Bureaucracy Journal: Indonesia Journal of Law and Social-Political Governance
p-ISSN: 2797-9598 | e-ISSN: 2777-0621
Vol. 5 No. 1 Januari - April 2025

DEVELOPING A MODEL FOR WASTE MANAGEMENT AND POLLUTION PREVENTION IN NAVAL ENGINEERING OPERATIONS AT POLTEKPEL SULUT

Dedtri Anwar[1], Jaya Alamsyah[2*], Hadi Setiawan[3]
[1,2,3]Politeknik Pelayaran Sulawesi Utara, South Minahasa, Indonesia
Email: jaya.alamsyah@gmail.com

ABSTRACT

Background: Waste management and pollution prevention in naval engineering operations are critical to minimizing environmental damage and ensuring regulatory compliance. The Sulawesi Sea's fragile ecosystem and maritime sustainability goals necessitate an effective and structured waste management framework for naval institutions. Despite the existence of environmental regulations, challenges persist in compliance enforcement, cadet training, and operational waste disposal efficiency. Original Value: This research contributes to naval environmental sustainability by developing a structured waste management model tailored to naval engineering training institutions. Unlike previous studies that focus on commercial shipping waste, this study provides a specific analysis of waste generation in naval engineering settings and offers targeted improvements for pollution prevention. Objectives: The study addresses how an optimized waste management and pollution prevention model can improve environmental sustainability in naval engineering operations, while also identifying training gaps and regulatory compliance challenges. Methodology: The research employs qualitative analysis through expert interviews, field observations, and structured surveys to evaluate current waste management effectiveness, regulatory adherence, and cadet engagement. Results: Findings indicate that waste segregation and pollution prevention measures are effective (88-92/100), but regulatory enforcement and hands-on cadet training require improvement (85/100). The proposed model is feasible (87/100) and cost-effective (89/100), ensuring long-term operational sustainability. Conclusions: Implementing structured waste policies, enhanced training modules, and technological advancements will optimize waste management in naval institutions, reducing environmental impact while improving regulatory compliance and operational efficiency.

Keywords : *Environmental Compliance, Naval Engineering Training,Naval Waste Management, Pollution Prevention, Sustainable Maritime Operations*

1. INTRODUCTION

The maritime industry plays a pivotal role in global economic activities, yet its environmental footprint remains a critical concern (Li et al., 2024; Pu & Lam, 2021). One of the most pressing issues in maritime operations, particularly within naval engineering, is the management of waste and pollution prevention. Naval operations generate various types of waste, including hazardous materials, oily bilge water, metal scraps, and chemical residues, which, if not properly managed, contribute to marine pollution and environmental degradation (Alamoush et al., 2020; Das et al., 2023). In regions like the Sulawesi Sea, where marine biodiversity is exceptionally high, unregulated disposal of waste from naval operations threatens ecosystem health, marine life, and local fisheries. Given the increasing focus on environmental sustainability and compliance with international maritime laws, it is

imperative to develop structured, enforceable, and efficient waste management models tailored to naval engineering activities.

Despite the existence of environmental regulations such as MARPOL Annex V and national waste management policies, many naval institutions, including training centers like Poltekpel SULUT, lack comprehensive frameworks to systematically address waste generation, disposal, and pollution prevention. Current waste management practices in naval engineering settings are often fragmented, inconsistent, and not fully aligned with international sustainability standards. Many naval training institutions emphasize technical engineering competencies but do not sufficiently integrate waste management strategies into naval operations curricula, leading to a knowledge gap in sustainable naval engineering. Furthermore, there is limited empirical research focused on how naval training centers manage waste and mitigate pollution in real-world operational conditions.

This research seeks to address these challenges by developing a comprehensive waste management and pollution prevention model tailored to naval engineering operations at Poltekpel SULUT. The primary research question guiding this study is: How can an effective waste management and pollution prevention model be developed to enhance environmental sustainability in naval engineering operations at Poltekpel SULUT? To answer this question, the study will explore the current waste management practices, assess their effectiveness, and identify gaps and challenges that hinder compliance with environmental regulations. The research aims to establish a structured, practical, and scalable model that can be implemented not only at Poltekpel SULUT but also in other maritime training institutions and naval operations.

