COMPUTATIONAL SCIENCE AND TECHNIQUES
Volume 9, 2025, 647-655

Publisher: Klaipėda University
https://e-journals.ku.lt/journal/csat
Online ISSN: 2029-9966
DOI: 10.15181/csat.v9.2501

THE PROJECT OF INSTALLING A BALLAST WATER TREATMENT SYSTEM ON THE KLAIPĖDA UNIVERSITY RESEARCH VESSEL *MINTIS*

Aidas Čurovas

Klaipėda University, Faculty of Marine Technologies and Natural Sciences

Abstract. This paper presents a comparative analysis of ballast water treatment technologies, along with a detailed evaluation of the selection of treatment equipment, calculations of hydraulic pressure loss, and a theoretical layout of the equipment. The technology analysis assesses 13 different treatment methods based on six criteria for installing such systems in the space-restricted engine room, aiming to mitigate the threat posed by untreated ballast water to marine life. The selected technologies are filtration and ultraviolet (UV) as the primary and secondary ballast water treatment technologies. These methods ensure efficient, rapid, and environmentally friendly ballast water treatment.

Another study component focuses on selecting and integrating the ballast water treatment system with the chosen technologies. It was determined that the PureBallast 3.2 Compact Flex ballast water treatment system, supplied by Alfa Laval, would be installed, offering a capacity of 85 m^3/h and recognised as one of the world's leading providers of high-quality water treatment solutions. Given the installation of the new system on board, hydraulic pressure loss calculations were conducted to assess whether the existing ballast pumps on the ship possess adequate capacity to support the treatment system. The results indicate that both pumps are insufficient to supply ballast water through the system at the required pressure. Practical solutions could involve replacing the impellers, adjusting the flow rate, or replacing the pumps.

Keywords: ballast treatment system, ballast, pump capacity.

1. Introduction

Ships play an integral role in the global trade network. According to the International Chamber of Shipping (ICS) data from 2020, approximately 90% of all goods worldwide are transported by this mode of transport [1]. Maritime trade volumes are expected to continue growing, resulting in an increase in both the number and size of ships. A crucial component of ships (excluding small recreational vessels, certain military ships, and similar types) is the onboard systems: cargo hold systems, fire-fighting systems, ballast systems, and others.

Ship systems consist of a network of pipelines along with mechanisms, fittings, devices, and tanks that carry out specific functions. They are employed to extinguish fires, supply the crew and passengers with food and water, remove contaminated water, take on and discharge ballast water, and fulfil other roles.

All onboard systems must meet general requirements. For instance, systems must be reliable throughout their entire service life, cost-effective, and, when designing pipeline layouts, as continuous as possible with minimal bends. In addition to these general principles, each system is also subject to specific technical requirements.

On 8 September 2017, the International Convention for the Control and Management of Ships' Ballast Water and Sediments, adopted by the International Maritime Organisation (IMO), entered into force. The aim of this convention is to protect the marine environment from the spread of invasive aquatic organisms through ballast tanks [2]. All ships with ballast systems built before 8 September 2017 were required to have ballast water treatment systems installed to comply with the D-1 standard of the convention. This standard applies to the Mintis, a catamaran-type research vessel built in 2014 and operated by Klaipėda University (KU). In addition, from 8 September 2024, all vessels must comply with the more stringent D-2 standard.

2. Threats of untreated ballast water

It is estimated that ships transport approximately 12 billion tonnes of ballast water globally each year [3]. In addition to the water, various organisms (including bacteria, microbes, cysts, and larvae of different species) are drawn into ballast tanks.

The intake and discharge of untreated ballast water pose a serious threat to the environment, public health, and the economy, as ships become carriers of harmful invasive aquatic species from one part of the world's oceans to another. This threat extends not only to marine ecosystems but also to human health, coastal industries reliant on water resources, and other biodiversity groups such as birds and terrestrial wildlife [4].

Many of these organisms can survive for extended periods in harsh conditions, including those found within ballast tanks. Upon discharge, these organisms are released and, without natural predators and in favorable conditions, non-native species can not only survive but also thrive, becoming invasive and potentially outcompeting or eliminating native populations.

