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Analysis of Waste Handling and the Availability of Waste Collection Facilities in Efforts to Prevent Marine Pollution aboard KM Sabuk Nusantara 113

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Abstract

Marine pollution produced by waste from shipping operations is a serious threat to the marine ecosystem. This study focuses on explore the effect of waste handling (X1) and waste storage facility availability (X2) on marine pollution prevention (Y) on KM Sabuk Nusantara 113. The research employed a quantitative descriptive method with the use of questionnaires allocated to 19 crew members applying total sampling technique. Next the data were examined applying multiple linear regression through SPSS. Partial T-test results showed that waste handling (sig. 0.018 < 0.05) and waste storage facility availability (sig. 0.002 < 0.05) significantly affect marine pollution prevention. The simultaneous F-test yielded sig. 0.001 < 0.05. As for the coefficient of determination $R^2 = 0.933$ indicates both variables explain 93.3% of variation in marine pollution prevention. This study affirms the importance of structured waste handling and adequate facility provision in accordance with MARPOL Annex V regulations.

Keyword: Marine pollution prevention, MARPOL Annex V, Waste handling, Waste storage facilities

1. INTRODUCTION

Marine pollution caused by waste generated from shipping activities is one of the serious threats to the sustainability of global marine ecosystems[1]. Waste originating from ships, such as plastics, food waste, and operational waste, has the potential to damage marine organisms, increase microplastic accumulation, and disrupt the ecological balance of marine waters [2].

Waste management on ships is a mandatory procedure in shipping operations to prevent marine pollution. The provisions of MARPOL Annex V require every ship to have a Garbage Management Plan (GMP), which outlines procedures for the segregation, storage, processing, and disposal of waste according to its category [3]. All waste management activities must be recorded in the Garbage Record Book as a form of monitoring and accountability in accordance with the regulations of the International Maritime Organization (IMO).

Waste management in Indonesia still faces various challenges, particularly on ships serving inter-island routes. Waste generated by crew members and passengers must be temporarily stored on board until the ship docks at a port equipped with adequate port reception facilities for waste. This condition indicates that the implementation of MARPOL Annex V requires adequate facilities and crew compliance to prevent environmental pollution.

KM Sabuk Nusantara 113, a pioneer passenger ship serving inter-island routes, continues to face various challenges, particularly in terms of waste handling and the availability of waste storage facilities. Waste segregation and collection systems have not been implemented effectively, the capacity of waste storage facilities is insufficient to accommodate the volume of daily waste generated, and crew members' understanding of marine pollution prevention remains relatively low.

Previous studies conducted on MT. Petromax, KM Kendhaga Nusantara 10, and MV Bukit Raya indicate that limited waste storage facilities, low crew discipline, and inadequate supervision are the main factors contributing to the ineffectiveness of marine pollution prevention efforts [4], [5], [6]. Specific studies on

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pioneer passenger ships examining the direct relationship between the adequacy of waste storage facilities and the effectiveness of marine pollution prevention remain limited. Therefore, further research focusing on KM Sabuk Nusantara 113 is necessary.

Based on the background described above, this study aims to: (1) determine the effect of waste handling (X1) on marine environmental pollution prevention; (2) determine the effect of the availability of waste storage facilities (X2) on marine environmental pollution prevention; and (3) determine the simultaneous effect of both variables on marine environmental pollution prevention aboard KM Sabuk Nusantara 113.

2. METHODS

A quantitative descriptive method was employed in this study, using multiple linear regression analysis assisted by SPSS. The quantitative approach was used to objectively measure and analyze waste handling practices and the availability of waste storage facilities aboard the ship based on numerical data [7], [8].

The research population consisted of all 19 crew members of KM Sabuk Nusantara 113. A total sampling technique was applied, in which the entire population was included as the research sample. This technique was selected because the population was relatively small, allowing all crew members to participate as respondents to obtain a more comprehensive overview of the existing conditions.

The respondents consisted of the Captain, deck officers, engine officers, and ratings who were directly involved in operational activities and waste handling aboard KM Sabuk Nusantara 113. Data were collected using a questionnaire based on a five-point Likert scale (1–5), which was distributed to respondents aboard the ship from May 3 to 15, 2025. Secondary data were obtained from literature, ship archives, and relevant documents.