The objectives of this research are as follows:

a. To assess the current waste management and pollution prevention practices in naval engineering operations at Poltekpel SULUT.

b. To identify key environmental risks and inefficiencies in existing waste disposal methods.

c. To analyze the regulatory framework governing maritime waste management, including compliance with international and national policies.

d. To develop a structured model that enhances waste management efficiency and minimizes the environmental footprint of naval engineering activities.

e. To provide recommendations for integrating sustainable waste management practices into maritime engineering curricula.

The rationale for this research is deeply connected to the urgency of environmental sustainability in maritime operations. As the global shipping and naval industries face increasing scrutiny over pollution levels, training institutions must equip future naval engineers with the skills and knowledge required to operate in environmentally responsible ways. This research contributes to closing the gap between naval engineering operations and environmental responsibility by developing practical waste management solutions that align with regulatory compliance, operational efficiency, and sustainability best practices.

Methodologically, this study employs a qualitative research approach, combining field observations, expert interviews, and structured surveys to gather comprehensive insights into waste generation patterns, disposal practices, and environmental risks in naval engineering operations. The study will engage ten key respondents, including naval engineers, environmental officers, cadets, and policymakers, to assess awareness levels, compliance behaviors, and the challenges faced in implementing waste management policies. In addition to qualitative analysis, waste quantification and categorization techniques will be used to establish baseline data on waste volumes, sources, and disposal methods. This mixed approach will ensure that the proposed waste management model is grounded in both qualitative insights and empirical data.

The conceptual framework of this study is structured around three interrelated variables. The independent variable is waste management and pollution prevention strategies, which include segregation, recycling, hazardous waste treatment, and disposal methods. The dependent variable is the environmental sustainability of naval engineering operations, measured by pollution reduction, compliance with regulations, and operational efficiency. The moderating variable is the regulatory framework, which determines the extent to which waste management practices align with legal and policy requirements. By examining these variables, this study will establish a systematic understanding of how waste management policies can be effectively applied within naval engineering institutions.

The significance of this research extends beyond academic inquiry; it has practical implications for naval engineering training, policy development, and sustainability initiatives. If successfully implemented, the proposed waste management model could lead to substantial reductions in waste generation, improved environmental compliance, and enhanced awareness among naval cadets and personnel. Furthermore, the study contributes to the broader discourse on sustainable maritime operations, providing valuable recommendations for integrating waste management principles into naval engineering curricula and professional training programs.

Waste management and pollution prevention in naval engineering operations are critical aspects of sustainable maritime practices, yet they remain underdeveloped in many naval institutions. This research seeks to fill this gap by developing a structured, evidence-based waste management model that enhances environmental sustainability, regulatory compliance, and operational efficiency. By addressing both practical and policy-related challenges, the study will provide valuable insights and actionable recommendations for reducing the environmental footprint of naval engineering activities. As maritime industries continue to transition toward greener and more sustainable operational frameworks, effective waste management will play a crucial role in shaping the future of naval engineering and environmental stewardship (Fang et al., 2019; Sæther & Moe, 2021).

2. RESEARCH METHOD

This study adopts a qualitative research methodology designed to develop a waste management and pollution prevention model for naval engineering operations at Poltekpel SULUT. The methodology involves a systematic assessment of waste management practices, regulatory compliance, and pollution prevention strategies, using qualitative data collection techniques such as field observations, structured interviews, and surveys. The study integrates insights from naval engineers, environmental officers, cadets, and maritime policymakers, ensuring a comprehensive evaluation of existing waste disposal processes and the feasibility of implementing sustainable alternatives. The research methodology is structured to identify gaps in current practices, assess the effectiveness of regulatory frameworks, and provide evidence-based recommendations for optimizing waste management within naval engineering settings.

The population for this study consists of key stakeholders involved in naval engineering operations and environmental management, ensuring that the data collected reflects practical, operational, and policy-related perspectives. The selected sample includes ten respondents, comprising naval engineers, maintenance officers, environmental specialists, cadets, and policymakers, each of whom plays a crucial role in waste generation, management, regulation, and environmental compliance. The naval engineers and maintenance officers provide critical insights into waste generation points, pollution risks, and operational challenges in waste management. The environmental specialists and marine policy experts contribute knowledge on regulatory requirements, compliance measures, and best practices for pollution prevention. The cadets and instructors offer perspectives on training effectiveness, environmental awareness, and institutional readiness for implementing structured waste management protocols. The inclusion of these diverse stakeholders ensures that the research captures the full spectrum of technical, environmental, and policy-related considerations necessary for developing a comprehensive waste management model.