One illustrative example of this destruction is the 1988 invasion of zebra mussels into the Great Lakes. This freshwater species, native to the Black and Caspian Seas in Europe, has caused significant environmental damage due to the discharge of ballast water from ships [5].

Such incidents are common in the waters off Lithuania. Across much of the Baltic Sea, the Chinese mitten crab is regarded as an invasive species. Consequently, the populations of native aquatic species, including local crabs, have experienced a significant decline.

Thus, to safeguard marine life and the environment, and to halt or at least mitigate the spread of invasive species, ballast water treatment technologies must be adopted in ballast systems.

3. Comparative Analysis of Ballast Water Treatment Technologies

Ballast water treatment technologies are generally classified into port-based and shipboard systems. Shipboard technologies are further divided into primary and secondary treatments. Primary treatments include mechanical methods, while secondary treatments are subdivided into physical and chemical methods [6]. In most cases, multiple technologies are employed simultaneously (typically at least one primary and one secondary method). For optimal results, it is advisable to combine, for instance, filtration with UV radiation [7].

To select a suitable ballast water treatment system that ensures discharged ballast complies with international regulations, it is essential to compare the available technologies by evaluating their advantages, disadvantages, and operational complexity. For this comparison, thirteen different shipboard technologies have been considered.

Based on the comparison results, filtration and UV treatment are the selected technologies. These methods ensure efficient, rapid, and environmentally friendly ballast water treatment. Filtration removes solid particles and organisms, thus reducing overall pollution levels. UV treatment inactivates any remaining microorganisms without the use of chemicals. The combined application of these methods is economically viable, and their compact size means this solution requires minimal space. It provides a sustainable and internationally compliant ballast water treatment approach [8].

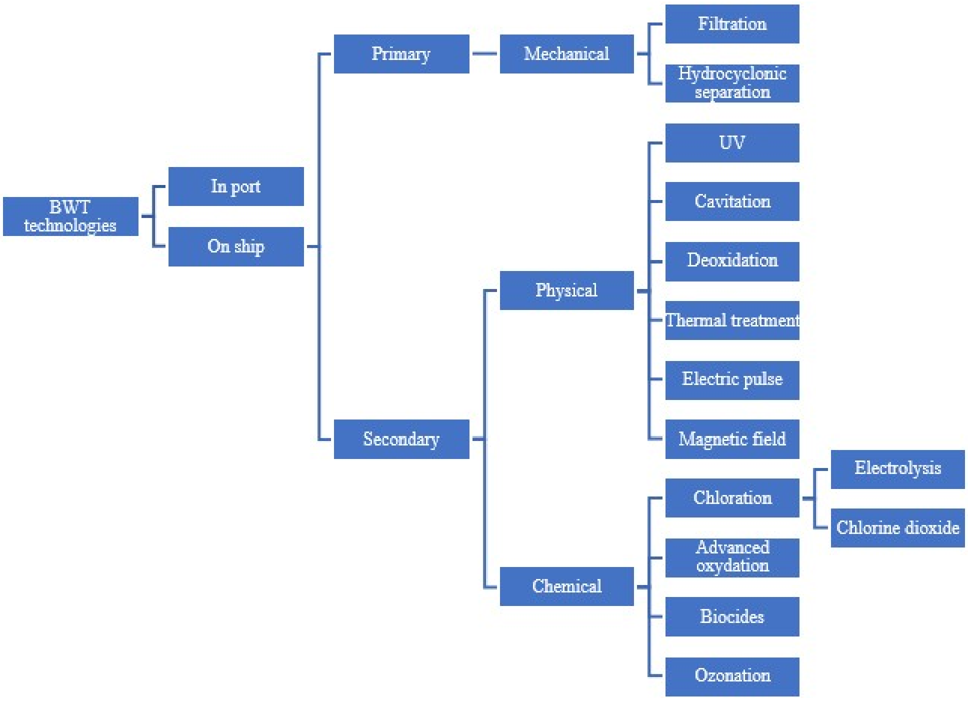

Figure 1. Ballast water management (BWM) technologies(adopted according to [8, 9])

4. Setting the Selection Criteria

When selecting ballast water treatment equipment, it is essential to carry out a comprehensive assessment based on various criteria: cost, spatial requirements, installation complexity, maintenance, and more. This assessment encompasses a comparative analysis of ballast water treatment technologies and a review of technical documentation issued and approved by the equipment manufacturers.

