

Original Article

Effectiveness of Ballast Water Management Convention Implementation at Samarinda Port

M. Musa T. Konde¹, Ganding Sitepu², Andi Sitti Chairunnisa Mappangara³

^{1,2,3}Transportation Study Program, Graduate School, Hasanuddin University, Jl. P. Kemerdekaan KM. 10, Makassar 90245, Indonesia

¹Corresponding Author : muliskonde@gmail.com

Received: 16 March 2026

Revised: 13 August 2026

Accepted: 26 August 2026

Published: 30 September 2026

Abstract - The implementation of the Ballast Water Management Convention (BWMC) is an important instrument in controlling ecological risks due to the movement of aquatic organisms through ship ballast water. Although Indonesia has ratified the BWMC, the effectiveness of its implementation at the port operational level, especially river ports, still requires empirical evaluation. This study aims to evaluate the implementation of the BWMC at Samarinda Port by examining the level of technical and regulatory compliance of calling ships. This study uses a qualitative-descriptive and quantitative approach, through interviews, document analysis, and field observations. Compliance evaluation was carried out using the Paris MoU Concentrated Inspection Campaign (CIC) indicators that cover regulatory and technical aspects. The results of the quantitative analysis show that the level of ship regulatory compliance is very low, with an average of 9.37%, especially in the availability and consistency of Ballast Water Record Book recording. Meanwhile, the level of technical compliance is relatively higher with an average of 37.5%, although still in the low category, especially in the operational aspects of the Ballast Water Management System and ballast sediment management. These findings indicate an imbalance in the implementation of the BWMC between regulatory and technical aspects, reflecting the still-partial implementation of the convention. This research provides an important empirical contribution in the context of river ports by demonstrating that effective BWMC implementation requires an integration of documentary compliance, technical readiness, and strengthened contextual risk-based oversight.

Keywords - BWMC, Vessel Compliance, River Ports, Port State Control, Samarinda Port.

1. Introduction

Maritime transport plays a central role in global trade, resulting in high use of ships, which also has an impact on the high use of ballast water. Globally, the movement of billions of tons of ballast water every year has an impact on the movement of microorganisms to new environments that can damage local ecology, the economy and even human health [1-5]. To avoid the negative consequences of the movement of ballast water, effective and consistent management is needed across ports with high ship traffic intensity, including river ports [6, 7]. Monitoring of ship compliance with international maritime regulations is needed to ensure maritime safety and environmental protection [8].

The IMO established the Ballast Water Management Convention (BWMC) in 2004 as the international regulation governing ballast water management. This regulation came into force in 2017. By 2024, 96 countries had ratified the convention, covering 92.53% of the world's commercial shipping tonnage. However, its global implementation faces various challenges such as technical, environmental, economic, and other challenges, including ship operators, ship

types, ship age and trade routes [9-11]. Thus, not all ships have ballast water treatment systems that function optimally throughout shipping operations. Indonesia has adopted BWMC through Presidential Regulation Number 132 of 2015 to protect the maritime environment. This regulation requires every Indonesian ship and foreign ship operating in Indonesia to comply with ballast water management provisions according to international standards.

Several studies have shown the impact of the implementation of BWMC. [12] showed that after the implementation of "saltwater flushing"/strict regulations, the rate of discovery of new non-indigenous species in the Great Lakes decreased by about 85% during 2007-2019 compared to the previous period. [13] Their research proved that the implementation of BWMS can reduce phytoplankton density by more than 99% and meet D-2 as required. [14] stated that the implementation of BWMS in Canada can reduce the frequency of entry of high-risk species. However, the implementation of ballast water management faces various challenges. [15] found that poor water conditions pose challenges in complying with Regulation D-2. [16] found that



challenges in ballast water management in the Caribbean include a lack of legislation, difficulties in law enforcement, political interests, and a lack of staff/budget allocation, and technical capacity. In Indonesia, challenges faced in ballast water management include limited infrastructure, a lack of supervision and law enforcement, limited human resources, and high implementation costs [17].

Samarinda Port is a strategic port frequently visited by domestic and international merchant vessels. It is dominated by the activities of coal vessels, fuel tankers, and some containers (BPS East Kalimantan, 2023; Directorate General of Sea Transportation, 2023). The dense ship activity makes this port vulnerable to invasive alien species carried through ballast water. Studies show that the water quality of the Mahakam River has a Total Dissolved Solids (TDS) value of 343366 mg/L, far below the international threshold of 1,000 mg/L used to define freshwater [18]. Furthermore, changes in water quality in the Lempake River, Samarinda, have resulted in a decline in fish populations and species [19]. This condition indicates that the aquatic ecosystem in the Samarinda region is highly sensitive to changes in water quality, including those caused by shipping activities and ballast water discharge. Therefore, an evaluation of ballast water management at this port is needed to maintain ecological sustainability in the surrounding waters. This study aims to evaluate ballast water management at Samarinda Port from technical, regulatory, and institutional aspects, through the Paris/Tokyo Memorandum of Understanding (MoU) 2025 indicators known as the Concentrated Inspection Campaign (CIC) 2025. The use of this instrument is important because each question item (Q1Q9) substantially represents IMO regulations, such as Regulation E-2 (Issuance or Endorsement of IBWMC), Regulation D-3 (Approval requirements for Ballast Water Management systems), Regulation D-2 (Performance Standard), Regulation B-5 (Sediment Management for Ships), Regulation B-1 (BWMP), Regulation B-2 (BWRB).

