

Effectiveness of Ballast Water Management for Marine Biota Conservation in Indonesia

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Abstract. *The implementation of ballast water management in Indonesia still faces significant challenges, despite efforts to adopt international standards as regulated by the International Maritime Organization (IMO). The main challenges include infrastructure limitations, lack of supervision and law enforcement, limited human resources, and high implementation costs. Consequently, the risk of invasive species entering through ballast water remains high and threatens Indonesia's marine ecosystem. To address these issues, strategic measures are needed, such as infrastructure development, strengthening supervision and law enforcement, enhancing human resource capacity through regular training, providing economic incentives, and reinforcing international cooperation. The implementation of these strategies is expected to improve the effectiveness of ballast water management, thereby supporting the preservation of marine ecosystems and the sustainability of Indonesia's maritime environment.*

Keywords: *Ballast Water Management, Invasive Species, Maritime Infrastructure*

Abstrak. Implementasi pengelolaan air balas di Indonesia masih menghadapi tantangan yang cukup besar, meskipun sudah ada upaya untuk mengadopsi standar internasional seperti yang diatur oleh International Maritime Organization (IMO). Tantangan utama yang dihadapi antara lain keterbatasan infrastruktur, kurangnya pengawasan dan penegakan hukum, sumber daya manusia yang terbatas, dan biaya implementasi yang tinggi. Akibatnya, risiko masuknya spesies invasif melalui air balas tetap tinggi dan mengancam ekosistem laut Indonesia. Untuk mengatasi permasalahan tersebut, diperlukan langkah-langkah strategis, seperti pembangunan infrastruktur,

penguatan pengawasan dan penegakan hukum, peningkatan kapasitas sumber daya manusia melalui pelatihan secara berkala, pemberian insentif ekonomi, dan penguatan kerja sama internasional. Penerapan strategi-strategi tersebut diharapkan dapat meningkatkan efektivitas pengelolaan air balas, sehingga dapat mendukung kelestarian ekosistem laut dan keberlanjutan lingkungan maritim Indonesia.

Kata Kunci: Infrastruktur Maritim, Manajemen Air Balas, Spesies Invasif

INTRODUCTION

Indonesia, as the world's largest archipelagic country, possesses a highly diverse marine biodiversity. This marine biodiversity not only serves as a vital natural resource for local communities but also plays a crucial role in maintaining the balance of the global marine ecosystem. However, the sustainability of Indonesia's marine life is currently facing serious threats, one of which is the introduction of invasive species through ships' ballast water.

Ballast water is water taken by ships to maintain stability and balance when they are not carrying cargo. This water often contains marine organisms, including plankton, larvae, and even adult species, which can be transferred from one body of water to another. When this ballast water is discharged at the destination, foreign organisms can become invasive species that threaten the local ecosystem. These invasive species can outcompete native species, alter habitats, and even lead to the extinction of local species, disrupting ecological balance.

This threat has been globally recognized, and the International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) in 2004. The convention aims to prevent the spread of invasive species through effective ballast water management. As an IMO member state, Indonesia has taken steps to implement this convention through national policies, such as the Ministry of Transportation regulations on ballast water management for ships operating in Indonesian waters.

The ecological impacts of invasive species are significant. They can disrupt food chains, reduce biodiversity, and damage natural habitats. Additionally, the economic impacts cannot be ignored. Invasive species can harm fisheries, aquaculture, and maritime

infrastructure, ultimately affecting the livelihoods of coastal communities and national revenue.

Therefore, the implementation of ballast water management has become increasingly urgent. Measures such as mid-ocean ballast water exchange, filtration systems, and chemical or physical treatment of ballast water need to be strictly implemented to reduce the risk of invasive species spread. These efforts will not only protect Indonesia's marine biodiversity but also support long-term economic and ecological sustainability.

This study seeks to investigate the effectiveness of ballast water management in Indonesia by addressing three key research questions. First, it examines how effectively current ballast water management practices prevent the entry of invasive species into Indonesian waters. Second, it identifies the main challenges and obstacles encountered during the implementation of these practices. Third, it aims to develop strategic recommendations to enhance the effectiveness of ballast water management nationwide. These questions guide the research in exploring regulatory frameworks, practical implementation, and opportunities for policy and operational improvements in protecting Indonesia's marine environment.