System capacity denotes the maximum volume of ballast water that can be treated per unit of time. In this case, the KU research vessel is equipped with two ballast pumps, each boasting a capacity of 27 m^3/h, resulting in a total throughput of 54 m^3/h. Furthermore, it has eight ballast tanks with a cumulative volume of 107.8 m^3.

The dimensions of the equipment are a crucial factor in the selection process, as the treatment system will be installed on a vessel that has been in operation for a decade. Since no dedicated space was allocated for such equipment during the vessel's initial design—and as previously mentioned—the engine room is limited in space. Therefore, it is necessary to choose equipment that can fit alongside existing systems without requiring additional compartments. Consideration must also be given to access ways, doorways, and other installed machinery to ensure that the dimensions of the treatment system do not obstruct transportation and installation in the chosen location.

Weight is another factor; each additional system increases the vessel's overall mass and impacts lightship displacement.

Energy consumption is also essential, as all systems on board draw power. The vessel's energy requirements are planned during its design stage, so adding new equipment introduces unanticipated power demands [10].

5. System Comparison and Selection

To select a treatment system rationally, considering the current market offerings, it is essential to compare the treatment systems provided by several different manufacturers. For this comparison, three companies were chosen: Alfa Laval (Sweden), DESMI (Denmark), and NGT (Norwegian Green Technology) (Norway). The systems from these manufacturers were selected to ensure their capacity is equal to or greater than the total capacity of Mintis ballast pumps ($\geqslant$54 m^3 /h). All systems utilise the same technologies – filtration (primary, mechanical ballast water treatment) and UV (secondary, physical treatment method).

The table is compiled based on company documentation and brochures available on the manufacturers' websites.

Table 1. Comparison of Ballast Water Treatment Systems Offered by Different Manufacturers

	Alfa Laval "PureBallast 3.2 Compact Flex" 85 m^3/h	**DESMI "CompactClean" 85 m^3/h**	**NGT BWMS 100 m^3/h**
Energy Consumption	Medium	Highest	Lowest
Installation Flexibility	Compact, suitable for vessels of all sizes	Compact, suitable for medium-sized vessels	Compact, suitable only for small vessels
Installation Costs	Highest	Lowest	Medium
Maintenance Needs	UV lamp replacement every 2 years; filter cleaning every 12 months	UV lamp replacement every 1–2 years; filter cleaning every 6 months	UV lamp replacement every 1–2 years; filter cleaning every 6–12 months
Pressure Requirements	1.7 bar	1.3 bar	1.5 bar
Service Availability	Global network, many repair options, spare parts available	Wide network in Europe	Widely available in Scandinavia and EU but limited

The table indicates that DESMI is the most cost-effective system, while NGT is the most expensive. For installation on Mintis, the NGT and Alfa Laval systems are best suited due to their compact design for small vessels. PureBallast 3.2 requires the highest minimum pressure; however, if the pressure is insufficient, the pump capacity, impeller can be adjusted, or the pump itself may need to be replaced.

Energy consumption is comparable across all systems, with DESMI recording the highest levels. A significant non-technical factor is the availability of service and spare parts. Alfa Laval provides exceptional support through a wide global network and easy access to components. In contrast, NGT's network is confined to Scandinavia and parts of the EU, with limited spare parts supply; like DESMI, it does not manufacture core components.

Although there are no major differences between the systems, some offer greater advantages while others present more significant drawbacks, and all are of equivalent size. A summary of these systems reveals that:

- **DESMI** appears to be a good option; however, it has been noted that in certain regions, such as the Baltic States, the system's flow rate decreases, which may significantly prolong the ballasting duration.
- **NGT** is an appealing system; however, the company itself is relatively small, which may result in difficulties when contacting specialists or acquiring spare parts.
- **Alfa Laval** is one of the largest manufacturers of this type of system. This is reflected in their customer support, a good price-to-quality ratio, and the comprehensive technical documentation provided.