Thus, the results of the vessel compliance assessment reflect globally recognized practices and can be used to measure the effectiveness of BWMC implementation at the port level, including at Samarinda Port. Various previous studies on ballast water management with various focuses, such as the use of technology [14], found that the use of the BWMS filter mesh size is an important predictor in BWMS processing. [20] combined ballast water management technology between filtration + UV-C radiation, sharing salinity. While [6] proposed FlowCAM technology. [21] found the effectiveness of using UV-C for BWMS. In Indonesia, studies related to the implementation of BWMC in various ports that focus on human resources such as [22] examined the readiness of human resources in implementing ballast water disposal regulations at Tanjung Emas Port and research by [23], regarding the level of crew compliance with ballast water management at Taboneo Offshore Port, as well

as research by [24] regarding the readiness of human resources in using Bow Tie Risk assessment at Surabaya Container Port. Until now, no one has studied the implementation of BWMC in the port. Regarding the indicators used to evaluate ballast water management, [25] used rules by MPEC (Marine Environment Protection Committee) to evaluate ballast water management at Pelindo II. Unlike previous studies, this study evaluates the effectiveness of BWMC implementation, focusing not only on human resources but also on technical and regulatory aspects covered by the Campaign (CIC) on Ballast Water Management, factors influencing the effectiveness of ballast water management, and strategies for improving the implementation of BWMC management in river ports. The results of this study can provide direction for strengthening supervision and increasing compliance for river ports with globally recognized practices.

2. Methodology

2.1. Types of Research

This study combines descriptive-qualitative and quantitative approaches. The quantitative descriptive approach aims to evaluate the effectiveness of the Ballast Water Management Convention (BWMC) implementation at Samarinda Port. The qualitative approach is used to understand the policy and operational context of BWMC implementation at Samarinda Port through empirical data, interviews, and document review.

2.2. Research Sample

The sample determination in this study used a purposive sampling technique. The selection was based on the availability of the main BWMC documents, namely the IBWMC, BWMP, and BWRB. The sources of this study consisted of; Head of the Sea Traffic and Transportation Section (technical-operational focus), and Head of the Legal Status and Ship Certification Division (regulatory and administrative focus), General Manager of Pelindo IV Samarinda (institutional focus and port infrastructure support), harbormaster office officers, port operators, ship agents, shipping companies, and ship captains or officers responsible for ballast water operations. Samples were taken from 8 observed ships.

2.3. Data Collection and Research Instruments

Primary data were obtained through semi-structured interviews, field observations, and questionnaire distribution. Secondary data consisted of official reports from the Directorate General of Sea Transportation, the Port State Control (PSC) Annual Report, *Inaportnet* data, ballast water inspection documents, as well as scientific literature from the IMO, international journals, and national laws and regulations (including Presidential Decree No. 132 of 2015). The instruments used were interview guides, observation sheets, and questionnaires compiled based on the nine Concentrated Inspection Campaign (CIC) indicators, as shown in Table 1.

Table 1. Indicators for assessing the effectiveness of BWMC implementation

Question Code	Questions in the Paris MoU Questionnaire	Research Aspects	Assessment Information
Q1	Is the BWMC certificate available and valid?	Technical	The IBWMC certificate is issued after the ship meets D-1 and D-2, which proves that ballast water management is in accordance with IMO standards. [David, M., Gollasch, S., & Hewitt, C. (2024) [1]
Q2	Is BWMPada, and has it been approved?	Regulative	BWMPs must be owned, updated, and implemented on ships.
Q3	Has the BWMP been updated, and does it comply with applicable requirements as required by IMO?	Regulative	BWMPs must be owned, updated, and implemented on ships.
Q5	BWMS approval requirements	Technical	The BWMS used by ships must be approved by the Administration or IMO.
Q6	Is BWMS operational?	Technical	Assessing the effectiveness of BWMS on the quality of treated ballast water in accordance with IMO standards (microbes and sediments).
Q7	Is ballast water management in accordance with BWMP?	Regulative	The BWMP must be kept on board, updated, and implemented
Q8	Has the BWRB been filled out correctly, including exceptions if granted?	Regulative	A BWRB must be provided and completed for every ballast operation.
Q9	Sediment Management for Ships	Technical	Ships are required to manage, remove, and dispose of sediment from ballast tanks in accordance with the BWMP. Ship designs must also minimize sediment buildup and provide safe access for cleaning and sampling, in accordance with IMO guidelines.

Source - Paris MoU & Tokyo MoU. 2025. Concentrated Inspection Campaign on Ballast Water Management (CIC Questionnaire) (Q4 & Q10 were not used in the study due to their contextual/NA nature in this sample.)

2.4. Data Analysis

Data analysis was conducted quantitatively and qualitatively, with quantitative analysis measuring the level of technical and regulatory compliance with the implementation

of BWMC into high, low, and medium categories (Table 2). A SWOT analysis was used to identify factors influencing vessel compliance with the implementation of BWMC, as shown in Table 2.

Table 2. Categories of BWMC implementation compliance levels based on percentage

Percentage Range	Categories	Explanation
76 100%	High	Demonstrating good compliance with BWMC technical or regulatory indicators
5675%	Medium	Demonstrating partial compliance, there are still technical/regulatory indicators that have not been met.
≤ 55%	Low	Demonstrating weak compliance with BWMC technical or regulatory indicators

Qualitative analysis was used to explain the implementation of BWMC at Samarinda Port, followed by a SWOT analysis to find factors that influence ship compliance with the implementation of BWMC and determine strategies for improving the implementation of BWMC.

