NOx, etc. have a negative impact on the air environment. In the current CoVid-19 period, the decline of these gases can be clearly seen, many studies show that the air environment becomes cleaner (Nguyen, 2021; Olcer and Huynh, 2021; Aktar et al., 2021; Huynh and Nguyen, 2021). In addition, intelligent control strategies to effectively reduce hydrocarbon and carbon monoxide emissions on diesel engines also significantly reduce harmful emissions emitted from ships (Vinayagam, 2021; Ravi and Pachamuthu, 2020). Ballast water is also a emission source from vessels, influence directly the sea ecosystem. To ensure the stability of a ship, depends on carried cargo, the ballast water can be intaken or discharged. The ship's ballast water may contain oil from an oil spill or leak from the ship's storage spaces.

This problem is solved by different technological solutions such as using different types of absorbing materials, devices using absorbent materials, etc (Duong and Huynh, 2021; Phan et al., 2018; Holley et al., 2021; Nizetic and Rowinski, 2021). Currently, the impact of the Covid-19 pandemic makes the global energy system change in the use of renewable energy and bioenergy, which also significantly reduces environmental pollution (Olcer et al., 2021; Chen, 2021; Le et al., 2021; Huynh, 2021; Pham and Nguyen, 2021). In addition, organisms in ballast water can be moved from a place to other places. When the discharge take place outside the organisms' native range, it is potential for the establishion and invasion of the non native species. According to some study, worldwide commercial shipping contribute to travel more than 50% of all marine invasive species, and ballast water is estimated to transport around 10,000 species (Molnar

Quick Response Code	Access this article online	
	Website: www.watconman.org	**DOI:** 10.26480/wcm.02.2021.114.120

Cite The Article: Nguyen Viet Linh Le, Dinh Tuyen Nguyen, Abdel Rahman M. Al-Tawaha, Dinh Tung Vo (2021). A Study on Legal Policies and Solutions For Ship Ballast Water Treatment. *Water Conservation & Management, 5(2): 114-120.*

et al., 2008; Saebi et al., 2020; Bax et al., 2003). Variety of investigation indicate that invasive species have negative effects on the environment, economic activities as well as health of people (Ruiz and Carlton, 2003; Chan, 2019; Lovell et al., 2006; Wan et al., 2016; Wan et al., 2018; David et al., 2019). Ballast water can also contain heavy metals and non-biodegradable waste such as plastic waste (Hoang et al., 2021; Pham, 2021). When released into the environment, it also seriously affects the marine ecosystem, there have been many studies to solve this problem (Upadhyay et al., 2021; Truong, 2020; Bai, 2019).

In practice, ballast water is used in almost all of vessels even bulk cargo carriers or oil tanker to ensure integrity if structure and to stable the ships as loading or unloading carried cargo at ports, see Figure 1. Ballast water is get at a marine region that contains various biological material, such as plants, viruses microorganism, and bacteria, after that may be moved to at different sea region. The travel of these biological material may damage aquatic ecology in large scale at new coastal regions, that impact economy of aquatic industry (Drillet, 2016; Lett, 2008; Hadiyanto, 2022; Hoang, 2022). The usage of sea water as ballast water can make them stability when the vessels move around the oceans (Chitsomboon and Koonsrisook, 2021; Hadiyanto, 2021). Intaking and discharging seawater for ensuring stability and maneuverability of ships in loading and unloading operations is called Ballast water (Singh, 2016). Ballast water is necessary for the safty of vessel operation on the sea but they are not good to environment of oceans. The hull stress due to adverse sea conditions or changes in the weight of cargo, fuel and water can be recduced by managing ballast water.

BWM Convention 2004 defines Ballast water as that "water with its suspended matter taken on board a ship to control trim, list, draught, stability or stresses of the ship." In addition, the definition of "Sediments" in Article 1 (11) of the BWM Convention (2004), is "matter settled out of ballast water within a ship". To put it simply, sediment is the suspended matter in ballast water that cause formation of solid and precipitation. Generally known as ballast water. Pathogens, harmful algae blooms as well as Non-Indigenous Species (NIS) introduction are mainly caused by discharging Ballast water (Lakshmi et al., 2021; Aguirre-Macedo et al., 2008; Drake and Lodge, 2004; Hallegraeff, 2007). In February 2004, The International Maritime Organization adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (referred after as "BWM Convention") for an effort of reducing environmental concerns, and influence of these introductions on human health as well as socioeconomic (IMO, 2004). The BWM Convention is applied after a minimum of 30 States symbolizing 35% of world merchant shipping tonnage ratification (IMO, 2016). Management of ballast water in commercial harbors is a challenge of the BWM Convention, for example, controlling the whole biodiversity that is discharged with ballast water to prevent and control Harmful Aquatic Organisms and Pathogens (HAOP) in the ports, along with monitoring presence of HAOP.