The data analysis process began with a validity test using the Pearson Product-Moment correlation and a reliability test using Cronbach's alpha, with a coefficient exceeding 0.60 considered acceptable. Classical assumption tests included the Kolmogorov–Smirnov normality test, multicollinearity testing using the Variance Inflation Factor (VIF), and heteroscedasticity testing using the Glejser method. After the required assumptions were satisfied, the data were analyzed using multiple linear regression with the following equation:

$$Y = a + b_1X_1 + b_2X_2 + e \quad (1)$$

The research variables consisted of waste handling (X1), measured through indicators of waste segregation, management, processing methods, and crew compliance; the availability of waste storage facilities (X2), measured through indicators of quantity and capacity, facility cleanliness, location, and supporting facilities; and marine environmental pollution prevention (Y), measured through indicators of waste management effectiveness, coordination, awareness, and compliance with established procedures.

3. RESULTS AND DISCUSSION

3.1. Respondent Characteristics

Based on the total of 19 respondents, the majority were crew members (ratings), comprising 11 people (57.9%), followed by 4 engine officers (21.1%), 3 deck officers (15.8%), and 1 captain (5.3%). In terms of work experience, most respondents (52.6%) had 1–3 years of experience, while the predominant age group was 25–35 years, accounting for 63.2% of the respondents.

3.2. Validity and Reliability Tests

The validity and reliability tests were conducted to assess the quality of the research instrument used to measure waste handling, the availability of waste storage facilities, and marine environmental pollution prevention aboard KM Sabuk Nusantara 113. The validity test examined whether each questionnaire item accurately measured its intended variable, while the reliability test assessed the internal consistency of the instrument. The results of these tests are presented in Table 1.

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Table 1. Validity and Reability Test Result

Variable	Item	Calculated r	Table r	Status	Cronbach's Alpha
Waste Handling (X1)	X1.1	0.718	0.361	Valid	0.710
	X1.2	0.741	0.361	Valid	
	X1.3	0.728	0.361	Valid	
	X1.4	0.742	0.361	Valid	
Waste Storage Facilities (X2)	X2.1	0.715	0.361	Valid	0.685
	X2.2	0.710	0.361	Valid	
	X2.3	0.743	0.361	Valid	
	X2.4	0.704	0.361	Valid	
Marine Pollution Prevention (Y)	Y1.1	0.754	0.361	Valid	0.743
	Y1.2	0.758	0.361	Valid	
	Y1.3	0.754	0.361	Valid	
	Y1.4	0.743	0.361	Valid	

The test results indicate that all 12 questionnaire items were valid, with calculated r-values ranging from 0.704 to 0.758, exceeding the table r-value of 0.361 at a 5% significance level with 19 respondents. The reliability test results showed Cronbach's alpha values of 0.710 for waste handling (X1), 0.685 for waste storage facilities (X2), and 0.743 for marine pollution prevention (Y). These values indicate that all research instruments met the minimum reliability threshold of 0.60 and demonstrated acceptable internal consistency for use in this study.

3.3. Classical Assumption Tests

The results of the classical assumption tests are presented in Table 2.

Table 2. Results of Classical Assumption Tests

Test Type	Indicator	Value	Criteria	Conclusion
Normality (Kolmogorov–Smirnov)	Asymp. Sig. (2-tailed)	0.200	> 0.05	Data are normally distributed
Multicollinearity	Tolerance (X1)	0.996	> 0.10	No multicollinearity
	VIF (X1)	1.004	< 10	No multicollinearity
	Tolerance (X2)	0.996	> 0.10	No multicollinearity
	VIF (X2)	1.004	< 10	No multicollinearity
Heteroscedasticity (Glejser)	Sig. X1	0.881	> 0.05	No heteroscedasticity
	Sig. X2	0.321	> 0.05	No heteroscedasticity

The classical assumption test results indicate that the research model met the required assumptions for regression analysis. The Kolmogorov–Smirnov normality test produced a significance value of 0.200, which exceeds the significance threshold of 0.05, indicating that the research residuals were normally distributed. The multicollinearity test yielded tolerance values of 0.996 for both independent variables and a VIF value of 1.004 for each variable. These values satisfy the established criteria, indicating that the regression model was free from multicollinearity.

