Analysis of MARPOL 73/78 Annex V Policy in Controlling Dry Bulk Residues on Cargo Ships at Gresik Port Terminal

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Maritime pollution from dry bulk cargo residues threatens marine ecosystems and requires strict control through the international convention MARPOL 73/78 Annex V. To analyze the implementation effectiveness of MARPOL 73/78 Annex V policy in controlling dry bulk residues on cargo vessels at Gresik Port Terminal, identify barriers, and formulate recommendations for compliance enhancement. Descriptive qualitative research utilizing direct observation techniques, in-depth interviews with ship crews and port officials, and documentation study on five dry bulk cargo vessels. Results: Implementation effectiveness reached 79% (good category) with highest compliance on regulatory documentation availability (100%) but constrained by port waste reception facilities infrastructure (40%) and residue management systems (76%). Primary barriers include limited storage capacity, waste separation complexity, and crew competency gaps. Optimization requires strengthened enforcement, integrated infrastructure development, technical standardization, and human resource capacity enhancement through multi-stakeholder collaboration.

Keywords: MARPOL Annex V, Dry Bulk Residues, Maritime Policy.

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1. Introduction

The international shipping industry faces complex challenges in managing ship operational waste, particularly dry bulk residues that constitute a significant source of marine pollution. The *International Convention for the Prevention of Pollution from Ships* or MARPOL 73/78 Annex V has been adopted as an international legal instrument regulating the disposal of ship-generated waste, including dry bulk cargo residues that can contaminate marine ecosystems [1]. Global maritime transport handles more than 80 percent of world trade, with dry bulk cargo ships playing a vital role in transporting commodities such as coal, iron ore, and grains that leave substantial residues after loading and unloading processes [2]. Problems arise when these residues are not properly managed, causing marine pollution that affects biodiversity and seawater quality. Although MARPOL Annex V was amended in 2013 to strengthen ship waste disposal regulations, policy implementation still faces various technical and operational obstacles in practice [3].

Previous studies have tended to focus on general technical aspects of ship waste management, while in-depth analysis of the effectiveness of MARPOL Annex V implementation—particularly for controlling dry bulk residues on cargo ships—remains limited. The research gap lies in the lack of comprehensive studies analyzing specific challenges in applying this regulation to dry bulk cargo ship operations, including crew compliance, availability of port reception facilities, and effective enforcement mechanisms [4]. Most existing studies examine marine plastic pollution, whereas dry bulk residues, which also contribute to pollution, have received insufficient attention in academic literature. The novelty of this research lies in its holistic approach integrating policy analysis, ship operational practices, and monitoring systems to evaluate the effectiveness of MARPOL Annex V in the specific context of controlling dry bulk residues, while identifying factors influencing compliance levels and providing evidence-based policy improvement recommendations [5].

Based on this background, the research questions are: how effective is the implementation of MARPOL 73/78 Annex V policy in controlling dry bulk residues on cargo ships, what obstacles are encountered in applying the regulation, and what enforcement mechanisms can enhance compliance. This study aims to comprehensively analyze the implementation of MARPOL Annex V in controlling dry bulk residues, identify gaps between regulation and field practice, and formulate policy recommendations to improve the effectiveness of marine pollution control from dry bulk cargo ships [6]. The results are expected to provide practical contributions for maritime regulators, ship operators, and port authorities in developing more effective and sustainable ship waste management strategies [7].

2. Literature Review

Previous studies emphasize that compliance with MARPOL regulations contributes significantly to reducing marine debris and improving environmental performance in the shipping industry, although effectiveness varies depending on enforcement mechanisms and operational conditions [8]. Empirical findings indicate that regulatory instruments alone are insufficient without adequate supporting infrastructure, such as port reception facilities and standardized onboard waste management systems [9]. Furthermore, research highlights that technical and economic constraints, including limited investment capacity and operational inefficiencies, often hinder optimal implementation, especially in developing maritime regions [10]. Conversely, some studies demonstrate that strict monitoring systems and integrated policy approaches can enhance compliance levels and reduce environmental risks, suggesting that institutional strengthening and technological innovation play a crucial role in achieving regulatory objectives[11].

