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Modification of Ballast Filtering Device on John Lie Training Ship to Prevent Marine Pollution

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Abstract

This study aims to present appropriate selection methods for evaluation, analysis, and comparison between different ballast water treatment technology systems in order to make good decisions in selecting the most optimal treatment system. This research designed a ballast water filter device on the John Lie training ship to prevent marine pollution due to species movement through the ballast water transfer process by referring to the D2 standard of the IMO Ballast Water Management Convention. During the ballasting process, ballast water contains thousands of species of marine animals and plants that are carried in ballast tanks, causing problems for the marine environment and human health. The modification of the filtration tool designed by the researcher used a 0,1 mm and 0,01 mm net tied to the ballast tank inlet pipe using a clamp on the ballast pipe of the John Lie training ship. This can fully be used during the process of filling ballast water from port seawater to enter the ballast tank through this filtration system. The results shown after passing the filter with a total plate count of 36 microorganisms indicate that the filtration system designed by the researcher can meet the D2 standard of the IMO BWM Convention Regulation.

Keywords: Ballast air; ballast filtering; marine pollution.

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1. Introduction

All new ships built after 2017 must be equipped with ballast water management systems (Standard D2). The ships built after 8 September 2017 may comply with the Convention by implementing ballast water exchange (Standard D1) or complete ballast water management systems if desired (Minh Quang Chau *et al.*, 2020). However, ship built before September 8, 2017, must be converted to ballast water management system (Standard D2) after the first renewal check of the IOPP certificate after September 8, 2019. No later than September 8, 2024, all ships are required to use a ballast water management system (D2) (Čampara et al., 2019; Hyun et al., 2021).

D1 standard of the IMO Ballast Water Management Convention stated that each ship must replace at least 95% of ballast water (Ivce *et al.*, 2021). If ballast water exchange is carried out by pumping through a ballast chamber, then the ballast water mass must be pumped through each ballast chamber at least three times (Hoang *et al.*, 2021). Since ballast water exchange at the sea depends on weather and sea conditions, so ballast water exchange is not always possible (Baroiu *et al.*, 2021). Furthermore, this exchange has the potential for marine species to keep in the water and can still be dangerous if the ship dries up near coast, especially if its hull is clogged with mud (Tuan Hoang &; Viet Pham, 2021). Ballast water exchange can also worsen the balance and stability of the ship (Buana et al., 2022; Chen et al., 2023; Hyun et al., 2021).

It is estimated that there are thousands of species in ballast water carried by ships, such as bacteria, jellyfish, larvae, animal eggs, as well as planktonic forms of larger animals. These small-sized animals commonly die during the journey due to the ballast process and the environment within the ballast tank (Ellyzabeth Sukmawati et al., 2022; Jang et al.,

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2020; Lee et al., 2017). Nevertheless, there are also species that survive and manage to escape at the time of discharge into the sea. This can endanger the marine environment's life, change the marine ecosystem, and disrupt the sustainability of coastal resource utilization. The movement of marine species due to the discharge of ballast water carried by ships from one place to another can cause the emergence of foreign marine species that are dangerous to the environment (Hess-Erga et al., 2019). This can also have an impact on the imbalance of marine ecosystems and adversely affect the marine life development (Bailey et al., 2022). The impact of the foreign species development at sea by the IMO is considered more difficult to overcome than the impact of pollution due to oil spills and has become a global problem that requires more serious attention from the entire world maritime community (Bradie et al., 2023; Casas-Monroy & Bailey, 2021; Čulin & Mustać, 2015).

The implementation of the Ballast Water Wastewater Management Convention will not only minimize the risk of invasive foreign/alien species entering the sea through ballast wastewater, but also requires the establishment of clear and strict waste management standards (Drake, 2015). Ballast water exchange at sea is not considered an ideal ballast water management method, so the efforts are focused on developing methods for treating ballast water (Goldsmit et al., 2019; Hasanspahić et al., 2022). In this situation, this method must meet the D2 standard of the IMO Ballast Water Management Convention (Drake, 2015; Ivce et al., 2021; Olenin et al., 2016).