3. Discussion

3.1. Level of Compliance of Vessels with Technical and Regulatory Aspects

Evaluation of the effectiveness of the Ballast Water Management Convention (BWMC) implementation on vessels operating at Samarinda Port was conducted using the nine indicators of the Concentrated Inspection Campaign

(CIC) Paris/Tokyo MoU 2025. Details of the level of compliance with each BWMC indicator based on inspection results are presented in Table 3. Based on the nine CIC indicators, the highest compliance rates were found in indicators Q1 (IBWMC certificate 62.5%) and Q4 (BWMS approval 50%), while the lowest compliance rates were found in indicators Q2, Q3, Q7, and Q9 (0%). This indicates that administratively, some vessels have fulfilled the convention's obligations, but from an operational and document management perspective, they are still not optimal. To understand these variations more specifically, the analysis continued on two main dimensions of BWMC effectiveness: technical and regulatory aspects.

Table 3. Level of vessel compliance with BWMC

Indicator Code (CIC 2025)	Types of Compliance	Number of Eligible Ships (n=8)	Compliance Percentage
Q1	Technical	5	62,5 %
Q2	Regulative	0	0,0 %
Q3	Regulative	0	0,0 %
Q5	Technical	4	50,0 %
Q6	Technical	3	37,5 %
Q7	Regulative	0	0,0 %
Q8	Regulative	3	37,5 %
Q9	Teknis	0	0,0 %

Source: Analysis results, 2025

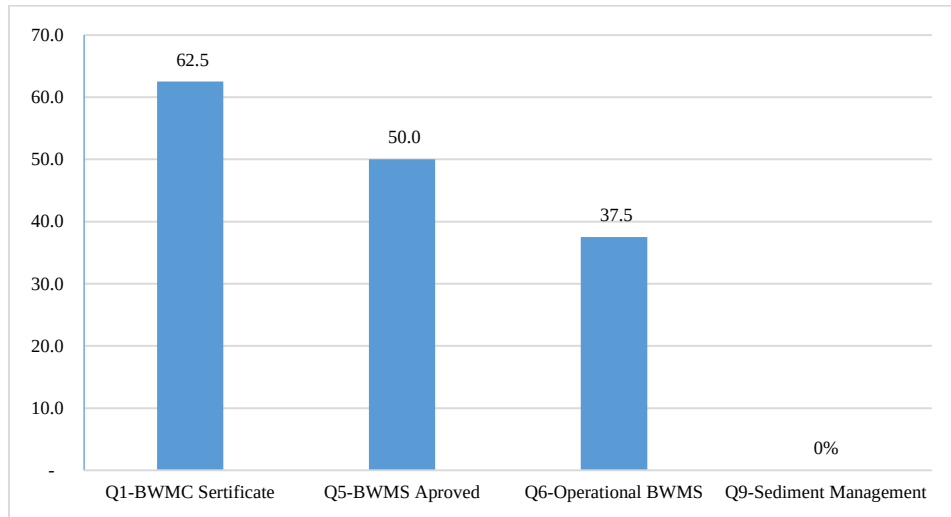


Fig. 1 Level of ship compliance with technical aspects

Figure 1 shows that technical aspects have a relatively higher level of compliance variation than regulatory aspects, but still fall short of the IMO optimal standard. The highest level of compliance is indicated by the availability of a BWMC certificate (62.5%), followed by an approved BWMS (50%), an operational BWMS (37.5%), and sediment management (0%). This means that ships are better prepared in terms of technical documentation compliance than in terms

of operational implementation in the field. The regulatory aspect focuses on administrative obligations, including the availability and updating of the Ballast Water Management Plan (BWMP), the implementation of ballast water management according to plan, and the completeness and occupancy of the Ballast Water Record Book (BWRB). A detailed level of vessel compliance with regulatory aspects can be seen in Figure 2.

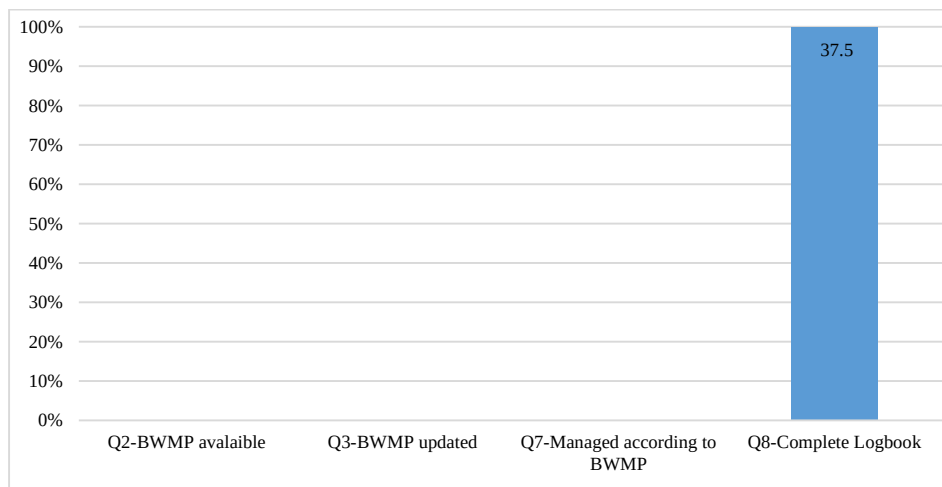


Fig. 2. Level of ship compliance with BWMC regulatory aspects

Figure 2 shows that of the four regulatory indicators, only Q8 (Ballast Water Record Book or BWRB) has a compliance rate of 37.5%, while the other three indicators (Q2, Q3, and Q7) are not met at all (0%). This indicates that the level of regulatory compliance of vessels operating at Samarinda Port is still very low.