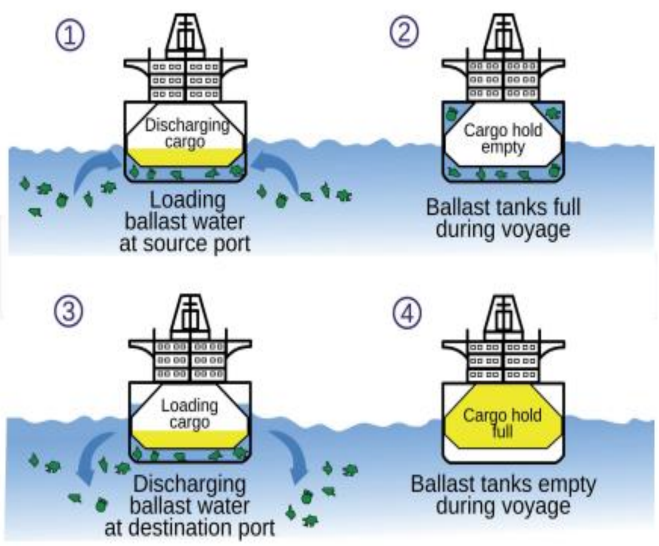

Figure 1: Ballasting and discharging of ships (Lakshmi et al., 2021).

According to some reports, in the ballast tanks, there are several marine organisms like comb jelly fish, European green crabs, mussels, whelks, chinese mitten crabs, holoplankton, American jack knife clam, and vibrio cholera can survive in the extrem conditions. They can adapt different environment that may disrupt the quality of water eco-system at the respective harbor. Planktons, microbes, and pathogens are able to survive in the ballas system in long voyages, till the voyage complete, that was firstly indentified in 1897 (Gollasch, 2000). In 1904, the existence of the Asian phytoplankton algae Odontella in the North Sea was found by scientist to recogize the evident of the invasive species (T.U.N.N.F.F.P, 2012). The increasing consciousness of protecting and conserving ecosystem leads to a conference on Human Environment that was held by United Nations in 1972, that emphasize how safeguarding the sources and environment is important. In 1973, an International convention for preventing pollution caused by ships operation and marine accident.

Due to variety of serious tanker leakages between 1976 and 1977, in 1978, this protocol was adopted definitely. The MARPOL was firstly use to categorize management of the ballast water and sediment, but then, IMO considered it as a separate category. With mentioned impacts, there is no doubt that vessels are the most polluted factors and directly effect the ocean environment. Among the polluted factors related with vessel, ballast water is judged one of the most bearing reasons. Although experts have discovered the effect of ballast water since the 19th century, however, the lack of concern about the ocean environment as well as the rapid development in all aspects of human race make the marine pollution even worse. Back to the current situation, with the explosive growth in the amount of global commodity exchange and ocean transport still plays an important role in the circle, the pollution problem is getting worse and deal huge damage to the ocean ecosystem. Therefore, this paper will indicate and emphasize the most dangerous effects of ballast water and provide solutions to reduce the impact of ballast water based on earlier published works.

2. Effects of Ballast Water on The Marine Environment

2.1 Displacement and aggression in the marine environment

On the way to conquer every corner of the world, human being has many times accidentally or intentionally affected the natural habitat. Sea voyages which cause the ballast water displacement are one of them. The vessel travel to different places and carry ballast water from the coastal and all the living organisms in its. By that way, these organisms are tranfered into a new ideal habitat where the natural environment is still suitable for them, but all the natural enemies are missing. And in consequence, these exotic species expand madly and start to invade as well as disorder the habitat. The unexpected development of these invaders is a kind of "biological pollution". The exotic species attack the habitat by seizing food and space from native species, reshape the enviroment habitat, food chain and of course the whole ecosystem. Threating the imbalance in the current ecosystem, the whole progress cause huge damage to new habitat, narrow the local biodiversity and usually end up with the existinction of one or many local species include both animals as well as plants (Raj, 2014). Many researchs are carried out to solve this problem but there is no potential way to regenerate the equilibrium in ecosystem until now. Moreover, the ballest water displacement not only causing negative effects on the environment, but also to the economy in general through affecting navigation security, agriculture, and aquaculture.