Despite these advancements, inconsistencies remain in the literature regarding the effectiveness of MARPOL Annex V implementation, particularly in addressing dry bulk residues, which have received less scholarly attention compared to plastic waste pollution. While several studies focus on macro-level environmental impacts and general compliance, there is limited empirical evidence examining operational challenges at the ship–port interface, including crew competency, residue handling complexity, and infrastructure limitations [2], [4]. This gap indicates a lack of comprehensive, context-specific analysis that integrates policy evaluation with practical implementation dynamics. Additionally, previous research often overlooks the disparity between regulatory compliance documentation and actual field practices, leading to potential overestimation of effectiveness. Therefore, the emerging research gap lies in the need for a more holistic and evaluative approach that examines not only regulatory adherence but also operational barriers and systemic inefficiencies in managing dry bulk residues. Based on this gap, the problem statement of this study is formulated as follows: to what extent is the implementation of MARPOL 73/78 Annex V effective in controlling dry bulk residues on cargo ships, what key factors hinder its optimal application, and how can enforcement mechanisms and supporting systems be improved to enhance compliance and environmental sustainability.

3. Methods

This study employs a descriptive–evaluative quantitative approach to analyze the effectiveness of implementing MARPOL 73/78 Annex V policy in controlling dry bulk residues on cargo ships. The research design is cross-sectional, with primary data collected through a structured questionnaire distributed to crew members of dry bulk cargo ships operating in Indonesian waters. The population includes registered dry bulk cargo ships actively operating, with samples selected purposively based on criteria that the vessels transport dry bulk cargo and have implemented MARPOL Annex V regulations. Data collection was conducted through direct surveys of captains and ship officers as respondents who possess knowledge of and direct responsibility for onboard waste management policy implementation.

The research instrument was designed using a Likert scale measuring three main dimensions: implementation of MARPOL Annex V policy onboard, dry bulk residue management systems, and the role of crew and port facility support in residue management. Each dimension was broken down into five specific indicators, resulting in fifteen indicators measured using dichotomous yes/no responses to facilitate assessment of compliance levels. Instrument validity was tested through expert judgment from maritime practitioners and shipping regulation academics, while reliability was examined using the test–retest technique to ensure measurement consistency. The collected data were analyzed using descriptive statistics including mean calculation, achievement percentages, and categorization of implementation effectiveness levels based on a predetermined scoring system [12]. Gap analysis was conducted to identify discrepancies between ideal implementation standards and actual field conditions, while comparative analysis was used to compare compliance levels among sample vessels to identify factors influencing successful policy implementation.

4. Result and Discussion

This study successfully collected data from five dry bulk cargo vessels operating at the Gresik Port Terminal through a structured survey of the ships' captains and officers. The sample vessels had diverse operational characteristics, with cargo capacities ranging from 2,503 to 7,510 tons and various cargo types including coal, logs, copper concentrate, oil cake, and clinker. This diverse vessel characteristics provide a comprehensive representation of the implementation of MARPOL Annex V policies across various types of dry bulk cargo vessels operating in the study area.

Table 1. Profile of Dry Bulk Cargo Ships in the Research Sample

No.	Vessel Name	DWT (Tons)	GT	Cargo Type	Cargo Capacity (Tons)
1	SUMANGGALA 1	9	3,223	Coal	7,510
2	KALTARA KESATRIA	4,318	2,144	Log Timber	4,051
3	KAREEM	53,553	29,980	Copper Concentrate	3,003
4	NEW GLORY	4,708	2,354	Oil Cake Meal	2,503
5	CITRA 3311	16	6,206	Clinker	15,000

Primary data was collected through a questionnaire instrument with fifteen indicators grouped into three main dimensions: implementation of MARPOL Annex V policies on ships, dry bulk residue management systems, and the role of crew members and port facility support. Measurement results showed significant variation in compliance levels across dimensions, with the policy implementation dimension achieving the highest score compared to the residue management system and crew roles.