This condition implies the inability to prove that ballast water management is carried out according to plan (Q7 = 0%), which means that the administrative obligations as stipulated in Regulation B-1 and B-2 of the Ballast Water Management Convention have not been fulfilled effectively. Ballast water management that is not systematically documented makes it difficult for the Port to conduct audits and compliance evaluations. This shows that regulatory compliance is still seen as a formality, not as part of a sustainable environmental quality control system. Meanwhile, only three ships have a Ballast Water Record Book (BWRB) with partial recording (Q8 = 37.5%), which indicates that a small number of operators have attempted to implement documentation, even though it has not met the standards set by the International Maritime Organization (IMO). One of the weaknesses in the implementation of BWMC lies in the administrative aspects and document management that do not comply with IMO guidelines [26].

3.2. Factors Causing Ineffective BWMS Implementation at Ports

The effectiveness of BWMC implementation at Samarinda Port is still low, with an average technical compliance of 37.5% and regulatory compliance of 9.37%. From the technical aspect, the highest level of compliance in indicator Q1 (62.5%) illustrates that most ships have understood the importance of having a BWMC certificate as proof of the legality of ballast water management. However, low compliance values in indicators Q5 (50%), Q6 (37.5%), and especially Q9 (0%) indicate that technical implementation in the field has not been carried out comprehensively. Ports and ship operators are more focused on administrative fulfillment (certification) than on sustainable technical implementation. In line with the findings of [27], who said that IMO member countries face similar challenges, where certification and completeness of BWMC documents have been fulfilled, but technical supervision and functional verification of BWMS are still limited. At Samarinda Port, there are several obstacles in the implementation of BWMS.

3.2.1. Technical Competence of the Ship's Crew

Low scores on operational indicators (Q6) and sediment management (Q9) indicate weak technical competence of ship crews. Specifically for indicator Q9 (0%), this result is a serious concern because it shows that no ship is properly managing ballast sediment. In fact, ballast sediment contains eggs and spores of organisms that have the potential to become vectors for the spread of invasive species across regions [28].

In addition, several bulk carriers and tankers flying foreign flags have been equipped with modern processing systems such as electro chlorination or UV treatment. However, their operation at Samarinda Port is often not carried out consistently due to short port waiting times and limited technical understanding.

These findings support the research results of [29], which stated that the failure of BWMC implementation globally is often caused by a lack of crew training on the BWMS system operational procedures. [1] also emphasized that the human factor is the main determinant of BWMS success, even certified systems can fail if not operated according to technical guidelines. In Europe, as many as 49% of ships fail to meet the D-2 standard due to minimal technical inspections and crew training [30]. Similarly, [14] found that higher levels of compliance can be achieved as crew experience in BWMS operation and maintenance increases. Effectiveness is not only determined by the availability of facilities, but also by the ability of policies to produce real impacts on the ground [31].

3.2.2. Use of Technology and Water Quality

Most vessels operating at Samarinda Port still use the Ballast Water Exchange (BWE) system on the high seas, due to the limited installation of Ballast Water Management Systems (BWMS) based on filtration and disinfection. Several studies related to the use of ballast water testing technology have proven to be able to meet the required standards. [13, 32] found that the electrolysis and UV-based BWMS treatment process showed the highest effectiveness in reducing phytoplankton density by more than 99%, while the hydroxyl radical oxidation and membrane separation-based systems still left living organisms. The combination of filtrationUV and filtrationelectrolysis had the highest effectiveness in meeting the IMO D-2 requirements; in addition, it was able to reduce the risk of chemical residues. [14] found that the BWMS filter mesh size is an important predictor in BWMS treatment. The findings of [20], combining ballast water treatment technology between filtration + UV-C radiation of various salinities, can meet the biological discharge standards required by the D-2 standard.

3.2.3. Water Quality

Water quality also influences the effectiveness of BWMS. The water conditions in the Mahakan River have different salinity compared to the waters from which ships originate, which can affect the survival rate of invasive alien species carried through ballast water. Ballast water analysis results between methods are often inconsistent, so standardized testing procedures are needed so that technical inspection results can be relied upon at the port level [33].

The technical success of a BWMS is greatly influenced by the use of technology that is appropriate to the characteristics of the waters [15, 34, 35]. A study at the Port of Shanghai noted that more than 80 percent of ballast water

samples treated with BWMS still exceeded the D-2 limit, with a density of living organisms reaching 2.3×10^4 ind./m³. This condition indicates that the technical effectiveness of a BWMS is greatly influenced by variations in environmental conditions and the operational quality of the ship. In selecting an appropriate ballast water treatment system, it is necessary to consider the water conditions (e.g., pH, temperature, salinity) and native species in the maritime area where the ship will operate. [15, 34].