In line with the problem formulation, this study has four primary objectives. The first is to assess the effectiveness of ballast water management implementation in Indonesia. This involves evaluating the current policies, regulations, and management practices to determine how well they prevent the introduction of invasive species through ballast water discharge. Through a review of the literature and relevant data, the research will highlight both the strengths and weaknesses of existing systems. The second objective is to identify the technical, operational, regulatory, and financial challenges that hinder the successful implementation of ballast water management. Recognizing these barriers is essential for understanding the underlying issues and developing targeted solutions.

The third objective is to formulate strategic recommendations aimed at improving the performance and effectiveness of ballast water management in Indonesia. These strategies will address regulatory enhancements, technological advancements, capacity building, and improved coordination among stakeholders. The final objective is to contribute meaningfully to marine environmental policy and management practices. By

offering practical insights and academic analysis, the study seeks to support national efforts in safeguarding Indonesia's marine biodiversity from the threat of invasive species, making the research both academically valuable and practically relevant.

This research offers both theoretical and practical benefits for a wide range of stakeholders, including policymakers, maritime professionals, researchers, and the general public. Theoretically, the study contributes to scientific knowledge in the field of marine environmental management, particularly with regard to ballast water regulation and the ecological risks posed by invasive species. It provides a solid reference point for future academic inquiries and innovative solutions related to ballast water treatment. Additionally, the research enhances understanding of the mechanisms behind invasive species spread, their ecological and economic impacts, and effective conservation strategies. Moreover, it evaluates the alignment between Indonesia's national policies and international standards, such as the IMO's Ballast Water Management (BWM) Convention, offering valuable insights for regulatory improvement.

From a practical perspective, the study provides recommendations for government agencies—particularly the Ministry of Transportation, Ministry of Marine Affairs and Fisheries, and Ministry of Environment—to support the development of more effective policies. For the maritime and port industry, the findings offer guidelines for ship operators, shipping companies, and port authorities to align ballast water practices with international regulations, thereby reducing the risk of environmental harm. The general public also benefits through increased awareness of the dangers of invasive species and the importance of responsible ballast water management. Finally, for fellow researchers, this study serves as a valuable source of knowledge and inspiration for further investigations into marine ecosystem protection, invasive species control, and sustainable maritime practices.

LITERATURE REVIEW

International Maritime Policies and Regulations

International maritime policies and regulations play a crucial role in ensuring safety and environmental protection in the shipping industry. Two of the most significant conventions in this regard are MARPOL and SOLAS.

1. MARPOL (International Convention for the Prevention of Pollution from Ships)

MARPOL, first adopted in 1973 and significantly amended in 1978, is the primary international convention aimed at preventing marine pollution by ships. It addresses various forms of pollution, including oil spills, noxious liquid substances, harmful substances in packaged form, sewage, garbage, and air pollution. According to Smith et al. (2021), MARPOL has been instrumental in reducing oil spills by 90% since its implementation. However, challenges remain in enforcing these regulations, particularly in developing countries where resources for monitoring and enforcement are limited (Johnson & Lee, 2022).

2. SOLAS (International Convention for the Safety of Life at Sea)

SOLAS, first adopted in 1914 and revised multiple times, sets minimum safety standards for the construction, equipment, and operation of ships. It includes provisions for fire safety, life-saving appliances, and emergency procedures. Anderson et al. (2020) highlight that SOLAS has significantly improved fire safety on ships, but they also note that human error remains a major factor in maritime accidents. Recent studies, such as Brown et al. (2023), emphasize the need for better training and stricter enforcement to reduce fire-related incidents on tanker ships.

National Policies and Regulations

In addition to international conventions, national governments have established their regulations to address maritime safety and environmental protection. These regulations often complement international standards but may include additional requirements tailored to local conditions.

1. Government Regulations on Safety and Environmental Protection

For example, Indonesia has implemented Government Regulation No. 21 of 2010 on the Protection and Management of the Marine Environment, which aligns with MARPOL but includes specific provisions for archipelagic waters. Wijaya et al. (2021) argue that while these regulations are comprehensive, their implementation is often hindered by a lack of coordination between government agencies and limited resources for enforcement. Similarly, Nguyen et al. (2022) discuss Vietnam's efforts to integrate MARPOL into national law, noting that while progress has been made, challenges such as corruption and inadequate infrastructure persist.

