International Journal of Science, Strategic Management and Technology
Volume **02** Issue **05** May-**2026** | ISSN: **3108-1762 (Online)** | Impact Factor: 3.8
An International, Peer-Reviewed, Open Access Scholarly Journal Indexed in recognized academic databases

Solid Waste Management in Maritime Ports: A Legal and Empirical Analysis of Haldia Dock Complex, India

Srija

Amity University

https://doi.org/10.55041/ijsmt.v2i5.029

Cite this Article: Srija, (2026). Solid Waste Management in Maritime Ports: A Legal and Empirical Analysis of Haldia Dock Complex, India. International Journal of Science, Strategic Management and Technology, *02*(05). https://doi.org/10.55041/ijsmt.v2i5.029

Abstract

Marine pollution from ship-generated waste has become a significant environmental issue in global maritime operations. Ports, where ship-generated waste is collected, treated, and managed, are considered critical points, so having port waste management systems is a necessary measure to safeguard marine ecosystems. This research work deeply looks into the solid waste management practices at Haldia Dock Complex (HDC), a major maritime gateway of India. A mixed-method approach was adopted combining the collection of empirical survey data and doctrinal legal analysis. This paper looks into types of waste generated by ships, mechanisms of waste disposal and compliance with international treaties like MARPOL Annex V and national environmental legislations. The results of this paper show changes in waste generation patterns among different categories of ships and also new infrastructural and regulatory factors that affect the efficiency of waste management.

The paper also points out the indispensable requirement for technology improvement, stricter enforcement of regulations, and more awareness among the port/maritime stakeholders. The research work is a step in the right direction of sustainable port management and proposes a roadmap to align with international standards of the marine environment and promote open and transparent environmental practices in the shipping industry.

Keywords: Marine pollution, Solid waste management, Maritime law, MARPOL Annex V, Port sustainability, Haldia Dock Complex

1. Introduction

Oceans cover more than 70 % of Earth's surface and have a critical role in maintaining ecological balances and supporting marine biodiversity. Increased maritime trade and the operation of ships have led to a rise in marine pollution, especially solid waste coming from ships (Abdel-Shafy & Mansour, 2012). Besides plastics, food waste, hazardous materials, and oily residues, ship-generated waste could be a very serious threat to the marine ecosystems and the communities living on the coast. Ports, being the main connection points between maritime transport and land infrastructure, are also the places where sustainable waste management practices must be implemented. The proper handling of ship-generated waste is one of the main measures to prevent the pollution of the oceans and at the same time, international maritime environmental regulations such asthe International Convention for the Prevention of Pollution from Ships (MARPOL) (Khan & Memon, 2021) might be met.

Located in West Bengal, India, the Haldia Dock Complex (HDC) is the main port of maritime trade in eastern India. The port manages a large throughput of cargo and also, since it has a wide variety of vessels, it is an interesting case for

studying the management of ship-generated waste. Besides the growth of maritime activities, the environmental issues that result from the disposal of waste and marine pollution have become sources of concern.This paper decides to investigate the solid waste management at Haldia Dock Complex through an empirical and legal point of view. The research is concerned with the waste management systems presently in place, the extent to which the vessels comply with the provisions of the law, and the contribution of international treaties to the development of sustainable painting maritime environmental practices.

2. Literature Review

2.1 Marine Pollution and Ship-Generated Waste

Marine pollution resulting from ship operations includes oil spills, chemical discharges, plastic waste, and hazardous materials (Gregory, 2009). Studies indicate that maritime transport contributes significantly to ocean pollution, particularly through operational waste generated by ships and crew activities (Abdel-Shafy & Mansour, 2012).

Plastic debris is among the most persistent pollutants affecting marine ecosystems, causing entanglement, ingestion, and ecological damage to marine species (Gregory, 2009). The increasing volume of maritime trade has further intensified the accumulation of ship-generated waste in ocean environments.