For the case of freshwater with poor water quality, such as in Samarinda Port, Further findings [15] said BWMS operating in freshwater ports with poor water quality may face challenges in meeting Regulation D-2. [36] also emphasized that in Southeast Asia, BWMS performance often fails to meet IMO D-2 standards in waters with high turbidity and Total Suspended Solids (TSS) levels due to filter clogging and decreased oxidation effectiveness.

3.2.4. Infrastructure Limitations

Ship inspections at the Port are more focused on checking BWMC documents, not on sampling. The absence of a ballast water testing laboratory at the Port means that the Port authorities can only conduct administrative verification without technical inspections in the laboratory to ensure the quality of the discharged ballast water. In fact, the effectiveness of BWMC supervision also depends on the port's ability to take samples and laboratory testing [37]. In line with the research of [17], ports in Indonesia still face similar obstacles due to limited supporting facilities for BWMS implementation. Limited supervision infrastructure also affects the weak implementation of BWMS [38].

3.2.5. Institutions

From an institutional perspective, the absence of a BWMP, BWRB, and suboptimal field supervision remain major obstacles hampering the effectiveness of BWMC implementation. Low ratings for the BWMP (Q7) and BWRB (Q8) indicate weak continuous compliance practices. This situation has the potential to undermine the credibility of the marine environmental monitoring system because ballast

water management activities are not documented through an audit trail. Oversight responsibilities are spread among the Authority Port Office (PAO), Pelindo, and environmental agencies. However, the lack of integration between the three has limited ballast water monitoring to document validation without technical verification in the field. [39] emphasize the importance of integrating ship environmental monitoring through a risk-based Port State Control (PSC) approach. Similarly, [27] found that the effectiveness of BWMC is influenced by the port authority's ability to conduct routine inspections of ship documents and operations. [40] argues that the complexity of inter-agency coordination and limited technical resources often result in non-uniform implementation of BWMC across ports. [41] also stated that weak coordination between maritime authorities and the limited ability of PSC officers to conduct rapid ballast water tests are the main obstacles to the implementation of the convention in China.

3.3. Development Strategy for the Implementation of BWMC at Samarinda Port

The implementation of the Ballast Water Management Convention (BWMC) at Samarinda Port still faces an imbalance between technical strengths and regulatory weaknesses. Therefore, a strategy is needed to maximize BWMS implementation at the port. A strategy is needed to optimize the implementation of BWMC at Samarinda Port through a SWOT analysis. This SWOT approach refers to the Paris/Tokyo MoU 2025 Concentrated Inspection Campaign (CIC) indicators on Ballast Water Management (Q1Q9). Thus, each SWOT factor directly represents the compliance area assessed in Port State Control (PSC), including documentary aspects, BWMS operations, and crew familiarization. This analysis is also supported by the results of semi-structured interviews with port authorities, PSC officers, and ship operators, as well as the results of a review of the latest literature on BWMC implementation practices in other ports. A SWOT analysis is used to identify this strategy by linking strengths, weaknesses, and opportunities to identify S-O, W-O, S-T, and W-T strategies, as shown in the matrix in Table 4.

Table 4. SWOT matrix

External/Internal Factors	Opportunities (O)	Threats (T)
	1. Regulatory pressure from the IMO and the Paris/Tokyo MoU 2. Technical cooperation with developed countries (Japan, Europe) 3. Access to international funding for the maritime environment	1. Risk of alien species invasion in the Mahakam River 2. Potential IMO sanctions or restrictions 3. Deterioration of the port's reputation in the global shipping network.
Strengths (S)	Strategy SO	Strategy ST
1. Ownership of IBWMC (62.5%) 2. Most vessels have a certified BWMS	1. Optimizing BWMC ownership as initial capital for international collaboration.	1. Highlight ownership of IBWMC and BWMS certification as proof of compliance and commitment to the IMO.

3. National regulatory support (Presidential Decree No. 132/2015)	2. Expanding BWMS installation through access to global funding and technical cooperation schemes. 3. Utilizing Presidential Decree No. 132/2015 as a basis for strengthening national policies for BWMC compliance.	2. Leverage national regulatory support to maintain reputation and mitigate sanctions risk. 3. Build compliance-based maritime diplomacy to enhance international trust.
Weaknesses (W)	Strategi WO	Strategi WT
1. BWMS operations are not optimal (Q6: 37.5%) 2. Sediment management has not been implemented (Q9: 0%). 3. BWMP is not available (Q2Q3: 0%) 4. BWRB is still limited (Q8: 37.5%) 5. No evidence of internal/external inspections 6. BWMS retrofit costs are high 7. Ballast testing facilities are not yet available.	1. Promote international technical cooperation to accelerate the installation and testing of BWMS. 2. Optimize access to global funding to cover vessel retrofit costs. 3. Implement a technology transfer and crew training program based on CIC indicators.	1. Develop a roadmap for the gradual fulfillment of technical indicators (CIC Q6 and Q9). 2. Strengthen the documentation and inspection system (Q2Q8) to avoid PSC sanctions. 3. Provide national fiscal incentives for ship operators to reduce the burden of retrofit costs.

The SO strategy emphasizes leveraging internal strengths to seize external opportunities.

- IBWMC ownership and national regulatory support form the basis for strengthening international cooperation and expanding BWMS adoption.
- CIC-based training (Q1 and Q5) is required to improve technical competence and operational compliance.
- The availability of ballast water management facilities enhances the role of Port State Control Officers (PSCOs) and Port Quarantine Agencies in ballast water supervision.