Previous Studies

Several studies have examined the effectiveness of maritime policies and regulations in preventing fires and environmental pollution. These studies provide valuable insights into the challenges and opportunities for improving regulatory frameworks.

1. Studies on Maritime Policies and Pollution Prevention

Zhang et al. (2020) conducted a comprehensive review of MARPOL's effectiveness in reducing oil spills in the Asia-Pacific region. They found that while the convention has been successful in developed countries, its impact in developing nations is limited due to weak enforcement mechanisms. Similarly, Kumar et al. (2021) analyzed the implementation of SOLAS on Indian-flagged ships and identified gaps in crew training and emergency preparedness as major obstacles to improving fire safety.

2. Case Studies on Tanker Ships

Garcia et al. (2023) conducted a case study on a major oil spill caused by a tanker ship in the Mediterranean Sea. They concluded that while MARPOL regulations were technically followed, human error and inadequate maintenance were the primary causes of the incident. This highlights the need for stricter oversight and better training for ship crews. Another study by Lee & Park (2024) focused on fire prevention measures on South Korean tanker ships. They found that while SOLAS requirements were generally met, there was a lack of regular drills and insufficient investment in fire detection systems.

3. Emerging Trends and Future Directions

Recent research has also explored the role of technology in enhancing maritime safety and environmental protection. Chen et al. (2023) discuss the potential of artificial intelligence (AI) and the Internet of Things (IoT) in improving fire detection and pollution monitoring on ships. They argue that integrating these technologies into existing regulatory frameworks could significantly reduce risks. Similarly, Ali et al. (2024) highlight the importance of green shipping initiatives, such as the use of alternative fuels and energy-efficient technologies, in achieving long-term sustainability in the maritime sector.

RESEARCH METHODOLOGY

Type of Research

This study employs a qualitative descriptive method with a literature review approach. This approach is chosen because the research aims to describe, analyze, and interpret phenomena related to ballast water management and its impact on Indonesia's marine biota based on available literature. A literature review enables researchers to collect and analyze secondary data from various reliable sources, such as scientific journals, books, reports, and official documents.

Data Sources

The data sources used in this study include:

1. Scientific Journals: Recent articles (2020–2025) discussing topics related to ballast water management, invasive species, and marine biodiversity.
2. Books: References covering marine ecosystems, maritime environmental management, and international policies related to ballast water.
3. Reports: Official reports from international organizations such as the International Maritime Organization (IMO) and Indonesian government institutions like the Ministry of Transportation and the Ministry of Marine Affairs and Fisheries.
4. Regulations and Legal Documents: National and international legal policies such as the BWM Convention and Minister of Transportation regulations on ballast water management.
5. Official Websites: Websites of international organizations, government agencies, and research institutions that provide data and information relevant to the research topic.

Data Collection Techniques

The data collection technique used in this study is a literature review, with the following steps:

1. Literature Search: Identifying relevant literature through academic databases such as Google Scholar, ScienceDirect, Springer, and JSTOR. The keywords used include "ballast water management," "invasive species," "Indonesia's marine biodiversity," and "BWM Convention."
2. Source Selection: Selecting credible and relevant sources, prioritizing the most recent publications (2020–2025).
3. Data Collection: Extracting data and information from selected sources, including text, tables, graphs, and statistics.

4. Data Categorization: Organizing data into themes or subtopics, such as policy analysis, ecological impacts, and ballast water management methods.

Data Analysis Techniques

The collected data is analyzed using qualitative descriptive analysis techniques. The analysis steps include:

1. Data Breakdown: Breaking down data and information obtained from various sources to understand the context and relationships between variables.
2. Phenomenon Explanation: Explaining phenomena related to ballast water management, invasive species, and their impact on Indonesia's marine biota based on literature findings.
3. Data Interpretation: Interpreting data to answer research questions, such as the effectiveness of policies, implementation challenges, and strategic recommendations.
4. Information Synthesis: Compiling findings and analyses into coherent conclusions that align with the research objectives.

This methodology ensures that the study provides a comprehensive and systematic analysis of ballast water management and its implications for Indonesia's marine environment.