The ballast water is acknowledged as one of the key factors responsible for the expand of the invasive exotic genus (Carlton, 1999). Each day, ballast water globally conveys approximately 7000 to 10000 various aquatic species include microbes, plants, and animals according to statistic. Experts estimate that new exotic genus can appoach to the ecosystem every 9 weeks. Globally and anually, the economy is injured nearly ten bilions US dollars because of this biological pollution (Marbuah et al., 2014). Furthermore, the progress also harms human health by increasing allergy ratio and outbreaking cholera etc**.** Thanks to the BWM Convention, some researchers collect data of ship traffic excutive in the Adriatic Sea from 2012 to 2015 and detect that approximately 22% of 39442 vessel circle had released more than 8.4 milion cubic meters of ballast water (Rak et al., 2019). 70% of the discharged ballast water is from Adriatic, 25% is from Mediterranean Sea and the 5% remaining is from other places of the world (David et al., 2016). Inspect the environment where the releases happen, accesible data reveals the existence of HAOP predominantly on the existence of NIS. 56% of the NIS have been tracked are created and start to extend in the Mediterraneean Sea (UNEP/MAP-Plan Bleu, 2009; UNEP/MAP-Plan Bleu, 2015). In 2012, it is reported that there are about 986 genus of NIS in Mediterraneean Sea and 190 of them are recorded the presence in Adriatic Sea (Klaoudatos and Kapiris, 2014). A researchers found out that there are more than 50 new NIS were documented in the Adriatic Sea since 2000, most of it occur in the north of the basin (Zenetos, 2012). In seperative research, a group researchers also indicated that ballast waters released by tanker vessels are mainly responsible for the metal contamination of the released areas and transform the chemical ingredients strongly and long last in unexpected way (Dobaradaran et al., 2018). Whereby, the content of Cd (4 samples) and Hg (14 samples) are respectively 11.76% and 41.18% higher in concentration level in comparision with the normal water level of EU estuary and harbor basin. The data is taken on Bushehr port in the region of the Persian Gulf.

2.2 Effects on sustainable economy

The progress is usually considered as a domino effects. The exotic invasive genus directly deals huge damage to the economy as mentioned above. The outcome of negative effects on different occupation such as fisheries, aquaculture, and tourism are the decrease in economic output and even other indirect results such as human health. A case study in Black Sea, an invasive species is responsible for the decline of a local fishery and costs millions of dollars loss a year (Shalovenkov, 2019). In Turkey, the harmful algal blooms cause the negative impacts on the aquaculture, which also strongly effect the economy. In 1989, it is estimated that about 1 billion tons of fish eggs and larvae was consumed by the biomass of Mnemiopsis leidyi as well as the zooplankton that commercially important fish indicate the huge crash of invasive exotic organism. In 1992, the estimated annual losses from the decrease of commercial catches were at least 240 milion US$ (IMO 2010).

2.3 Effects on human

Ecologists found a direct relationship between ship ballast water pollution and human disease outbreaks. Ballast water has posed a hazard to coastal ecosystems and human health in a number of nations (Feng et al., 2015). According to Seiden and Rivkin [91], environmental and human health would be affected by microzooplankton grazing which was moved via ballast water (Seiden and Rivkin, 2014). A group researchers offered risk assessment research for exemptions that were utilized to intra-Baltic shipping, and the authors concluded that credible species data at the ports under consideration are not accessible to them (David et al., 2013). In accordance with the precautionary principle, no exceptions should be given under any applicable laws or regulations. There have been many cholera outbreaks that have been connected to ballast water. An indication of this was the outbreak that began in three Peruvian ports in 1991 and divided across South America. In 1994, a microbial strain via ballast water affected more than one million individuals and claimed the lives of more than 10,000 people. The strain has only ever been discovered in Bangladesh, and this is the first time (Kim, 2013; Pham, 2018).