The WO strategy is aimed at addressing internal weaknesses by exploiting external opportunities.

- International technical cooperation programs can accelerate the installation of BWMS and support the construction of ballast water testing laboratories. The effectiveness of BWMC implementation is greatly influenced by a combination of compliance with international regulations, increasing ship crew competency through continuous training, and adequate port infrastructure support [42, 43]. Technical training and ballast water sampling guidelines as part of the WO strategy in the context of Indonesian ports [44]. Thus, the strategy of strengthening technical and institutional capacity through international cooperation is a key step in overcoming operational obstacles to BWMS while increasing the effectiveness of BWMC implementation at Samarinda Port.

The ST strategy aims to use internal strengths to minimize external threats. Ownership of IBWMC and BWMS certification is evidence of Indonesia's commitment to compliance with IMO, while strengthening Indonesia's diplomatic position in international maritime forums.

Strengthening national compliance and regulatory aspects can serve as legitimacy to reduce the risk of sanctions and maintain the port's reputation in the global shipping network. The application of strict sanctions for violations of ballast water regulations and the establishment of safe ballast disposal zones to minimize the risk of marine pollution and maintain the port's reputation at the international level [44].

The WT strategy focuses on defensive measures to prevent internal weaknesses from exacerbating external threats.

- Developing a roadmap for the gradual fulfillment of technical indicators (CIC Q6 and Q9), as well as improving the documentation system (CIC Q2Q8), is necessary to avoid the risk of IMO sanctions.
- Providing fiscal incentives for ship operators can encourage increased compliance without increasing operational costs.
- A BWMS retrofit subsidy scheme and compliance-based incentives are effective measures to strengthen national preparedness for IMO inspections and regional MoUs [17]. This WT strategy is a preventative approach oriented towards mitigating institutional and economic risks.

Overall, these four strategies complement each other in building a measurable, sustainable, and risk-based Port State Control compliance system. This approach aligns with [45] strategic management theory, which emphasizes that integrating internal and external factors is key to generating implementable and contextual strategies to strengthen the effectiveness of national maritime policy.

4. Conclusion and Implication

4.1. Conclusion

- The level of vessel compliance is still low in regulatory aspects and moderate in technical aspects. Although most vessels have BWMC certificates, document management, such as BWMP and BWRB, is not yet optimal.
- Factors contributing to the ineffectiveness of the BWMC at Samarinda Port include: low testing laboratory capacity, a lack of certified inspection officers, and limited crew training, which are the main obstacles to meeting IMO standards.
- Strategy for improving BWMS implementation at Samarinda Port:
 - Strengths and Opportunities (SO) can serve as strategic capital for building international cooperation and expanding BWMS implementation.
 - Weaknesses and Threats (WT) require institutional improvements and the development of a gradual BWMC implementation roadmap.
 - A balance between adaptive and defensive strategies is key to successfully strengthening the BWMC at Samarinda Port.

4.2. Implication

- This study provides the first empirical contribution using the Paris/Tokyo MoU 2025 Concentrated Inspection Campaign (CIC) indicators to assess vessel compliance with the BWMC at river ports.

- A two-dimensional analysis of technical and regulatory compliance indicates that the gap between administrative compliance and technical performance is a major challenge to implementing the BWMC at the regional port level. This situation emphasizes the need for an adaptive oversight model that, in addition to focusing on administrative certification, also focuses on improving technical and institutional capacity through training, periodic audits, and the integration of digital-based oversight systems.
- To increase the effectiveness of BWMC implementation, strategic steps are needed in the form of: (1) construction of ballast water testing laboratories at river ports; (2) increasing the technical competence of ship crews and port officers; (3) integration of digital reporting systems through Inaportnet and the Smart Port concept; and (4) strengthening cross-institutional coordination between Authority Port, Pelindo, and regional environmental agencies. These efforts are expected to improve the technical and regulatory compliance of ships with international standards, strengthen the reputation of Samarinda Port as a port that complies with environmental conventions, and protect the Mahakam River ecosystem from the threat of invasive species.
- Academically, this research broadens the horizon of maritime environmental governance studies by presenting a new, understudied context: the application of global environmental conventions to tropical river ports in developing countries. These findings not only emphasize the importance of harmonizing national policies with IMO standards but also open up space for the future development of the adaptive compliance framework concept. Thus, this article makes a significant contribution to the international literature on the implementation of sustainable maritime policies in the operational context of river ports in Southeast Asia.

References

- [1] Matej David, and Stephan Gollasch, *Global Maritime Transport and Ballast Water Management*, 1st ed., Springer Dordrecht Publishing, 2015. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [2] Weifeng Zhou et al., "Diversity and Potential Environmental Risks of DNA Viruses on International Ships' Ballast Water at Shanghai Port, China," *Marine Pollution Bulletin*, vol. 225, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [3] Romina Kraus, "Ballast Water Management in Ports: Monitoring, Early Warning and Response Measures to Prevent Biodiversity Loss and Risks to Human Health," *Journal of Marine Science and Engineering*, vol. 11, no. 11, pp. 1-28, 2023. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [4] Setyo Budi Kurniawan et al., "Ecological impacts of Ballast Water Loading and Discharge: Insight into the Toxicity and Accumulation of Disinfection by-Products," *Heliyon*, vol. 8, no. 3, pp. 1-8, 2022. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [5] Verónica Soto-López et al., "Risk Analysis of Invasive Species by Ballast Water: Case Study in the Port of Gijón, Bay of Biscay," *Journal of Marine Systems*, vol. 252, pp. 1-12, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [6] Yating Chen et al., "Ballast Water Management Systems (BWMS) Type Approval: A new Application for Flow Imaging Microscopy (FlowCAM)," *Regional Studies in Marine Science*, vol. 65, 2023. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [7] Yanan Wang et al., "Assessing the Effectiveness of Filtration+ UV-C Radiation for the Treatment of Simulated Ballast Water at Various Holding Times," *Water Science and Technology*, vol. 87, no. 10, pp. 2564-2576, 2023. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]