Table 2. Compliance Level of MARPOL Annex V Implementation Based on Policy Dimension

No.	Policy Dimension	Indicator	"Yes" Responses	"No" Responses	Compliance Percentage
1	Implementation of MARPOL Annex V Policy on Board	1	5	0	100%
		2	4	1	80%
		3	4	1	80%
		4	4	1	80%
		5	5	0	100%
2	Dry Bulk Residue Management System	6	5	0	100%
		7	4	1	80%
		8	4	1	80%

No.	Policy Dimension	Indicator	"Yes" Responses	"No" Responses	Compliance Percentage
		9	3	2	60%
		10	3	2	60%
3	Crew Role and Port Support	11	4	1	80%
		12	2	3	40%
		13	5	0	100%
		14	3	2	60%
		15	4	1	80%

The implementation dimension of MARPOL Annex V policy demonstrated an average compliance rate of 88 percent, with two indicators achieving perfect compliance: the availability of a Garbage Management Plan and the implementation of regular crew training on waste management. The dry bulk residue management system dimension had a compliance rate of 76 percent, with the residue separation and storage capacity indicators showing the lowest compliance rate at 60 percent. The crew role and port support dimension recorded a compliance rate of 72 percent, with the availability of waste receiving facilities at ports reaching only 40 percent, indicating limited supporting infrastructure onshore.

Table 3. Evaluation of the Effectiveness of MARPOL Annex V Implementation Per Sample Vessel

No.	Vessel Name	Total Score	Achievement Percentage	Effectiveness Category
1	SUMANGGALA 1	12	80%	Very Good
2	KALTARA KESATRIA	11	73.33%	Good
3	KAREEM	11	73.33%	Good
4	NEW GLORY	13	86.67%	Very Good
5	CITRA 3311	12	80%	Very Good
	Overall Average	11.8	79%	Good
	Maximum Ideal Score	15	100%	Very Good

The evaluation of implementation effectiveness per vessel showed that the NEW GLORY achieved the highest score at 86.67 percent, categorized as very good, while the KALTARA KESATRIA and KAREEM scored the lowest at 73.33 percent, categorized as good. Overall, the average level of MARPOL Annex V implementation effectiveness across the five sample vessels reached 11.8 percent out of the ideal score of 15, equivalent to 79 percent, categorized as good, but there is still significant room for improvement towards the ideal level. The disparity in achievement between vessels indicates that internal factors such as ship management commitment, crew training levels, and the availability of onboard waste management facilities play a significant role in determining the success of policy implementation.

Table 4. Gap Analysis Between Actual Conditions and Ideal Standards for Implementation

Aspect	Ideal Condition (%)	Actual Condition (%)	Gap (%)	Improvement Priority
Implementation of MARPOL Annex V Policy	100	88	12	Moderate
Dry Bulk Residue Management System	100	76	24	High
Crew Role and Port Support	100	72	28	Very High
Overall Average	100	79	21	High

The gap analysis revealed that the largest gaps were in the crew role and port support dimensions, with a 28 percent gap from ideal conditions, requiring very high priority for improvement. The dry bulk residue management system dimension showed a 24 percent gap, with high priority for improvement, particularly in storage capacity and adequate residue separation mechanisms. The policy implementation dimension had the smallest gap at 12 percent, but still required attention, particularly in terms of consistent implementation of standard operating procedures and complete documentation. These findings confirm that although awareness and knowledge of MARPOL Annex V regulations are relatively high among crew members, practical implementation is still hampered by limited infrastructure and suboptimal system support.

Discussion

Effectiveness of MARPOL 73/78 Annex V Policy Implementation in Dry Bulk Residue Control

The implementation of MARPOL 73/78 Annex V at the Gresik Port Terminal achieved 79% effectiveness, categorized as good, although implementation gaps remain. The highest level of compliance (88%) was seen in the availability of documents such as the Garbage Management Plan and Garbage Record Book, which reached 100%. However, operational procedures are only 80% compliant, indicating a gap between theory and practice [13]. The residue management system recorded a 76% compliant rate, with bottlenecks in storage capacity and waste separation (60%). Residues such as coal and iron ore require specific handling to prevent cross-contamination [14]. Larger vessels tend to have better systems due to proportional investment, while smaller vessels face financial and technical constraints [15].