RESULTS AND DISCUSSION

Effectiveness of Ballast Water Management in Indonesia

Ballast water management is a strategic effort to prevent the spread of invasive species through ship movements. In Indonesia, although the country has ratified the Ballast Water Management (BWM) Convention through Minister of Transportation Regulation No. 29 of 2021, field implementation still faces numerous challenges. According to Gunawan & Sutrisno (2021), the application of this system remains suboptimal due to the gap between existing regulations and operational conditions at Indonesia's major ports.

Compliance Levels and Current Data

Data released by the Ministry of Transportation (2023) indicates that compliance with ballast water management standards is still low, with only 40% of foreign vessels and 30% of domestic vessels adhering to regulations. Sari et al. (2022) further highlight that the low compliance rates indicate technical implementation issues and insufficient supervision. They emphasize that limited infrastructure and inadequate ballast water treatment technology are the main obstacles to achieving the desired effectiveness.

Technical Barriers and Infrastructure Limitations

Several obstacles identified in the literature include:

1. **Limited Port Facilities:** Many Indonesian ports lack modern ballast water treatment facilities. Rahmawati & Hidayat (2023) explain that low investment in treatment infrastructure prevents an optimal ballast water management system from being fully implemented.
2. **Technology in Small Vessels:** Many small vessels do not have adequate technology to treat ballast water. This limitation hinders compliance with international standards, as noted by Sari et al. (2022).

Case Study: Tanjung Priok Port

At Tanjung Priok Port, Jakarta, reports indicate the presence of invasive species, such as *Mytilopsis sallei* (black mussels), suggesting that ballast water management has not fully prevented the entry of foreign organisms. Gunawan & Sutrisno (2021) argue that the Tanjung Priok case is a clear indication of weak ballast water treatment effectiveness, caused by a lack of infrastructure and inconsistent supervision.

Improvement Efforts and Recommendations

Despite various challenges, there are ongoing efforts to improve ballast water management effectiveness, particularly through:

1. **Training and Awareness Enhancement:** Increased awareness and training for ship crews have shown progress, although, according to Rahmawati & Hidayat (2023), these training programs need to be further expanded and strengthened.
2. **Technology and Infrastructure Development:** Sari et al. (2022) suggest greater investment in port infrastructure and the adoption of advanced ballast water treatment technologies to overcome current limitations.

Overall, ballast water management effectiveness in Indonesia remains in the development stage and is not yet fully optimized, as evidenced by studies conducted between 2020 and 2025. The key influencing factors include low compliance levels, limited infrastructure, and insufficient treatment technology. Strengthening training programs and infrastructure investment is crucial to ensuring that management standards are met comprehensively and systematically.

Challenges and Obstacles

The implementation of ballast water management in Indonesia faces significant challenges and obstacles. The main challenges identified in the literature include:

1. Limited Facilities at Ports

Many Indonesian ports lack adequate ballast water treatment facilities. According to Wibowo et al. (2023), only 15% of major ports are equipped with ballast water treatment systems. This limitation hampers the ability of ports to prevent invasive species entry through ships' ballast water discharge.

2. Weak Supervision and Law Enforcement

Supervision of ship compliance with ballast water management regulations remains weak due to limited human resources and monitoring tools. For example, at Tanjung Emas Port, Semarang, strengthening the role of Port State Control (PSC) and imposing stricter sanctions have been recommended to enhance compliance among merchant vessels with BWM regulations.

3. Lack of Stakeholder Awareness

Many shipowners and port operators do not fully understand the importance of ballast water management. This lack of awareness leads to suboptimal implementation. Aqila (2024) found that although Indonesia has ratified the BWM Convention, further socialization and training efforts are needed to improve stakeholders' understanding and commitment.

4. High Implementation Costs

The implementation of ballast water treatment technology requires significant investment, especially for small and medium-sized vessels. Arumsari (2017) states that the cost per unit of crude oil export increased by 0.8% to 3%, depending on the ballast water treatment method used. These high costs place an additional financial burden on shipowners, particularly those with limited financial capacity.

To address these challenges and obstacles, collaboration between the government, port authorities, and shipowners is essential in enhancing facilities, supervision, awareness, and financial support for effective ballast water management implementation in Indonesia.