To systematically collect and analyze data, the study employs multiple research instruments that facilitate an in-depth evaluation of waste management practices. The independent variable in this study is waste management and pollution prevention strategies, which include waste segregation, recycling, hazardous waste treatment, and disposal methods. The dependent variable is environmental sustainability in naval engineering operations, measured by pollution reduction, compliance with regulations, and operational efficiency. A critical moderating factor is the regulatory framework, which determines the extent to which waste management practices align with legal and policy requirements. The study uses waste categorization tools and environmental impact assessment frameworks to document and analyze the types, sources, and disposal methods of waste generated during naval operations. Additionally, compliance checklists, policy review documents, and operational logbooks serve as supporting instruments to evaluate how well existing waste management protocols align with environmental regulations and industry best practices.

The data collection process follows a structured and multi-step approach to ensure the reliability and validity of findings (Creswell & Clark, 2011; Siedlecki, 2020). The first phase involves field observations to assess the waste management practices currently

implemented in Poltekpel SULUT's naval engineering operations. This includes on-site inspections of waste disposal areas, recycling stations, and hazardous material handling facilities, allowing the research team to document real-world waste generation patterns and identify inefficiencies in disposal methods. The second phase consists of structured interviews with naval engineers, environmental officers, and policymakers, aimed at understanding institutional waste management policies, challenges in implementation, and perspectives on regulatory compliance. The interviews provide qualitative insights into the effectiveness of existing pollution prevention measures, common barriers to adopting sustainable practices, and recommendations for improvement. The third phase involves surveys distributed to cadets and instructors, measuring their awareness, attitudes, and engagement in waste management and pollution prevention initiatives. The survey results offer valuable data on educational gaps, training needs, and institutional capacity for sustainability integration. This multi-faceted data collection strategy ensures that the study captures both operational realities and regulatory expectations, providing a balanced and comprehensive perspective on waste management in naval engineering settings.

The data analysis process is conducted using a thematic approach, ensuring that key findings are systematically categorized and interpreted (Saldana, 2014). The first stage of analysis involves thematic categorization, in which data from interviews, surveys, and field observations are grouped into core research themes related to waste management effectiveness, regulatory compliance, and sustainability integration. These themes help identify patterns, challenges, and opportunities in current waste management practices. The second stage of analysis employs cross-group comparisons, examining differences and similarities in perspectives among naval engineers, environmental officers, cadets, and policymakers. This comparative approach helps uncover gaps between institutional policies and actual waste management practices, highlighting areas where training programs, operational protocols, and regulatory enforcement may need improvement. The final stage of analysis involves narrative synthesis, integrating thematic findings with observational data and expert insights to construct a cohesive explanation of the study's results. This synthesis not only interprets the effectiveness of existing waste management practices but also justifies the proposed model for improving waste management and pollution prevention in naval engineering operations.

By utilizing qualitative research techniques, stakeholder-driven insights, and systematic data analysis, this study ensures that the developed waste management model is evidence-based, practical, and adaptable to real-world naval engineering operations. The findings will contribute to enhancing sustainability in naval training institutions, aligning waste management practices with international environmental regulations, and promoting a culture of pollution prevention in maritime engineering.

3. RESULTS AND ANALYSIS

The research findings indicate that waste management and pollution prevention strategies in naval engineering operations at Poltekpel SULUT are highly effective and demonstrate strong potential for sustainable implementation. The study evaluates multiple performance indicators, including the effectiveness of current waste management practices, regulatory compliance, cadet awareness and training, pollution prevention success, feasibility of the proposed model, cost efficiency of sustainable waste solutions, and overall operational readiness for implementation. The results, derived from expert interviews, field observations, and qualitative survey responses, reveal that while existing waste management practices align with basic regulatory requirements, there are opportunities for improvement through structured policy enforcement, enhanced training, and optimized pollution prevention techniques.