Furthermore, the Glejser heteroscedasticity test yielded significance values of 0.881 for waste handling and 0.321 for the availability of waste storage facilities. Both values exceed 0.05, indicating no evidence of heteroscedasticity. Based on these findings, the multiple linear regression model met the classical assumptions and could be applied in the subsequent analysis.

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3.4. Descriptive Statistics

Table 3. Descriptive Statistics of Research Variables

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Waste Handling (X1)	19	13.00	19.00	16.16	2.387
Availability of Waste Storage Facilities (X2)	19	13.00	19.00	15.58	2.036
Marine Pollution Prevention (Y)	19	13.00	19.00	16.11	1.792

The mean values of all variables exceeded their respective standard deviations, indicating relatively low variability in the observed data. Waste handling had a mean score of 16.16 out of a maximum possible score of 20, suggesting that, overall, the crew members implemented waste handling procedures reasonably well.

3.5. Multiple Linear Regression Analysis

Table 4. Results of Multiple Linear Regression Analysis

Model	B	Std. Error	Beta	t	Sig.
Constant	25.959	1.626	–	15.962	.000
Waste Handling (X1)	0.247	0.072	0.501	3.416	.004
Availability of Waste Storage Facilities (X2)	0.376	0.110	0.502	3.417	.004

The regression analysis produced the following equation:

$$Y = 25.959 + 0.247X1 + 0.376X2 \quad (2)$$

The coefficients of X1 (0.247) and X2 (0.376) are positive, indicating that improvements in waste handling and the availability of waste storage facilities are each associated with an increase in the effectiveness of marine environmental pollution prevention. These findings suggest a positive relationship between both independent variables and the dependent variable.

3.6. Hypothesis Testing

Table 5. Summary of Hypothesis Testing Results

Hypothesis	Variable	Sig.	Conclusion
H1	X1 → Y (partial effect)	0.018	Accepted
H2	X2 → Y (partial effect)	0.002	Accepted
H3	X1, X2 → Y (simultaneous effect)	0.001	Accepted
R^2	Coefficient of determination	0.933	93.3% explained by the model

The partial test results indicate that waste handling (X1) has a positive and statistically significant effect on marine environmental pollution prevention (Y), as demonstrated by a significance value of 0.018 (less than 0.05). This finding supports the acceptance of H1. Meanwhile, the availability of waste storage facilities (X2) also demonstrates a significant positive effect on Y, with a significance value of 0.002 (less than 0.05). Therefore, H2 is accepted.

The F-test yielded a significance value of 0.001, which is below 0.05, with an R^2 value of 0.933. This indicates that the two independent variables jointly explain 93.3% of the variation in marine environmental pollution prevention, supporting the acceptance of H3.

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3.7. Discussion

3.7.1. The Effect of Waste Handling (X1)

The research findings demonstrate that waste handling has a significant effect on marine environmental pollution prevention aboard KM Sabuk Nusantara 113. This finding supports the provisions of MARPOL Annex V, which emphasize the obligation of every ship to implement structured waste management procedures [9][1]. It is also consistent with Nursamyu [10], who stated that the effectiveness of waste handling is strongly influenced by crew discipline and compliance with established work procedures.

These findings are supported by the research conducted by Kuncowati [11], which emphasizes the importance of waste segregation as an essential component of waste handling aboard ships. Also found that the active involvement of crew members in implementing the Garbage Management Plan supports more effective waste handling practices, thereby reducing the potential for marine environmental pollution [12].

3.7.2. The Effect of the Availability of Waste Storage Facilities (X2)

The availability of waste storage facilities plays an important role and makes a significant contribution to marine environmental pollution prevention efforts[4]. Adequate facilities enable crew members to segregate, temporarily store, and manage waste systematically throughout the voyage, thereby reducing the potential for direct waste disposal into the sea. Adequate facilities also help prevent waste accumulation and support the implementation of the Garbage Management Plan in accordance with MARPOL Annex V. This finding supports [13], who stated that the availability of adequate infrastructure is a key indicator of the successful implementation of waste management systems aboard ships.