- [8] Ömer Arslan, and Remzi Fiskin, “Understanding the Impact of Ballast Water Management Deficiencies on Ship Detentions: A Hybrid Predictive Approach,” *Reliability Engineering and System Safety*, vol. 267, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [9] Nwigwe Thank God Ifeanyi, and Minami Kiyokazu, “Challenges Hindering the ballast Water Management Compliance in Nigeria,” *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, vol. 6, no. 2-3, pp. 141-147, 2022. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [10] Jihong Chen et al., “Multi-Data Fusion and Machine Learning for Predicting Ballast Water Discharge in Ports,” *Marine Pollution Bulletin*, vol. 224, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [11] Wei Feng et al., “Evaluate the Compliance of Ballast Water Management System on Various Types of Operational Vessels based on the D-2 Standard,” *Marine Pollution Bulletin*, vol. 194, 2023. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [12] Anthony Ricciardi, and Hugh J. MacIsaac, “Vector Control Reduces the Rate of Species Invasion in the World’s Largest Freshwater Ecosystem,” *A Journal of The Society for Conversation Biology*, vol. 15, no. 2, pp. 1-12, 2022. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [13] Yan Zhang et al., “Comparative Study on Phytoplankton Treatment Effectiveness of the Ballastwater Management System with four Different Processes,” *Water*, vol. 16, no. 15, pp. 1-15, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [14] Sarah A. Bailey et al., “First Evaluation of Ballast Water Management Systems on Operational Ships for Minimizing Introductions of Nonindigenous Zooplankton,” *Marine Pollution Bulletin*, vol. 182, pp. 1-11, 2022. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [15] Sean Yardley et al., “Optimizing Ballast Water Management: An Evaluation of Ballast Water Treatment System Performance in Challenging Water Conditions,” *Canadian Journal of Fisheries and Aquatic Sciences*, vol. 83, pp. 1-10, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [16] Richmond Santani Basant et al., “Ballast Water Management in Small Island Developing States (SIDS) of the Caribbean,” *Marine Policy*, vol. 187, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [17] Ridho Apriansyah, K.P. Suharyono S. Hadiningrat, and Febri Pramudya Wardani, “Effectiveness of Ballast Water Management for Marine Biota Conservation in Indonesia,” *Journal of the Universe of Management and Economic Science*, vol. 1, no. 4, pp. 404-417, 2025. [[Google Scholar](#)] [[Publisher Link](#)]
- [18] Dominic C. DiGiulio, Seth B.C. Shonkoff, and Robert B. Jackson, “The need to Protect Fresh and Brackish Groundwater Resources During Unconventional Oil and Gas Development,” *Current Opinion in Environmental Science and Health*, vol. 3 pp. 1-7, 2013. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [19] Sri Purwati et al., “The Diversity of Fish Species in the Lempake Tepian River, Sungai Pinang District, Samarinda City,” *BioSmart Scientific Journal (Jibs)*, vol. 7, no. 1, pp. 12-24, 2021. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [20] Zhaowen He et al., “Evaluation Efficacy of Filtration + UV-C Radiation for Ballast Water Treatment at Different Salinity,” *Journal of Environmental Management*, vol. 401, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [21] Á. Rodríguez-Ruiz et al., “Effects of UV-LED Irradiation on Decapod Crustacean Larval Mortality, Motility, and Respiration: Implications for Ballast Water Treatments and Invasive Species Management,” *Marine Pollution Bulletin*, vol. 225, pp. 1-9, 2026. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [22] Nuris Samsi Aningtyas, and Minto Basuki, “Implementation Model of Government Regulations Concerning Ballast Water Management at Tanjung Perak Port, Surabaya,” *Proceedings of the Seminar on Earth and Marine Technology*, vol. 2, no. 1, pp. 61-66, 2020. [[Publisher Link](#)]
- [23] A. Sulaiman et al., “The Compliance of Ship's Crew Toward International Convention Implementation for Controlling of Ballast Water and Sediment from Ships in Offshore Port of Taboneo,” *Omni-Akuatika*, vol. 14, no. 1, pp. 62-68, 2018. [[Google Scholar](#)]
- [24] Arul Efansyah, and Minto Basuki, “Ship Ballast Water Management Model Due to Deballasting at Surabaya Container Port using Bow Tie Risk Assessment Method,” *Proceedings of the Seminar on Earth and Marine Technology*, vol. 3, no. 1, pp. 232-236, 2021. [[Google Scholar](#)] [[Publisher Link](#)]
- [25] Minto Basuki, Lukmandono, and Maria Margareta Zau Beu, Externalities Factors Based on Environmental Risk Assessment in Ballasting and Deballasting Processes in the Pelindo II Jakarta Area, Applied Technology Based on Local Wisdom, 2019. [Online]. Available: https://www.academia.edu/103913404/Faktor_Eksternalitas_Berbasis_Environmental_Risk_Assessment_Pada_Proses_Ballasting_Dan_Deballasting_DI_Daerah_Pelindo_II_Jakarta
- [26] Hugi Cerlyawati, and Apriyanto Budhi Wibowo, “Implementation of Ballast Water Management Convention Compliance by Merchant Vessel Crews in Indonesia,” *Journal of Engineering and Science Control*, vol. 1, no. 4, pp. 104-114, 2023. [[Publisher Link](#)]
- [27] D.A. Wright, “Compliance Assessment for the Ballast Water Convention: Time for a Re-Think? A UK Case Study,” *Journal of Marine Engineering and Technology*, vol. 20, no. 4, pp. 254-261, 2018. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [28] Elizabeta Briski, Sarah A. Bailey, and Hugh J. MacIsaac, “Separation Strategies for Invertebrate Dormant Stages Contained in Sediment,” *Aquatic Biology*, vol. 18, no. 3, pp. 209-215, 2013. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [29] Øyvind Endresen et al., “Challenges in Global Ballast Water Management,” *Marine Pollution Bulletin*, vol. 48, no. 7-8, pp. 615-623, 2004. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]