Strategic Recommendations

1. Infrastructure Improvement

- A. **Building Ballast Water Treatment Facilities at Major Ports:** Major ports such as Tanjung Priok, Surabaya, and Makassar should be equipped with adequate ballast water treatment facilities. Basuki et al. (2019) suggest a ballast water management model that involves storing ballast water in barges or tank trucks for treatment before being discharged.
- B. **Providing Incentives for Ships Using Eco-Friendly Technology:** Incentives should be provided to encourage shipowners to adopt environmentally friendly ballast water treatment technologies, such as filtration and electrolysis systems. Arif et al. (2016) highlight the importance of technical and economic analysis in selecting ballast water management systems for ships in Indonesia.

2. Strengthening Supervision and Law Enforcement

- A. **Increasing the Number and Capacity of Inspectors:** Adding more inspectors equipped with advanced monitoring tools is necessary to ensure ships comply with BWM regulations. Aqila (2024) emphasizes the importance of strengthening the role of Port State Control (PSC) and imposing stricter sanctions on non-compliant vessels.
- B. **Conducting Regular Ship Inspections:** Routine inspections are needed to ensure ships operating in Indonesian waters adhere to ballast water management standards. Aqila (2024) highlights the need for defensive strategies in BWM implementation, including strengthening PSC roles and enforcing stricter sanctions.

3. Human Resource Capacity Building

- A. **Regular Training for Ship Crews and Port Operators:** Routine training on ballast water management procedures will enhance the competence and awareness of ship crews and port operators. Aqila (2024) stresses the importance of training and capacity building in ballast water management implementation.
- B. **Developing an Inclusive Maritime Education Curriculum:** A maritime education curriculum covering ballast water management topics should be developed to ensure comprehensive understanding from an early stage. Aqila

(2024) underscores the importance of education and training in BWM implementation.

4. Public Awareness and Socialization

- A. Public Awareness Campaigns on the Impact of Invasive Species: Campaigns highlighting the negative impacts of invasive species and the importance of ballast water management can raise public awareness. Aqila (2024) stresses the significance of socialization and public awareness efforts in BWM implementation.
- B. Engaging Coastal Communities and NGOs: Active participation from coastal communities and non-governmental organizations (NGOs) in marine conservation efforts can strengthen ballast water management strategy implementation. Aqila (2024) highlights the importance of collaboration among various stakeholders.

5. International Cooperation

- 1. Strengthening Collaboration with Other Countries and International Organizations: Partnerships with other countries and international organizations, such as the International Maritime Organization (IMO), can enhance knowledge sharing and technology adoption. Aqila (2024) emphasizes the importance of international cooperation in BWM implementation.
- 2. Adopting Best Practices from Other Countries: Learning from countries that have successfully implemented ballast water management can help Indonesia develop effective strategies. Aqila (2024) stresses the importance of adopting best practices in BWM implementation.

By implementing these strategies, Indonesia's ballast water management effectiveness can improve, reducing the spread of invasive species and protecting marine biodiversity.

CONCLUSION AND RECOMMENDATIONS

The implementation of ballast water management in Indonesia continues to face considerable challenges, despite efforts to align with international standards set by the International Maritime Organization (IMO). Several critical factors contribute to the suboptimal enforcement of these standards. One major issue is the limitation of

infrastructure, as many Indonesian ports lack adequate ballast water treatment facilities, making compliance difficult for visiting ships. In addition, supervision and law enforcement remain weak, with limited regulatory oversight and insufficient penalties for non-compliance. Human resource constraints also play a role, as many ship crews and port officials lack the necessary knowledge and training to manage ballast water effectively. Furthermore, the high costs associated with installing and maintaining treatment systems present financial burdens, especially for small and medium-sized vessels. These combined issues increase the risk of invasive species being introduced through ballast water discharge, posing a significant threat to Indonesia's marine ecosystems.

To address these challenges, several strategic recommendations are proposed to enhance the effectiveness of ballast water management in Indonesia. First, it is essential to develop and upgrade infrastructure by building proper treatment facilities at major ports. Second, supervision and enforcement should be strengthened by increasing the number and competence of inspectors and ensuring strict penalties for violations. Third, capacity-building initiatives such as regular training for ship crews and port personnel are necessary to ensure proper implementation of ballast water procedures. Fourth, economic incentives like tax reductions or subsidies could encourage shipowners to invest in environmentally friendly technologies. Lastly, international cooperation should be reinforced through partnerships with other countries and global organizations to exchange knowledge, technology, and best practices. By implementing these strategies, Indonesia can significantly improve its ballast water management system, thereby reducing the spread of invasive species and safeguarding marine biodiversity.

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