Many research have been conducted to determine the impact of treated ballast water on people's health. The environmental risk assessment was done implementation, data was collected at 2 ports of Koper in Slovenia and Port of Hamburg, Germany (David et al., 2018). A group researchers published their study, they utilized the same raw data but they assessed the hazards to human health in their new publication (Dock et al., 2019; David et al., 2018). The approach has been taken into consideration in this investigation (IMO, 2017). In the research specified compounds have the biggest contribution to the accumulated exposure of people (bromate, tribromomethane, and isocyanuric acid). Additionally, the health implications of ballast water on the employees on board the ship who come into close contact with it are mentioned in this article (Dock et al., 2019).

3. Ballast Water Treatment Solutions

With all the harmful impact mentioned above, many treatments are urgently studied to solve the pollution generated by ballast water. In reality, many single treatments can combine to achieve the best solution. During designing of new vessel, a group researchers performed treatment systems that combine both physical and chemical technique to face the ballast water problem (Lakshmi et al., 2021). The treatment systems are suitable for industrial and metropolitan applications. Studies show that with the existence of different species on the ecosystem, there are dissimilar suitable combination of treatment respectively. By observation and analysis, the combination between mechanical treatment with filtration is the most productive treatment for different living organism as well as different physical and chemical conditions in the ballast tank. Some extreme effective combined methods that discovered can 100% remove organisms such as zooplanktons and bacteria are filtration and magnetic separation; filtration and gravity separation; Ultrasound technology, Electrochemical and ozone treatment. Besides, another fultration method based on radical treatment has been proved to be the most cost effective, energy and power saving method, also has the ability to remove 100% of organisms. However, to make the ballast water achieve D-2 standard, further researchs has been studied to generate a better technology. See the standard procedure in ballast water treatment in Figure 2.

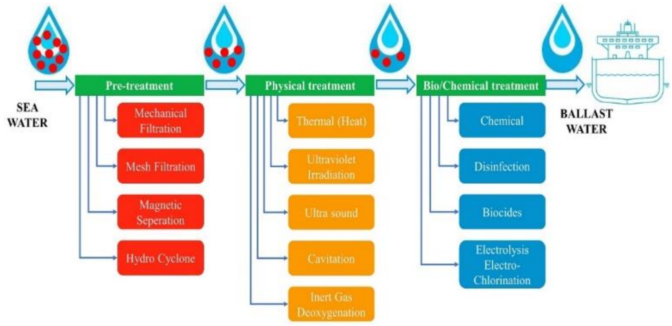

Figure 2: Standard procedure in ballast water treatment

A group researchers upgraded a software that integrates decision support tools and can modify system as well (Etemad et al., 2022). The Ballast Water Information System (BWIS) is developed to allow continuous application of best-available science to assist daily ballast water implement activities and scientific study in Canada. The BWIS improve the ability of accessing ballast water record data, assist data operation and provide the best solution through an online program. For the last 15 years, BWIS allows regulators and scientists to approach effectively connected ballast water data management at the same time reduces daily workloads as well as provide more reliable data to serve scientific researchs. The methods to release the sediments collected at factories are restricted by article 5 of the BWM convention. The discharge of these sediments is to eliminate the transfer of unexpected organism into marine environment.

Hence, it refers to filter potential harmful biological organism from the sediments or move the sendiments to a managed area that lack of ability to spread out unwanted organism. Also following B-5 regulation of the Convention, management plans of the ballast tank sediment are demonstrated clearly in overall BWMP of the vessel. Management plans are only relevant when vessel is in recognized vessel repair yards. Throughout usual ballasting and de-ballasting activities, it is not essential to carry out any treatment or discharge of ballast tank sediment although sediment de-ballasting may happen during ocean BW trade-off as suggested (Prange, 2013). The convention asks the BW to be trade at sea, at least 200 nautical miles from the coast and at least 200 m of water depth. Besides, the convention also asks EU Member States to recognize reception station for treating or removing sediment for ballast tank, but it does not necessary to construct reception area for BW. In seperated research, Renato published The Shore Based Treatment System (Ivce et al., 2021).