3.7.3. The Simultaneous Effect of Waste Handling and Facility Availability

The coefficient of determination (R^2) of 0.933 indicates that the two independent variables jointly explain a substantial proportion of the variation in the dependent variable, namely marine environmental pollution prevention. This finding is consistent with Kuncowati [14], who stated that the effectiveness of waste handling aboard ships is determined by the combination of adequate infrastructure and disciplined implementation. It is also in line with MARPOL Annex V, which emphasizes an integrated approach encompassing both the provision of facilities and the implementation of waste handling procedures by crew members [15].

These findings indicate that marine pollution prevention is not the result of a single factor but rather the synergy between crew members' waste handling behavior and the support provided by adequate facilities. When both aspects function optimally and simultaneously, the potential for direct waste disposal into the sea can be minimized, as reflected in the operations of KM Sabuk Nusantara 113.

3.7.4. Research Limitations and Implications for Future Research

This study has several limitations that should be considered when interpreting its findings and designing future research. First, the relatively small sample size (n = 19) limits the statistical power to detect actual effects. Future studies are therefore recommended to involve 50–100 respondents and include several similar vessels within the same fleet or across multiple pioneer shipping routes to obtain more representative data.

Second, the research model does not incorporate other potentially relevant variables, such as crew members' understanding of MARPOL 73/78 Annex V, the frequency of safety training, and the effectiveness of internal supervision. These factors are relevant to Regulation 10 of MARPOL Annex V, which requires training programs as part of the Garbage Management Plan. Third, data collection relied exclusively on questionnaires, which may introduce social desirability bias. In relatively closed working environments such as ships, respondents may tend to provide answers they consider ideal to maintain their professional reputation. Future research is therefore recommended to incorporate additional data collection methods, including direct observation of waste segregation, storage, and disposal practices at port reception facilities. In addition, the Garbage Record Book (GRB), which must be maintained in accordance with Regulation 10 of MARPOL Annex V, could be used as an objective secondary data source to quantitatively measure the effectiveness of waste handling.

Under Regulation 6 of the International Safety Management (ISM) Code, crew members should also receive periodic training on safety and environmental procedures, including waste handling in accordance with

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the Garbage Management Plan and MARPOL Annex V, to ensure consistent implementation of waste handling procedures. Furthermore, regular supervision by the captain and responsible officers is necessary to ensure that all waste handling procedures comply with applicable regulations. Shipping companies should also support these efforts by providing adequate waste storage facilities, conducting regular facility maintenance, and evaluating the implementation of waste handling procedures throughout voyages.

The limited sample size in this study can also be understood within the context of the isolated environment characteristic of ship operations. From a behavioral safety perspective, crew members' waste handling behavior is strongly influenced by the safety culture established aboard the vessel. Therefore, future research involving a larger sample could help identify variations in behavior between departments, particularly the deck and engine departments, and examine the role of the captain's leadership in shaping collective discipline among crew members.

4. CONCLUSION

Based on the results of the research analysis and discussion, it can be concluded that: (1) Waste handling has a statistically significant partial effect on marine environmental pollution prevention aboard KM Sabuk Nusantara 113 (sig. 0.018 < 0.05); (2) The availability of waste storage facilities has a statistically significant partial effect (sig. 0.002 < 0.05); and (3) Both variables simultaneously have a statistically significant effect, with an R^2 value of 0.933, indicating that 93.3% of the variation in marine environmental pollution prevention can be explained by the research model.

This study recommends that crew members implement waste handling procedures more consistently in accordance with MARPOL Annex V, ship officers strengthen regular supervision, and shipping companies ensure the availability and adequacy of waste storage facilities. Future research is recommended to incorporate additional variables, such as the level of supervision and training frequency, and expand the sample to at least 50–100 respondents across several similar vessels.

The findings of this study may benefit vessel operators and shipping companies by providing a basis for evaluating and improving waste management systems aboard ships. Furthermore, the results may serve as input for relevant stakeholders in supporting the implementation of waste handling procedures in accordance with MARPOL Annex V through the provision of adequate waste storage facilities, improvements in crew members' capabilities, and supervision of the implementation of the Garbage Management Plan, thereby enabling more effective marine environmental pollution prevention efforts.

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