This study aims to present appropriate selection methods for evaluation, analysis, and comparison between different ballast water treatment technology systems in order to make good decisions in selecting the most optimal treatment system.

2. Reseaech Methodology

This research designed a ballast water filter device on the John Lie training ship to prevent marine pollution due to species movement through the ballast water transfer process by referring to the D2 standard of the IMO Ballast Water Management Convention. This research was carried out on the Jon Lie Training Ship which was anchored at Amurang Port for six months. Ballast water sampling was carried out 4 (four) times, namely seawater sampling before being sucked into the ballast pipes, seawater sampling after passing through the pipe and filtered with filter modifications made, seawater sampling remain/attached to modified filter, and seawater sampling when ballast water has been discharged back into the sea at Amurang Port. Ballast water sampling 4 (four) times used plaquenet. This research employed the services of Water Laboratory Nusantara (WLN) and the Center for Standardization and Industrial Services (BSPJI) Manado City to identify seawater sampling results.

3. Result and Discussion

Seawater test results around Amurang Port. Seawater tested in the laboratory measuring 100 ml/8 m^3, the output is as follows:

Table 1. Seawater Samples before Passing Ballasting Pipes of WLN Manado Results

No.	Microorganism	UoM	Result	D2 Standard	Ballast Water Tank	Result
1.	Total Plate Count	CFU/mL	1080	10/m^3	8 m^3	NOT PASS

Source: Processed by the Researcher (2023)

From the laboratory tests results tested at the Nusantara Water Laboratory (WLN) Manado, a total plate count of the number of microorganisms was found in seawater samples before passing the ballast pipe of the John Lie training ship around Amurang Port in seawater samples measuring 100 ml/8 m^3, which was found as many as 1080 total plate count microorganisms. So, seawater at Amurang Port before being pumped into the tank of the John Lie training ship had not passed based on the D2 standard Water Management Convention is ten organisms 10/m 3 where it is known that the John Lie training ship has a number of 10 ballast tanks with the size of each ballast tank is 8/m^3 tank which means that the standard passes with the size of the ballast tank of the John Lie training ship is 80 total plate count of microorganisms in the ballast water according to the capacity of each ballast water tank of the John Lie training ship. The test results found 1080 total plate count microorganisms are pure total organisms that live in seawater around Amurang Port.

As for the outputs can be seen as follows:

Table 2. Seawater Samples After Passing Ballasting Pipes of WLN Manado Result

No.	Microorganism	UoM	Result	D2 Standard	Ballast Water Tank	Result
1.	Total Plate Count	CFU/mL	36	$10/m^3$	$8\ m^3$	PASS

Source: Processed by the Researcher (2023)

Based on the test results of laboratory tested at the Nusantara Water Laboratory (WLN) Manado, a total plate count of the number of microorganisms in seawater samples was found after passing through a filter made by researchers tied to the inlet pipe of the John Lie training ship ballast tank around Amurang Port in seawater samples measuring 100 ml/8 m^3, which was found as many as 36 total plate counts of microorganisms. So, seawater in the ballast tank after passing a filter made by researchers and entering the ballast tank passed the results based on the D2 Water Management Convention standard, which are ten organisms $10/m^3$ is known that the size of the ballast tank on the John Lie training ship has a size of 8 m^3. It means that the standard passes with the size of the ballast tank of the John Lie training ship, which is 80 total plate count of microorganisms in the ballast water according to the capacity of each ballast water tank of the John Lie training ship. In other words, seawater in the ballast tank after passing pipes and filtered made by researchers on the John Lie Training Ship has passed the D2 standard from the IMO BWM Convention Regulation.