2.2 International Regulatory Framework

The MARPOL Convention is the primary international legal instrument regulating marine pollution from ships. MARPOL Annex V specifically addresses garbage disposal from vessels and restricts the discharge of plastics and other solid waste into the ocean (IMO, 2022). Studies show that effective enforcement of MARPOL provisions significantly reduces marine pollution when ports provide adequate reception facilities (Arguello, 2020).

UNCLOS also establishes obligations for coastal states to protect the marine environment and regulate pollution originating from ships (Khan, 2023).

2.3 Waste Management Technologies in Maritime Operations

Technological innovations such as onboard incinerators, waste compactors, segregation systems, and port reception facilities have improved waste management efficiency in maritime operations (Baric et al., 2011). Integrated waste management systems combining recycling, energy recovery, and safe disposal mechanisms are increasingly recommended for sustainable maritime practices (Kaza et al., 2018).

Recent research highlights the role of smart waste management technologies and digital monitoring systems in improving waste collection and environmental compliance in ports (Ramesh et al., 2021).

3. Research Objectives

The study aims to:

1. Examine the types and quantity of solid waste generated by vessels operating at Haldia Dock Complex.
2. Evaluate the effectiveness of existing waste management systems at the port.
3. Analyze compliance with international and national maritime environmental regulations.
4. Identify technological and policy measures to improve sustainable waste management in maritime ports.

4. Research Questions

1. What is the composition and volume of solid waste generated by vessels at Haldia Dock Complex?
2. How effectively do vessels comply with international regulations governing marine waste disposal?
3. What technological innovations can reduce waste generation in maritime operations?
4. How can education and awareness programs improve waste management practices among ship crews?

5. Hypotheses

H1: Adoption of advanced waste treatment technologies significantly reduces the volume and environmental impact of ship-generated solid waste.

H2: Shipping companies implementing responsible waste management practices experience improved corporate reputation and stronger corporate social responsibility outcomes.

6. Methodology

This study employs a **mixed-methods research design**, combining empirical and doctrinal approaches.

6.1 Empirical Approach

A structured questionnaire survey was conducted among maritime stakeholders including port personnel, ship crew members, and waste management operators. The survey collected data regarding waste generation patterns, disposal practices, regulatory awareness, and compliance with environmental standards.

6.2 Doctrinal Analysis

Legal analysis was conducted to evaluate international and national regulations governing ship-generated waste, including:

- MARPOL Convention
- UNCLOS
- Environmental Protection Act (India)
- Solid Waste Management Rules, 2016

Ship-generated waste includes municipal, industrial, commercial, hazardous, biomedical, and electronic waste produced during vessel operations and crew activities. Improper disposal of such wastes significantly contributes to marine pollution and ecological degradation. In particular, hazardous components such as heavy metals—including mercury, lead, cadmium, and arsenic—pose serious risks to marine ecosystems due to their toxic, persistent, and bioaccumulative characteristics (Abdel-Shafy & Mansour, 2012; Gregory, 2009). These pollutants can accumulate in marine organisms and eventually enter the human food chain, threatening both biodiversity and public health. Additionally, the increasing prevalence of plastic debris and microplastics originating from shipping activities and land-based sources has heightened concerns about long-term marine environmental degradation (Kaza et al., 2018). International regulatory frameworks such as the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex V, developed under the International Maritime Organization (IMO), play a vital role in controlling ship-generated garbage and preventing its discharge into the ocean (IMO, 2022). MARPOL Annex V mandates strict guidelines for waste segregation, storage, treatment, and disposal, as well as maintaining garbage management plans and record books onboard vessels. Technological systems such as waste compactors, incinerators, oil–water separators, bilge water treatment units, and segregated waste storage bins are widely adopted to support compliance with these regulations (Arguello, 2020). Furthermore, the chapter highlights operational strategies adopted at Haldia Dock Complex, including port reception facilities, scheduled waste collection, pollution control measures, and emergency response mechanisms for hazardous spills. Overall, the findings stress that effective maritime solid waste management requires integrated approaches involving waste segregation, waste minimization, treatment technologies, safe disposal practices, and systematic monitoring in accordance with IMO environmental guidelines and MARPOL standards.