The decision was also influenced by communication with company representatives; the Alfa Laval representative in Latvia was responsive, provided detailed information, and offered consultations on relevant issues. Consequently, the system supplied by the Swedish company was chosen.

6. *Alfa Laval*'s system overview

The ballast water management system provided by Alfa Laval, along with its key components, is presented below.

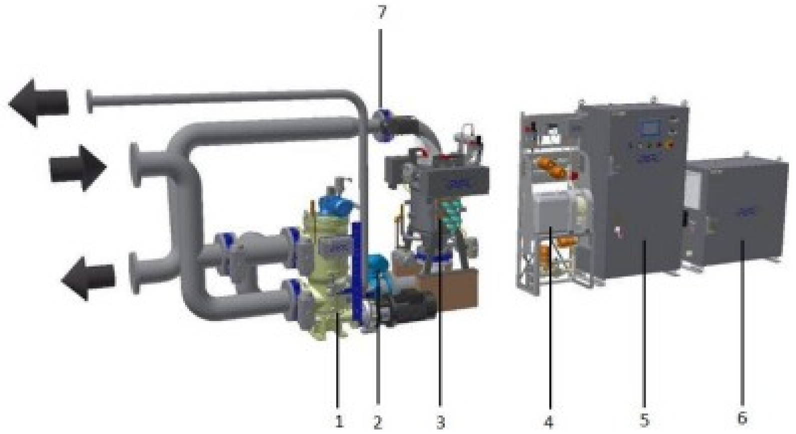

Figure 2. "PureBallast 3.2 Compact Flex" components [11]

- 1) Filter; 2) Flow meter with conductivity sensor; 3) UV reactor; 4) Cleaning-in-place (CIP) module; 5) Electrical cabinet; 6) Lamp drive cabinet (not included); 7) Control valve.
- Not depicted in the illustration – sampling devices, pressure monitoring device, backflush pump, system bypass valve.
- General system requirements:
- • System components must be installed in the engine room or similar areas.
- • All system components must be securely fastened (bolted or welded).
- • The installation of any equipment must not increase vibrations to or from the hull or other devices.
- • All pipes connected to system components (UV reactor, filter, and CIP module) must be adequately supported to prevent additional mechanical stress on the equipment.
- • Sufficient space must be maintained around the equipment to facilitate maintenance.
- An important consideration when installing the system on board is the length of the piping. In this case, the length requirements are as follows:
- • The maximum pipe length between the CIP module and the filter and UV reactor is 5 metres.
- • The maximum pipe length between the UV reactor and valve V201-8 is no more than 2.5 metres.

7. Projected Calculations of the Ballast System

7.1 Comparison of System Performance with One and Two Pumps

The Klaipėda University research catamaran is equipped with two NISM32-160 pumps, as mandated by the PRS (Polish Register of Shipping) classification society. Each pump has a capacity of 27 m^3/h, which means that 27 cubic metres of ballast water are discharged from the ballast tanks per hour by each pump.

The entire ballast system can also be operated using a single pump, allowing water to be pumped from the starboard side into both the starboard and port-side ballast tanks. This configuration is deemed viable, as the ballast system was designed with this flexibility in mind.

When both pumps are operational, water taken in on the port side must still be transferred to the starboard side to pass through the treatment system. Therefore, it is necessary to evaluate the benefits of operating both ballast pumps simultaneously.

The pumps' total capacity is 54 m³/h, while the total volume of all ballast tanks on the catamaran is 107.8 m³.

A couple of calculations were performed using the following formula:

$$t = \frac{V}{Q} \qquad (1)$$

where t – time, s; V – total capacity of ballast tanks, m^3; Q – total pump flow rate, m^3/h.

The results indicate that when both pumps are in operation, the catamaran's ballast tanks are completely filled within 2 hours; however, when only one pump is employed, the filling process takes approximately 4 hours.