After the second stage test, researchers tested seawater around Amurang Port after passing the Ballasting Pipe, filtered, and left the rest on the filtering filter made by researchers tied to the ballast tank inlet pipe of the John Lie Training Ship. Seawater tested in the laboratory measuring 100 ml/8 m^3 output is as follows:

Table 3. Seawater Samples Remaining/Residual in the Filtration Filter

No.	Microorganism	UoM	Result	D2 Standard	Ballast Water Tank	Result
1.	Total Plate Count	CFU/mL	930	$10/m^3$	$8\ m^3$	NOT PASS

Source: Processed Researchers (2023)

Based on the test results of laboratory tested at the Nusantara Water Laboratory (WLN) Manado, a total plate count of the number of microorganisms in seawater samples was found to be left residual in the filter made by researchers tied to the inlet pipe of the ballast tank of the John Lie training ship around Amurang Port in seawater samples measuring 100 ml/8 m^3, which found as many as 930 total plate counts of microorganisms. In other words, the filter made by this researcher is able to filter out microorganisms that will enter the ballast tank from 1080 total plate count before passing through the filter until getting 36 total plate count after going through the filter filer on the ballast water that enters the ballast tank of the John Lie training ship.

After the third stage test, the researchers tested seawater around Amurang Port in the final stage, namely seawater after passing through ballast pipes and being discharged back into the sea. The output seawater tested in the laboratory measuring 100 ml/8 m^3 is as follows:

Table 4. Seawater Samples After Passing Ballast Pipes and Thrown Back into the Sea

No.	Microorganism	UoM	Result	D2 Standard	Ballast Water Tank	Result
1.	Total Plate Count	CFU/mL	650	$10/m^3$	$8\ m^3$	NOT PASS

Source: Processed by the Researcher (2023)

Based on the test results of laboratory tested at the Nusantara Water Laboratory (WLN) Manado, a total plate count of the number of microorganisms was found in seawater samples after passing through the ballast pipe and being thrown back into the sea in seawater samples measuring 100 ml/8 m^3, which was found as many as 650 total plate counts of microorganisms. Seawater contained in the ballast tank with the number 36 total plate count of microorganisms after passing through the ballast pipe the process of thrown back into the sea without filter filters with the number of total plate count microorganisms increased to 650 total plate count thrown back into the sea.

Sample testing in this study was carried out in four stages, namely:

1) Seawater sampling before passing a filter on the ballasting pipe

2) Seawater sampling after passing a filter on a ballasting pipe
3) Sampling seawater left in the filter/filtration
4) Seawater sampling after passing the ballast pipe is discharged back into the sea

Before testing the effectiveness of the Ballasting Pipe Filter, the first thing to do is to test the seawater around Amurang Port. The output of seawater tested in the laboratory measuring 600 ml/8 m^3 is as follows:

Table 5. Seawater Samples Before Passing Ballasting Pipes of BSPJI Manado Results

No.	**Microorganism**	**UoM**	**Result**	**Standard D2/PP No. 22 of 2021**	**Ballast Water Tank**	**Result**
1.	Total Plate Count	CFU/mL	1.8×10^2	$10/m^3$	8 m^3	NOT PASS
2.	Coliform	MPN/100 mL	46	100	8 m^3	PASS

Source: Processed by the Researcher (2023)

Based on the the test results of laboratory tested at the Center for Standardization and Industrial Services (BSPJI) Manado, a total plate count of the number of microorganisms was found in seawater samples before passing the ballast pipe of the John Lie training ship around Amurang Port in seawater samples measuring 600 ml/8 m^3, which was found as many as 108 total plate count microorganisms. So, the seawater at Amurang Port before being pumped into the tank of the John Lie training ship had not passed based on the D2 Water Management Convention standards, namely ten organisms 10/m 3 where it is known that the John Lie training ship has a number of 10 ballast tanks with a size on each ballast tank that is 8 m^3/tank. It means that the standard passes with the size of the ballast tank of the John Lie training ship is 80 total plate count of microorganisms in ballast water according to the capacity of each training ship ballast water tank of John Lie. The test results found 108 total plate count microorganisms are pure total organisms that live in seawater around Amurang Port.