6.3 Results and Discussion Sources of Ship-Generated Waste Ship-generated waste primarily includes:

- Food waste
- Plastics and packaging materials
- Domestic waste from crew activities
- Hazardous waste such as oil residues and chemicals

Studies indicate that improper disposal of plastics and hazardous waste is a major contributor to marine pollution (Khan & Memon, 2021).

6.4 Waste Management Practices at Haldia Dock Complex

Haldia Dock Complex has implemented several waste reception facilities and operational mechanisms, including:

- Oil waste collection systems
- Hazardous liquid waste management facilities
- Scheduled waste collection from vessels
- Pollution monitoring systems
- Environmental protection infrastructure

These facilities help ensure compliance with international maritime environmental standards.

6.5 Regulatory Compliance

The study indicates that MARPOL Annex V plays a critical role in regulating waste disposal practices. However, challenges such as limited awareness among crew members, inadequate monitoring, and infrastructure constraints hinder full compliance.

6.6 Environmental and Operational Challenges

Key challenges include:

- Insufficient waste segregation onboard vessels
- Limited technological adoption
- Inadequate monitoring of waste disposal
- Financial constraints for infrastructure upgrades

7. Policy Implications

To improve waste management practices in maritime ports, the following measures are recommended:

1. Expansion of port reception facilities for ship-generated waste.
2. Adoption of digital monitoring systems for waste disposal.
3. Strengthening enforcement of MARPOL regulations.
4. Training programs for ship crews on sustainable waste management.
5. Promotion of green port initiatives and circular economy practices.

8. Conclusion

Marine pollution from ship-generated waste is a serious environmental issue in worldwide maritime operations. This paper emphasizes the necessity of effective management systems for waste at ports like Haldia Dock Complex. Although the port has initiated various methods of waste collection and disposal, there are still major areas of upgrading technologically, enforcing the regulations, and making the stakeholders more aware.

Adding green waste management procedures in line with the environmental rules of international maritime can go a long way in reducing the pollution of the oceans and encouraging ecologically responsible maritime transport.

References

Abdel-Shafy, H. I., & Mansour, M. S. (2012). A review on marine pollution: Sources, effects and management. *Egyptian Journal of Aquatic Research*, 38(3), 209–216.

Arguello, G. (2020). Environmentally sound management of ship wastes: Challenges and opportunities for European ports. *Marine Policy*, 117, 103915.

Baric, M., Smokrovic, M., & Butorac, D. (2011). Methods for waste disposal on commercial ships. *Pomorstvo*, 25(2), 335–351.

Bhatia, H. S. (2019). *A comprehensive book on solid waste management with applications*. New Delhi: Misha Books.

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings.
Philosophical Transactions of the Royal Society B, 364(1526), 2013–2025.

Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. World Bank.

Khan, A. (2023). Marine pollution by garbage from ships under UNCLOS 1982. *Ocean and Coastal Law Journal*, 28(1), 45–60.

Khan, A., & Memon, S. (2021). Addressing marine pollution: An analysis of MARPOL 73/78 regulations and global implementation efforts. *Marine Environmental Research*, 167, 105292.

Ramachandra, T. V. (2009). *Management of municipal solid waste*. New Delhi: TERI Press.

Ramesh, U., Wanjari, R., & Chakraborty, R. (2021). Smart waste collection and disposal systems: A review. *Environmental Technology Reviews*, 10(1), 45–60.
Abdel-Shafy, H. I., & Mansour, M. S. (2012). A review on marine pollution: Sources, effects and management. *Egyptian Journal of Aquatic Research*, 38(3), 209–216.

Arguello, G. (2020). Environmentally sound management of ship wastes: Challenges and opportunities for European ports. *Marine Policy*, 117, 103915.

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings.
Philosophical Transactions of the Royal Society B, 364(1526), 2013–2025.

International Maritime Organization (IMO). (2022). *Prevention of pollution by garbage from ships (MARPOL Annex V)*. London: IMO.
Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. World Bank.