In this case, the ballasting rate is not critical for the Klaipėda University research vessel. Consequently, ballasting operations are conducted through both sides of the vessel, whereas de-ballasting is carried out solely through the starboard side (under non-emergency conditions). It is also worth noting that the chosen PureBallast 3.2 system, with a capacity of 85 m³/h, can be substituted with a lower-capacity 32 m³/h system, as the manufacturer, Alfa Laval, has provided the option to adapt the system accordingly.

7.2 Hydraulic Pressure Loss Calculations

In accordance with the requirements of the PureBallast 3.2 treatment system, it must be ensured that the pressure within the system is no less than 1.7 bar (the pressure generated by each of the installed pumps is 2 bar).

To evaluate the suitability of the existing pumps, calculations of hydraulic pressure loss must be performed. The results are shown in the table.

Table 2. Results of Hydraulic pressure loss calculation

	Hydraulic pressure losses					
	PS ballast pump → Ballast tank			SB ballast pump → Ballast tank		
Pipe diameter	DN65	DN100	DN150	DN65	DN100	DN150
Piping length, m	15.1	23	4.8	15.1	0.7	4.8
Pressure losses, bar	0.345	0.218	0.032	0.345	0.015	0.032
In total, bar	0.60			0.39		

Based on the results obtained by subtracting the hydraulic pressure losses from the pump pressure, it is evident that both the port-side pump (1.40 bar < 1.7 bar) and the starboard pump (1.61 bar < 1.7 bar) are insufficient to supply ballast water through the system at the required pressure. One solution (without replacing the pumps) would be to replace the impellers to achieve the highest possible pressure output. However, if the current setup already provides the maximum achievable performance, the pumps should be replaced.

8. Theoretical Equipment Layout in the Engine Room

The layout of the ballast water treatment equipment on Mintis was developed theoretically, based on the available 3D visual materials and general arrangement drawings. The system was installed immediately after the pump on the starboard side. It may be necessary to adjust the position of the foundations or equipment already installed.

The components of the "PureBallast 3.2" system depicted in Figure 3 include the filter (1), pressure gauge (2), UV reactor (3), remote control panel (4), CIP module (5), electrical cabinet (6), backflush pump (7), and flow meter (8).

Due to limited space, the installation of the flow meter does not fully comply with the standard requirement. According to Alfa Laval specifications, the minimum distance between the filter and the flow meter should be 5 DN (0.5 m), and the distance between the flow meter and the UV reactor should be 2 DN (0.2 m). In such cases, Alfa Laval reprogrammes the flow meter parameters to ensure accurate flow measurement under the actual installation conditions.