- [30] Okko Outinen et al., “Biological Testing of Rhipps Ballast Water Indicates Challenges for the Implementation of the Ballast Water Management Convention,” *Frontiers in Marine Science*, vol. 11, pp. 1-13, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [31] Terry Connolly, Edward J. Conlon, and Stuart Jay Deutsch, “Organizational Effectiveness: A Multiple-Constituency Approach,” *Academy of Management Review*, vol. 5, no. 2, pp. 211-217, 1980. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [32] T.H. Nguyen et al., “A Study on Selection of Ballast Water Treatment Technologies to Meet Bwm 2004 Convention,” *Water Conservation*, vol. 5, no. 1, pp. 53-59, 2021. [[CrossRef](#)] [[Google Scholar](#)]
- [33] Johanna Bradie et al., “A Shipboard Comparison of Analytic Methods for Ballast Water Compliance Monitoring,” *Journal of Sea Research*, vol. 133, pp. 11-19, 2018. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [34] Burcu Sayinli et al., “Recent Progress and Challenges Facing Ballast Water Treatment - A Review,” *Chemosphere*, vol. 291, 2022. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [35] Jieyou Xiang et al., “Discharge Compliance at Shanghai Port – A Case Study on Discharged Ballast Water from Vessels with Ballast Water Treatment System,” *Management of Biological Invasions*, vol. 14, no. 1, pp. 178-191, 2023. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [36] Pung-Guk Jang, Bonggil Hyun and Kyoungsoo Shin, “Ballast Water Treatment Performance Evaluation Under Real Changing Conditions,” *Journal of Marine Science and Engineering*, vol. 8, no. 10, pp. 1-19, 2020. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [37] Qiong Wang et al., “Towards More Effective Ship Ballast Water Monitoring: Evaluating and Improving Compliance Monitoring Devices (CMDs),” *Water*, vol. 17, no. 19, pp. 1-17, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [38] Vidya Selasдини, and Nafi Almuzani, “Implementation of Port Acceptance Facilities: Study at Tanjung Priok Port,” *Journal of Accounting and Finance Management*, vol. 3, no. 2, pp. 56-66, 2022. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [39] Arif Junaidi, Hartono Yudo, and Hasnida Ab-Sama, “Identification of Data Analysis Methods and Focus Trends in Port State Control Inspections: A Comprehensive Literature Review,” *International Journal of Technology*, vol. 15, no. 1, pp. 179-194, 2024. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [40] Teemu Makkonen, and Tommi Inkinen, “Systems of Environmental Innovation: Sectoral and Technological Perspectives on Ballast Water Treatment Systems,” *WMU Journal of Maritime Affairs*, vol. 20, no. 1, pp. 81-98, 2021. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [41] Shuai Hao, “China's Implementation of the Ballast Water Convention, Analysis of Treatment Technology and Main Points of PSC Inspection,” Dissertation, Dalian, China, 2020. [[Google Scholar](#)] [[Publisher Link](#)]
- [42] Wei Feng et al., “Evaluate the Compliance of Ballast Water Management System on Various Types of Operational Vessels based on the D-2 Standard,” *Marine Pollution Bulletin*, vol. 194, pp. 1-25, 2023. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [43] Ramayanti Ramayanti, “Manajemen Ballast Water untuk Mencegah Pencemaran Lingkungan Laut di Kapal MT.Timur Laut Mas 2,” *Publications in the Industrial Engineering Sub-Discipline*, vol. 3, no. 2, pp. 79-89, 2025. [[CrossRef](#)] [[Google Scholar](#)] [[Publisher Link](#)]
- [44] Agus Tjahjono, and Wisnu Handoko, “The Implementation of Ballast Water Management in Port of Tanjung Emas Semarang: Strategy and Model,” *Aquaculture, Aquarium, Conservation and Legislation*, vol. 11, no. 4, pp. 1231-1247, 2018. [[Google Scholar](#)] [[Publisher Link](#)]
- [45] J. David Hunger, and Thomas L. Wheelen, *Strategic Management and Business Policy: Toward Global Sustainability*, 16th ed., Pearson Education, 2024. [[Google Scholar](#)] [[Publisher Link](#)]