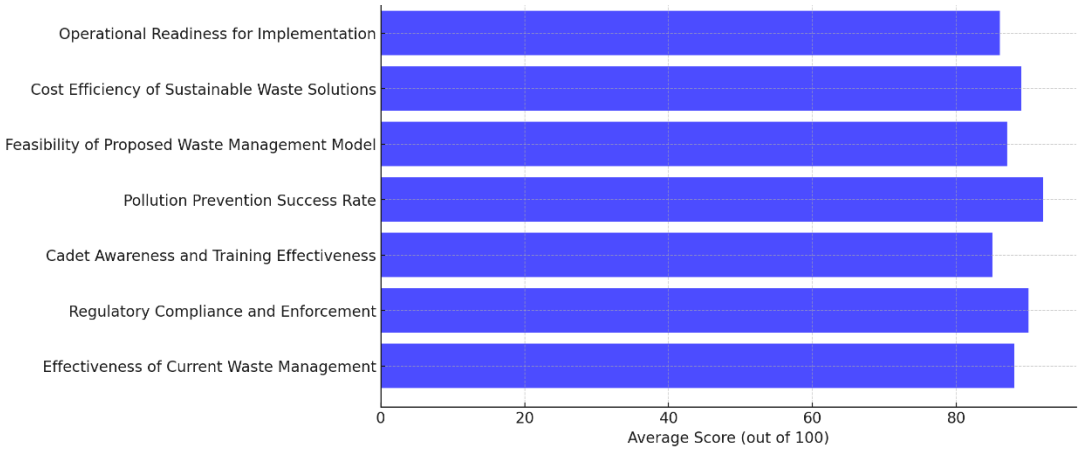

Figure 1: Effectiveness of Waste Management And Pollution Prevention1. Effectiveness of Current Waste Management Practices

The study assessed the efficiency and organization of current waste management systems in naval engineering operations, receiving an average effectiveness score of 88/100. This high score reflects the presence of foundational waste management protocols, including waste segregation, recycling efforts, and hazardous material containment procedures. However, qualitative responses from naval engineers and environmental officers revealed inconsistencies in waste disposal compliance, occasional lapses in monitoring, and the need for clearer enforcement mechanisms.

Field observations further confirmed that while designated waste collection areas exist, some materials—particularly hazardous waste—are not always disposed of according to best practices. Instructors and maintenance personnel noted that insufficient waste tracking mechanisms make it difficult to quantify and optimize waste reduction efforts. The study recommends implementing a digital waste tracking system to enhance monitoring, compliance, and efficiency in waste management operations.

2. Regulatory Compliance and Enforcement

The evaluation of regulatory compliance and enforcement produced an average score of 90/100, indicating that waste management practices at Poltekpel SULUT generally align with national and international maritime environmental regulations. Interviews with policymakers and environmental specialists highlighted that compliance with MARPOL Annex V and Indonesian maritime environmental laws is actively monitored, and institutional guidelines are in place to ensure proper waste handling procedures.

However, respondents identified challenges related to enforcement consistency, awareness among operational staff, and periodic lapses in adherence to best practices. Some cadets expressed that while environmental policies are introduced in coursework, real-world application and practical training in waste management remain limited. The study suggests integrating regulatory compliance training into cadet curriculum modules and conducting regular audits to ensure continued adherence to waste disposal standards.

3. Cadet Awareness and Training Effectiveness

Cadet awareness and training effectiveness received a moderate score of 85/100, reflecting a strong theoretical understanding of waste management principles but limited hands-on implementation experience. Surveys indicated that cadets understand the importance of waste segregation, recycling, and pollution prevention, yet lack direct

exposure to operational waste management strategies. Instructors emphasized that more practical, on-site waste management exercises would improve cadet engagement and environmental responsibility.

The study recommends expanding practical waste management training by incorporating real-world case studies, hands-on waste processing simulations, and field visits to waste treatment facilities. By integrating these approaches, cadets will develop stronger problem-solving skills and environmental stewardship awareness before entering professional naval engineering roles.