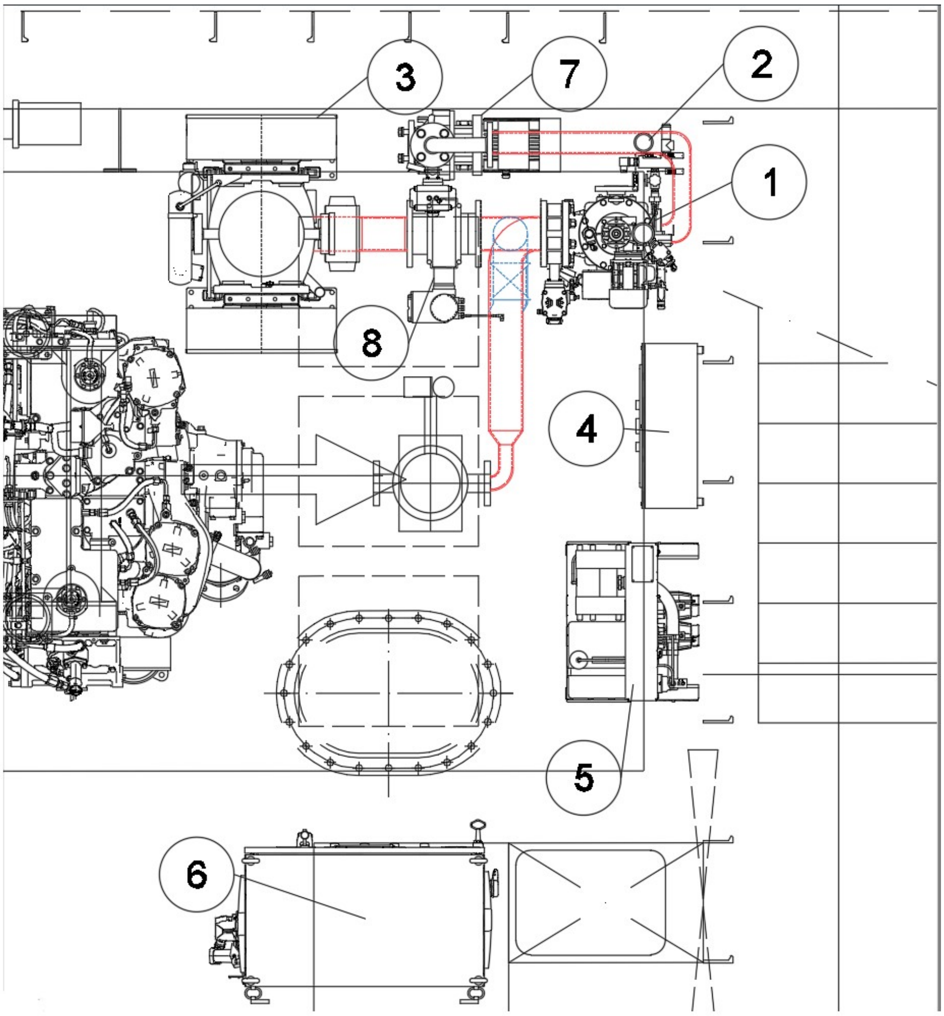

Figure 3. Theoretical equipment layout in the engine room

Conclusions

A combination of mechanical (primary) and physical (secondary) treatment methods was selected following a comparative analysis of thirteen different ballast water treatment technologies. Although filtration and hydrocyclonic separation exhibited similar advantages and disadvantages, filtration was chosen due to its simpler maintenance requirements and lower installation costs. Furthermore, the performance of hydrocyclonic separation is highly dependent on water properties, rendering it less reliable under varying conditions. Due to space limitations in the Mintis engine room and adjacent compartments, a physical rather than chemical secondary treatment method was selected. In practice, filtration is almost always paired with ultraviolet (UV) radiation, as filtration removes solid particles and larger organisms while UV inactivates remaining microorganisms without the use of chemicals. The compact size of this combination was also a significant factor influencing the final selection.

A comparative analysis was conducted on ballast water treatment systems provided by three companies: Alfa Laval, DESMI, and NGT. All selected systems utilise a combination of filtration and UV disinfection. The evaluation was based on several key criteria: treatment capacity, physical dimensions, weight, energy consumption, acquisition costs, maintenance requirements, and the availability of service and spare parts. According to the results, Alfa Laval's PureBallast 3.2 Compact Flex system (85 m^3/h capacity) was chosen as the most suitable option. This decision was supported by its extensive global service network, reliable and timely supply of original components, favourable cost-to-performance ratio, compact design, and effective communication with company representatives. An additional advantage is the Clean-in-Place (CIP) module, which enhances the operational efficiency of the UV reactor.

After the equipment layout was finalised, it was determined that both pumps would operate during ballasting and de-ballasting operations. However, de-ballasting will occur exclusively through the starboard overboard discharge pipe, thus eliminating the need to install an additional pipe across the vessel's beam for de-ballasting via the port-side overboard discharge. Based on the hydraulic pressure loss calculations (0.39 bar for the starboard pump and 0.60 bar for the port pump), it was concluded that the port-side pump must either be replaced or fitted with a new impeller to achieve optimal performance. The flow rate of the starboard pump can be adjusted to meet the current pressure requirements.