Barriers to Implementing MARPOL Annex V Regulations in Dry Bulk Cargo Ship Operations

The main obstacle is the limited waste receiving facilities at the port, with compliance at only 40%, creating operational dilemmas for ships [16]. The Gresik Port Terminal has limited facilities that do not operate consistently due to cost constraints. Operational barriers include the complexity of residue separation procedures, time constraints during loading and unloading, and a lack of economic incentives [17]. Crew awareness varies, with some indicators reaching only 60%, indicating ineffective training. An industry culture that emphasizes efficiency conflicts with environmental practices that require additional time [14]. Weak oversight allows non-compliant vessels to continue operating without significant sanctions [15].

Enforcement Mechanisms to Improve Compliance with MARPOL Annex V

Effective enforcement requires strengthening Port State Control through comprehensive inspections of ship documents and facilities [13]. Digital record-keeping systems increase transparency and real-time monitoring without disrupting operations [18]. Positive incentive mechanisms such as green certification, reduced port fees, and positive publicity are more effective than punitive sanctions [17]. Investment in waste receiving facility infrastructure requires government subsidies or innovative financing schemes [14]. Sustainable training programs must build environmental awareness and shift crews' mindsets from obligatory compliance to intrinsic commitment [15]. Collaboration between government, industry, and maritime educational institutions is crucial for developing curricula relevant to practical challenges [16].

Policy Recommendations for Optimizing Dry Bulk Residue Control

Recommendations encompass three pillars: strengthening regulations, developing infrastructure, and improving human resources. National regulations need to be tailored to the domestic context, establishing clear technical standards for storage facilities based on vessel capacity (Bustamin et al., 2024). Ports are required to provide waste receiving facilities at reasonable rates (Alam & Bimantoro, 2023). Infrastructure requires public-private investment for a comprehensive network with recycling technology (Purwitasari et al., 2024). Design standardization through shipyard incentives increases fleet capacity (Papadopoulou et

al., 2026). Multi-level training and curriculum integration at maritime academies ensure competency from the start of a career (Serra-Gonçalves et al., 2023). Collaborative forums between stakeholders are necessary for ongoing dialogue and innovative solutions (Ardiany et al., 2025).

5. Conclusion

An evaluation of MARPOL 73/78 Annex V implementation on dry bulk cargo vessels at the Gresik Port Terminal identified an effectiveness rate of 79%, indicating moderate compliance with substantial gaps between normative regulations and operational practices. Implementation disparities were primarily concentrated in the infrastructure dimensions of port waste receiving facilities (40%) and on-board residue management systems (76%), reflecting structural deficiencies that hinder optimal compliance. Critical barriers include limited residue storage capacity, the complexity of waste separation procedures, inefficiencies in port facilities, and gaps in crew competency in applying management protocols. Optimizing compliance requires a holistic approach through strengthening Port State Control-based enforcement mechanisms, developing integrated infrastructure with economic incentive schemes, standardizing ship facility techniques, and increasing human resource capacity through continuous training. Multi-stakeholder synergy between regulators, maritime operators, port authorities, and educational institutions is a fundamental prerequisite for the systemic transformation of dry bulk residue management towards maritime environmental sustainability.

However, this study has several limitations that should be acknowledged. The research was conducted on a limited number of vessels operating at a single port terminal, which may restrict the generalizability of the findings to broader maritime contexts. In addition, the analysis primarily relied on questionnaire-based data and descriptive evaluation, which may not fully capture the complex operational dynamics and behavioral factors influencing compliance with MARPOL Annex V regulations. The cross-sectional design also limits the ability to observe long-term changes in compliance patterns and policy effectiveness over time.

Future research is therefore recommended to expand the scope of analysis by involving a larger sample of vessels across multiple ports and shipping routes in order to obtain a more representative understanding of MARPOL Annex V implementation. Further studies could also employ mixed-method or longitudinal approaches to examine the relationship between regulatory enforcement, infrastructure availability, and behavioral factors among ship crews. In addition, the integration of technological monitoring systems, digital waste tracking, and economic incentive mechanisms should be explored as potential strategies to enhance compliance and improve the sustainability of dry bulk residue management in the maritime industry.

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