After the first stage test, the researchers tested seawater around Amurang Port after passing a filter made by researchers tied to the Ballast tank inlet pipe on the John Lie Training Ship. The output of eawater tested in the laboratory measuring 600 ml/8 m^3 is as follows:

Table 6. Seawater Samples After Passing Ballasting Pipes of BSPJI Manado Results

No.	**Microorganism**	**UoM**	**Result**	**Standard D2 / PP No. 22 of 2021**	**Ballast Water Tank**	**Result**
1.	Total Plate Count	CFU/mL	4.4×10^1	$10/m^3$	8 m^3	PASS
2.	Coliform	MPN/100 mL	13	100	8 m^3	PASS

Source: Processed by the Researcher (2023)

Based on the test results of laboratory on the number of microorganisms in seawater samples after passing a filter made by researchers tied to the inlet pipe of the ballast tank of the John Lie training ship around Amurang Port in seawater samples measuring 600 ml/8 m^3 were found as many as 44 total plate counts of microorganisms. So, the seawater in the ballast tank after passing the filter passed the results based on the D2 Water Management Convention standard, namely ten organisms $10/m^3$ and it is known that the size of the ballast tank on the John Lie training ship has a size of 8 m^3 which means that the standard passed with the size of the ballast tank of the John Lie training ship is 80 total plate count of microorganisms in the ballast water according to the capacity of each ballast water tank. Thus, it has obtained the results of passing the D2 standard from the IMO BWM Convention Regulation besides the total plate count. The results of coliform in seawater after passing the filtering filter process for coliform results found a total of 13 coliforms known coliform is an indicator of seawater pollution. The higher the level of coliform bacteria contamination, the higher the risk of the presence of bacteria. The output of seawater tested in the laboratory measuring 600 ml/8 m^3 is as follows:

Table 7. Seawater Samples Remaining/Residual in BSPJI Manado Filtration System

No.	Microorganism	UoM	Result	Standard D2 / PP No. 22 of 2021	Ballast Water Tank	Result
1.	Total Plate Count	CFU/mL	5.8×10^1	$10/m^3$	$8\ m^3$	PASS
2.	Coliform	MPN/100 mL	23	100	$8\ m^3$	PASS

Source: Processed by the Researcher (2023)

Based on the test results, it was found that the total plate count of the number of microorganisms in residual seawater samples in the filter system made by researchers tied to the ballast tank inlet pipe was found to be 58 total plate count microorganisms. So, the filter made was able to filter out microorganisms that would enter the ballast tank of the John Lie training ship from 108 total plate counts before passing the filter to get 58 total plate counts after passing a filter filer on ballast water that enters the ballast tank. The coliform results found a total of 23 coliforms that were still within the standard limits. These bacteria are microbes found in polluted seawater and can cause disease and health problems for humans. Coliform standard is 100 Jml/100mL. After the third stage test, seawater was tested through ballast pipes and discharged back into the sea. The output of seawater tested in the laboratory measuring 600 ml/8 m^3 is as follows:

Table 8. Seawater Samples After Passing Ballast Pipes and Discharged Back into the Sea

No.	Microorganism	UoM	Result	Standard D2/PP No. 22 of 2021	Ballast Water Tank	Result
1.	Total Plate Count	CFU/mL	1.1×10^2	$10/m^3$	$8\ m^3$	NOT PASS
2.	Coliform	MPN/100 mL	33	100	$8\ m^3$	PASS

Source: Processed by the Researcher (2023)