References

1. International Chamber of Shipping. Shipping and World Trade: Top Containership Operators (Overview). Viewed on May 3rd, 2025. Available at: <https://www.ics-shipping.org/shipping-fact/shipping-and-world-trade-top-containership-operators/>.
2. NIPPON KAIJI KYOKAI (ClassNK). Ballast Water Management Convention. Viewed on May 3rd, 2025. Available at: <https://www.classnk.or.jp/hp/en/activities/statutory/ballastwater/index.html>.
3. Bilgin Güney, Ceren (2022). "Ballast Water Problem: Current Status and Expected Challenges," *Journal of marine Science and Technology Bulletin* 11(4): 397-415.
4. Liang, Jing, Bing, Chen, Baiyu, Zhang, Hongxuan, Peng (2012). "A review of ballast water management practices and challenges in harsh and arctic environments," *Journal of Environmental Reviews* 20: 83-108.
5. Apaydin Yağci, Meral, Yildirim Zeki, Mehmet (2022). "The invasive zebra mussel (Dreissena polymorpha) literature review and density reduction synthesis," *Bilge International Journal of Science and Technology Research*, 6(2): 138-146.
6. Casas-Monroy, Oscar, D. Linley, Robert, Chan, Po-Shun, Kydd, Jocelyn, Vanden Byllaardt, Julie, Bailey Sarah (2017). "Evaluating efficacy of filtration+UV-C radiation for ballast water treatment at different temperatures," *Journal of Sea Research* 133: 20-28.

7. Šateikienė, Diana (2019). "Laivo balastinio vandens valymo įrangos, veikiančios filtravimu ir ultravioletiniu spinduliavimu, analizė," *Darnios aplinkos vystymas* 16(1): 55-61.
8. Šateikienė, Diana, Stanelytė, Daiva (2013). "Laivo balastinio vandens valymo metodų analizė ir parinkimo kriterijai". *Jaunųjų mokslininkų darbai* 1(39): 138-142.
9. Šateikienė, Diana, Janutėnienė, Jolanta, Bogdevičius, Marijonas, Mickevičienė, Rima (2015). "Analysis into the selection of a ballast water treatment system". *Journal of Transport* 30 (2): 145–151.
10. PureBallast Ballast Water Treatment System. System Manual PureBallast 3.2 Compact Flex PB-04954. Viewed on May 3rd, 2025. Available at: <https://maritimesafetyinnovationlab.org/wp-content/uploads/2024/07/BWTS-Manual.pdf>.

BALASTINIŲ VANDENŲ VALYMO SISTEMOS ĮRENGIMO KLAIPĖDOS UNIVERSITETO MOKSLINIŲ TYRIMŲ LAIVE „MINTIS" PROJEKTAS

Santrauka

Šiame straipsnyje pristatoma balastinio vandens valymo technologijų palyginamoji analizė, išsamus valymo įrangos pasirinkimo vertinimas, hidraulinių slėgio nuostolių skaičiavimai bei teorinis įrangos išdėstymas. Technologijų analizėje vertinamos 13 skirtingų valymo metodų pagal šešis kriterijus, svarbius diegiant tokias sistemas ribotos erdvės laivo mašinų skyriuje, siekiant sumažinti grėsmę jūrų gyvybei, kurią kelia nevalytas balastinis vanduo. Pasirinktos technologijos – filtravimas ir ultravioletinis (UV) apdorojimas – kaip pirminės ir antrinės balastinio vandens valymo technologijos. Šie metodai užtikrina efektyvų, greitą ir aplinkai draugišką balastinio vandens valymą.

Kita šio tyrimo dalis skirta pasirinktos balastinio vandens valymo sistemos integravimui. Nuspręsta įrengti „PureBallast 3.2 Compact Flex" sistemą, kurios našumas siekia 85 m^3/h, tiekiamą kompanijos „Alfa Laval" – vieno iš pasaulyje pirmaujančių aukštos kokybės vandens valymo sprendimų tiekėjų. Atsižvelgiant į planuojamą naujos sistemos diegimą, buvo atlikti hidraulinio slėgio nuostolių skaičiavimai, siekiant nustatyti, ar esami laivo balastiniai siurbliai turi pakankamą galią sistemos veikimui užtikrinti. Remiantis gautais rezultatais, akivaizdu, kad abu siurbliai yra per silpni norint tiekti balastinį vandenį reikiamu slėgiu. Praktiniai sprendimai galėtų būti sparnuočių keitimas, srauto reguliavimas arba siurblių keitimas.

Raktažodžiai: balastas, siurblių galingumas, balastinio vandens apdorojimo sistemos.