This system also contributes a well control of ballast water method and support to develop the Ballast Water Management. Hristos Karahalios also suggested the methodogy which is followed by expert evaluation, optimized the BWTS solution for vessel operator (Karahalios, 2017). Play an important part in the study methodology, the combination of the TOPSIS and the Analytic Hierarchy Process (AHP) creates a tool to control cost-benefit which help the vessel operators in making decision. In this paper, a case study is presented, indicating the potentials of the methodology as well as anlyzing option for the Ballast Water Treatment Systems for vessel, trading in the USA. In this paper, a case study is carried out, showing the potentials of the methodology and evaluating the choice of the Ballast Water Treatment Systems for ships, trading in the USA. Also according to this study, the author believes that the marine industry wasn’t ready to begin enforcing the Ballast Water Management Convention yet. However, despite the convention's efforts to protect the marine environment, the solutions have yet to be firmly accepted by the United States government. The IMO's legitimacy might be further challenged if it takes unilateral action. Ship operators may have a difficult time meeting regulatory requirements if they do business as usual.

4. Some Policies for Ballast Water Treatment

In addition to ballast water treatment measures as short-term treatment tactics, management policy strategies to reduce ballast water emissions are seen as long-term measures for this situation. A group researchers built scenario and calculated risk by using a higher-order analysis of patterns of the global spread of ship-borne species and estimating the cost for ballast water treatment system of fleets (Wang et al., 2021). The authors found that tougher criteria might lower the danger of species transmission by a coefficient of 17 worldwide and considerably simplify the complicated network of shipborne species spread if they are implemented. Also, according to the authors, an increasing number of states are enacting nationally strict rules for the environment, which is nothing new in the marine sector. Although the International Maritime

Organization (IMO) has issued laws aimed at improving worldwide management efficiency and developing a framework for allocating costs in this respect, however, the IMO Convention did not permit the treatment of ballast water in ports (including barges) to be mandated.

The problem of treating ballast water at the port was transferred to the countries with seaports. Therefore, the harmony between port countries in this problem was very important. IMO ratified the BWM Convention in 2004 and the Convention met the conditions to enter into force in 2017. The Convention consists of two parts: the Article and the Annex. According to the provisions of the BWM Convention 2004, from September 8, 2017, all new ships must be equipped with a ballast water management system (Standard D2). Ships built before this date can comply with the Convention by performing a ballast water exchange (Standard D1) or can be fitted with a ballast water management system if desired. However, ships built before September 8, 2017 must be equipped with a ballast water management system (Standard D2) after the first renewal inspection of the IOPP certificate after September 8, 2019. By September 8, 2024, all ships must use a ballast water management system (Standard D2). Ship documents must be available from September 8, 2017: ballast water management plan; ballast water log; and international certificate of ballast water management (vessels > 400GT). See timeline according Conventions BWS at Figure 3.

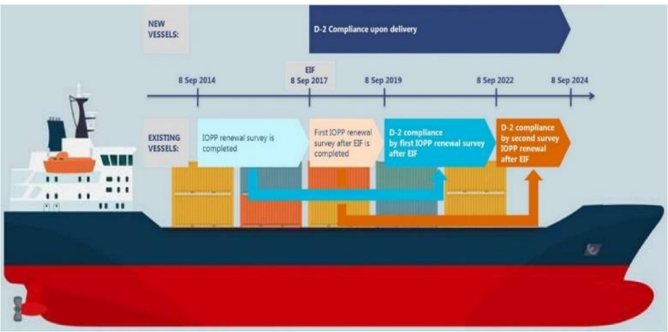

Figure 3: Illustrated according Conventions BWS (Gard, 2018)

In 2020, a group researhcers discussed about shipping expenses could rise because of the new global ballast water restrictions policies designed to reduce the spread of aquatic organisms (Wang et al., 2020). In this research, the solution of integrated shipping cost and global economic modeling approach was used by the authors to investigate the affection of ballast water rules on bilateral commerce, country economies. There were 2 scenarios of ballast water treatment policy that were built by researchers, A script was built according to current international regulations, and B script was built based on harsher regional policies that might target ships to and from the United States. The result of the article demonstrated that compliance expenses for ballast water management lead to small negative effects on international commerce and national economies in general in both situations. However, the damage of scenario B will be greater if placed in bilateral trade with a specific commodity. Another research has introduced a policy to regulate ballast water treatment methods in the market (Top et al., 2021).