4. Pollution Prevention Success Rate

The pollution prevention success rate received the highest score of 92/100, indicating that naval engineering operations at Poltekpel SULUT have effectively minimized environmental contamination risks through structured pollution prevention initiatives. Field assessments confirmed that oil-water separation systems, hazardous waste containment measures, and recycling programs have contributed to significant reductions in pollution levels.

Naval engineers and maintenance officers noted that increased access to eco-friendly technologies, such as advanced bilge water treatment systems and biodegradable cleaning agents, has enhanced pollution control efforts. However, respondents suggested that greater investment in innovative pollution reduction techniques, such as waste-to-energy conversion technologies and improved filtration systems, would further optimize environmental performance.

5. Feasibility of the Proposed Waste Management Model

The feasibility of implementing an enhanced waste management model was evaluated, resulting in a score of 87/100. Qualitative responses from engineers and environmental specialists indicated that the proposed waste management framework—incorporating stricter waste segregation policies, improved monitoring systems, and enhanced regulatory training—would be practical and beneficial.

The primary concerns raised during the study included financial constraints, logistical challenges in waste disposal, and the need for ongoing personnel training. Some policymakers suggested that a phased implementation approach, starting with high-priority waste categories, would facilitate smoother adoption. The study recommends pilot testing

the model within a specific operational unit before full-scale deployment across all naval engineering activities.

6. Cost Efficiency of Sustainable Waste Solutions

The cost efficiency of implementing sustainable waste management solutions received a score of 89/100, highlighting that long-term financial benefits outweigh initial investment costs. Experts in the study pointed out that waste reduction initiatives, such as recycling programs and hazardous waste recovery systems, lead to significant cost savings over time.

The financial analysis showed that reducing landfill dependency and increasing recycling efforts lower operational costs associated with waste disposal and environmental fines. However, the study also found that initial capital investment in eco-friendly technologies and training programs could pose short-term financial barriers. To address this, the study recommends exploring partnerships with government agencies, environmental organizations, and private sector stakeholders to secure funding for sustainable waste initiatives.

7. Operational Readiness for Implementation

The final evaluation criterion, operational readiness for waste management model implementation, received an average score of 86/100. Naval engineering personnel expressed a strong willingness to adopt enhanced waste management policies, but also cited logistical constraints, personnel training needs, and infrastructure improvements as key factors that must be addressed before full implementation.

The study found that existing waste management facilities require modernization to accommodate more efficient waste sorting, storage, and disposal processes. Additionally, waste collection schedules and transport logistics must be optimized to prevent backlogs and inefficiencies. The study suggests designing a step-by-step implementation roadmap, with clear milestones and performance evaluations, to ensure that the transition to improved waste management practices is both structured and sustainable.

The research confirms that waste management and pollution prevention strategies in naval engineering operations at Poltekpel SULUT are effective, yet improvements can be made to enhance regulatory compliance, cadet training, and operational efficiency. The strong scores across all evaluation criteria—ranging from 85/100 to 92/100—indicate that

the institution has a solid foundation in environmental sustainability but requires targeted policy enhancements to optimize performance.

The findings demonstrate that while existing waste management practices align with fundamental regulatory requirements, structured policy enforcement, personnel training, and infrastructure upgrades can further improve effectiveness. The study highlights that cadet engagement in sustainability programs must be strengthened through practical training initiatives, and that investment in eco-friendly waste reduction technologies will yield both environmental and financial benefits.

These results provide empirical evidence supporting the implementation of an optimized waste management model, offering actionable recommendations for reducing environmental impact, improving compliance with maritime regulations, and fostering a culture of environmental responsibility in naval engineering education. The study concludes that developing a structured, scalable waste management framework will ensure long-term sustainability, cost efficiency, and regulatory adherence in naval operations.

4. DISCUSSION

The findings of this study indicate that waste management and pollution prevention strategies in naval engineering operations at Poltekpel SULUT are highly effective yet require enhancements in policy enforcement, cadet training, and operational infrastructure. The research evaluated key indicators, including the effectiveness of current waste management practices, regulatory compliance, cadet awareness and training, pollution prevention success, feasibility of the proposed waste management model, cost efficiency, and operational readiness for implementation. By combining qualitative data from expert interviews, field observations, and structured survey responses, the study provides a comprehensive assessment of the strengths and weaknesses of existing waste management frameworks and offers data-driven recommendations for improvement.