Based on the test results, it was found that the total plate count of the number of microorganisms in the seawater sample after passing the ballast pipe and discharged back into the sea in seawater samples measuring 100 ml/8 m^3, which was found as many as 101 total plate count of microorganisms. There were 44 total plate count of microorganisms after going through the ballast pipe. The discharging back process into the sea without passing the filtration system designed by this researcher the number of total plate count of microorganisms increased to 101 total plate count discharged. Coliform results on the rest of the ballast water filter results were found a total of 33 coliforms with coliform standards of 100 Jml/100mL. This shows that the amount of coliform increased after the process of removing ballast water without passing a filter made by researchers that was discharged back into the sea. It means the BWT design of the filter filtration method made by researchers with a net size of 0.1 mm is able to filter filters microorganisms and coliforms contained in seawater that will enter the ballast tank. However, when the ballast water in the ballast tank is discharged back into the sea without using a filter, the total plate count of microorganisms and coliforms in seawater increases. Therefore, there is a need for a filtration method when discharging seawater from the ballast tank back into the sea because the filtration system designed by the researchers cannot be installed when the process of discharging seawater from the ballast tank. This is because the filtration system will be sucked into the ballast tank pipe, causing the pipe to become clogged by the researcher's filtration system. This return seawater discharge modification from the ballast tank into the sea must be implemented by the John Lie Training Ship so that the training ship can still operate no later than September 8, 2024, which is required by all ships to meet the D2 ballast water management standard from the IMO BWM Convention Regulation.

In this current condition, *ballast water treatment* that can be applied to the John Lie training ship is through *Ultraviolet Radiation/UV Radiation*. This method uses UV light produced by the *quartz sleeve* to change the structure of the DNA of the microorganism, preventing it from reproducing. This method is very commonly used in the water treatment industry because it is effective on almost all microorganisms. However, the weaknesses is the need for an even UV rays distribution so that it requires clear water to be more effective in its use. Therefore, in order to improve the effectiveness of the John Lie Training Ship BWT to meet the overall D2 standard of the IMO Ballast Water Management Convention D2 Standard, UV + Photocatalytic Oxidation + Filtration method were proposed by the researchers.

Photocatalytic Oxidation (*Advanced Oxidation Process*) or commonly called AOP, is a chemical treatment process that uses UV light and other chemical processes, such as Hydrogen Peroxide (H_2O_2) or Titanium Dioxide (TiO_2) to produce hydroxyl radicals (-OH). It aims to kill microorganisms. Photocatalytic Oxidation is an AOP process that uses a combination process between Titanium Dioxide (TiO_2) catalyst and UV light to produce hydroxyl radicals. This process only produces water and carbon dioxide as the residues so that ballast water can be discharged directly into the sea.

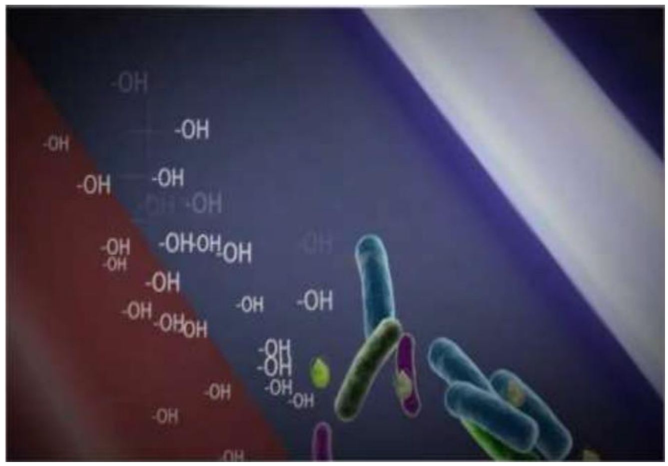

Figure 1. Photo-Catalytic Film Reaction for Microorganism Extermination on AOP (Advanced Oxidation Process)

The following is a comparison of UV Radiation treatment with Photocatalytic Oxidation:

Table 9. Comparison of Treatment Methods

Treatment Method	Working Mechanism	Advantages	Disadvantages
UV	UV radiation alters DNA and RNA in microorganisms, Resulting in the paralysis of the microorganism.	It is very commonly used because of the high efficiency of this method and it does not leave any additional pollution or residue on seawater.	UV light uses a lot of energy and requires a second treatment to make sure the microorganisms are completely dead.
Photocatalytic Oxidation	It uses photocatalytic film to form hydroxyl radicals (-OH) compounds that will kill microorganisms.	Produce water and carbon dioxide as treatment residues, so that water can be directly discharged into the sea.	Requires UV light or chemical compounds, such as Hydrogen Peroxide (H_2O_2) or Titanium Dioxide (TiO_2) to carry out chemical reactions, so the tool cannot work on its own.