All policies are based on standard D-2 of the Ballast Water Management Convention. The purpose of this research was to determine the parameters utilized by Turkish shipowners when selecting ballast water treatment systems depending on the ship's voyage region. The introduction and clarification of such a policy were necessary for ship owners, to enable them to be more proactive in choosing ballast water treatment technology as well as to have a choice base based on the shipping route of the ship vehicle. Regarding the seaport, a strategy model for adopting Ballast Water Management (BWM) for inland and international merchant vessels in Tanjung Emas Semarang (PTES) waters was designed by Agus Tjahjono and Wisnu Handoko (Tjahjono and Handoko, 2018). In the development of this strategy, random sampling was employed to choose the research samples. Data were gathered via the utilize of questionnaires and interviews, both of which were used. The SWOT matrix analysis was then used to determine the strategy's parameters.

The Tanjung Emas HMPAO (Tanjung Emas Harbour Master and Port Authority Office) implemented a protective approach in this case. This plan focused on strengthening fines and Port State Control (PSC). To guarantee ship stability, the port authority also recommended that ballast tanks be filled with fresh water instead of seawater. Moreover, Pelindo III factory has been accepted as a ballast water treatment station by the port administrator. This company is licensed to treat ballast water for bulk and tanker ships. The proposed policies require all shipping vehicles to have a ballast water treatment system in accordance with the D-2 standard of the BWM Convention. But for each different country, different routes, ship owners always want to choose the least expensive technology but still meet the requirements of the convention. The role and influence of ballast water on each area is also different, therefore, it is still difficult to make policies based on common conventions. The ability to enforce these conventions in some countries is still poor, especially in developing countries.

The situation is stated through research paper. Therefore, in order to be able to complete and easily apply the activities of shipping under the BWM Convention, countries should come up with a specific policy of each country, corresponding to each region based on the BWM Convention (Mohd Zaideen, 2019). This will help maritime countries in the world can both comply with international regulations and also have their own development policies adapted to the country. Enables efficient ballast water treatment without too much impact on existing transport models. The cost of handling is also a big difficulty, however, according to the current trend of sustainable development, ship owners are also required to be more responsible for international waters and ports. This is a remarkable thing in the current development process that affects the environment. Regulatory policy and solutions for ballast water treatment have always been an open issue for regulators, researchers, and environmentalists. Different policies and solutions for ballast water treatment have been discussed in this paper.

However, each different policy and solution brings with it both advantages and disadvantages when placed in the technical-environmental-economic relationship. The rapid development of industries in the world makes the environment increasingly polluted. In particular, ballast water from the maritime industry also has a great impact on the environment. Legal policies are introduced with the goal of controlling ballast water for all ships in the world, thereby ensuring that ballast water from ships does not affect the environment. Achieving this also means that maritime organizations and governments must act decisively. The introduction of the WBM convention in 2004 and the official entry into force of the convention in 2017 have provided clear regulations on ballast and ballast water treatment with universal uniformity.

More stringent regulations are needed for ballast and ballast handling, with the goal of having ballast water from ships not have a negative impact on the environment. However, these regulations will face a reaction from ship owners because they can raise the cost of ship operation, which means the profit of the ship owner will decrease. Along with updating and supplementing appropriate legal policies, there is also a need for more research related to ballast water treatment technologies. Ballast water treatment will directly deal with invasive organisms, harmful chemicals, and bad actors in it. The solution is good, the ballast water of ships clean, and the environment will not be negatively affected. However, today's treatment technologies still have many limitations, such as high cost, existence of toxic chemicals, etc. It is necessary to find solutions so that ships do not need to use ballast water while still ensuring buoyancy and stability in operation.

5. Conclusion

Legal policy specifically regulates ballast-related issues, ballast water treatment and other issues, helping ship owners to be proactive in complying with regulations. Ballast water treatment solutions provide technical as well as other issues for the design and production of ballast water treatment equipment to suit the characteristics of ships. Legal policy and solutions for ballast water work together to effectively address the problem of ballast water treatment. The International Convention on the Control and Management of Ships' Ballast Water and Sediments, in force, sets forth the basic provisions for ballast management and treatment of ballast water for ships worldwide. However, it is still necessary to have more specific regulations and regularly amend and supplement them to suit different sea areas. Ballast water treatment solutions play a very important role in helping to reduce the negative impact of ballast water on the environment. The treatment of ballast water requires limited or no use of chemicals. This helps to avoid the existence of harmful chemicals in the environment after ballast water treatment. In addition, more research is needed to ensure that ships without ballast water can still ensure balance and stability during operation.

Acknowledgement

The authors would like to thank Van Lang University, Vietnam for funding this work. Also, the authors would like to thank HUTECH University and Ho Chi Minh City University of Transport for supporting this work.

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