Source: Processed by the Researcher (2023)

The results of BWT with the UV + AOP + Filtration method according to the method that can be applied to the John Lie training ship as an effective consideration applied to the John Lie training ship. From the results of laboratory tests Marine Organism Tested combination treatment between the UV + AOP + Filtration method is very effective in eradicating microorganisms contained in ballast water on ships from the results of the ballasting and deballasting processes from the loading port to the unloading port. So, this BWT method is will not cause any inconvenience to either the ballast water discharge processes, considering that the filtration method used by the researcher in this study cannot be used in the ballast water discharge process, but only in the ballast tank filling process. Of course, the filtration created by the researcher is still not effective in the ballast water discharge process from the ballast tank into the sea.

4. Discussion

During the ballasting process, ballast water contains thousands of species of marine animals and plants that are carried in ballast tanks, causing problems for the marine environment and human health (Gollasch & David, 2017; Jang et al., 2020). Ballast water disposal into the sea will cause poisoning for marine life and other microorganisms. This causes various problems, such as changes in growth patterns, hormonal cycle damage, birth defects, decreased immune system, causes cancer, tumors and genetic disorders or even death if consumed by humans (Dachev et al., 2021; Lakshmi et al., 2021; Outinen et al., 2021).

Although it plays an important role in supporting the safe and efficient operation of modern vessels, ballast water has a serious impact on the economy (BİLGİN GÜNEY, 2022; Sayinli et al., 2022; Wang et al., 2020). This is because many marine species are brought or carried into ships during the ballasting and deballasting processes. As well as threatening the human economy that depends on healthy marine ecosystems. Furthermore, it gradually affects the productivity of fish development in the ocean and also economy of fishermen around the ballast water disposal location where the water is discharged recklessly (Friedman et al., 2020; Rees et al., 2020; Saha et al., 2019).

5. Conclusion

The modification of the filtration tool designed by the researcher used a 0,1 mm and 0,01 mm net tied to the ballast tank inlet pipe using a clamp on the ballast pipe of the John Lie training ship. This can fully be used during the process of filling ballast water from port seawater to enter the ballast tank through this filtration system. However, for the ballast water discharge process from the ballast tank back into the sea using this filtration filter, it cannot be used yet because the filtering net can be sucked by the ballast water discharge from the ships's thank into the sea, which can cause the ballast water discharge pipe to be clogged. Thus, the researcher must release this filtration when the ballast water discharge process from the tank is discharged into the sea. From the results of the Water Laboratory Nusantara (WLN) laboratory data, it can be concluded that the filtration system device designed by the researcher is able to filter the total plate count of microorganisms between 930 – 1044 microorganisms at the time before seawater enters the tank until seawater enters the ballast water tank through a filtration system designed by the researcher. The results shown after passing the filter with a total plate count of 36 microorganisms indicate that the filtration system designed by the researcher can meet the D2 standard of the IMO BWM Convention Regulation. Meanwhile, the laboratory results of the Manado Center for Standardization and Industrial Services (BSPJI) concluded that the filtration system device designed by the researcher is able to filter the total plate count of microorganisms between 58 – 64 microorganisms at the time before seawater enters the tank until seawater enters the ballast water tank through a filtration system designed by the researcher. The results shown after passing through a filter with a total plate count of 44 microorganisms. This indicates that the filtration system designed by the researcher can meet the D2 standard of the IMO BWM Convention Regulation. Beside the total plate count, the researcher also identified the number of coliforms through the laboratory of the Manado Center for Standardization and Industrial Services (BSPJI). It was found that the coliform results of seawater from before entering the ballast tank to after entering the ballast tank through the filtration, the residual results from the filtration to the process of discharging ballast water back into the sea were shown to still meet the standards Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management in Annex VIII of the coliform standard Sea Water Quality Standard, which is 100 Jml/100mL.

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