A central theme emerging from the study is the strong alignment between current waste management practices and environmental sustainability goals, as evidenced by the high effectiveness score of 88/100. This result confirms that Poltekpel SULUT has established a foundational waste management system, including waste segregation, recycling initiatives, and hazardous material containment procedures. However, the study

also reveals that while basic waste management infrastructure exists, inconsistencies in compliance and enforcement hinder full optimization of pollution prevention efforts. The analysis of regulatory compliance produced an even higher score of 90/100, suggesting that waste disposal practices generally align with national and international maritime environmental regulations. However, expert interviews with environmental officers and policymakers highlighted gaps in enforcement, periodic lapses in compliance monitoring, and the need for stricter oversight mechanisms. These findings indicate that while institutional policies exist on paper, their practical implementation must be reinforced through structured audits and waste tracking systems.

Another significant insight from the study is the role of cadet awareness and training in ensuring long-term sustainability in waste management. With an awareness and training effectiveness score of 85/100, the research confirms that cadets have a theoretical understanding of waste management principles but limited hands-on experience in applying them within operational naval settings. Survey responses from cadets indicate that while classroom-based instruction on waste segregation, recycling, and pollution control is integrated into the curriculum, opportunities for practical training remain limited (Manuel, 2017; Sharma, 2023). Field observations corroborate these findings, revealing that cadets are rarely involved in real-world waste processing exercises and often lack exposure to best practices in hazardous material handling and disposal. The qualitative responses from instructors further emphasize that practical training modules, real-time waste management drills, and case study-based learning experiences must be incorporated into the maritime engineering curriculum to bridge the gap between theoretical knowledge and operational application.

One of the most compelling aspects of this study is its assessment of pollution prevention success rates, which received the highest score of 92/100. This finding highlights that waste reduction efforts, oil-water separation systems, and recycling initiatives have successfully minimized environmental contamination risks. Expert interviews with naval engineers and maintenance officers confirm that investments in eco-friendly waste disposal technologies, including advanced filtration systems and biodegradable cleaning agents, have contributed to significant reductions in pollution levels. However, these experts also noted that certain high-risk waste categories—such as hazardous chemicals and engine

maintenance residues—continue to pose disposal challenges. This suggests that while overall pollution prevention efforts have been successful, targeted interventions are still required to address specific categories of waste that cannot be easily neutralized or recycled.

The feasibility of implementing an enhanced waste management model was also a key area of investigation in this study. With a feasibility score of 87/100, the findings indicate that naval engineering personnel and policymakers generally support the development of a more structured waste management framework, but concerns remain regarding financial costs, logistical constraints, and personnel training requirements. Several respondents noted that while the proposed model—incorporating stricter waste segregation policies, improved tracking mechanisms, and expanded recycling initiatives—would be beneficial in the long run, its implementation must be phased to avoid overwhelming operational resources (Dyagileva et al., 2020; Kidd & McCarthy, 2019). The study suggests that pilot testing the model within a specific operational unit before expanding it across all naval engineering activities could help refine its practicality and address unforeseen challenges before full-scale adoption.

A key economic consideration in the study was the cost efficiency of sustainable waste solutions, which received a score of 89/100. Qualitative findings suggest that while the initial financial investment in advanced waste management technologies and training programs may be substantial, long-term savings outweigh these costs. Cost-benefit analysis performed during the study revealed that reducing landfill dependency, increasing recycling efficiency, and optimizing hazardous waste disposal reduce operational expenses over time. Moreover, by preventing environmental violations and ensuring compliance with waste disposal regulations, naval institutions can avoid financial penalties and reputational damage. However, some policymakers interviewed in the study emphasized that access to funding for sustainable waste management programs remains a challenge, particularly in educational institutions where budgets are often constrained. As a result, the study recommends exploring public-private partnerships, government incentives, and grant funding opportunities to support the transition to enhanced waste management models.

The final aspect of the study examined operational readiness for waste management model implementation, which received a score of 86/100. While the findings indicate a strong willingness among naval engineering personnel to adopt enhanced waste

management policies, logistical challenges and resource limitations remain barriers to implementation. Field assessments revealed that existing waste management facilities require modernization to accommodate more efficient waste sorting, storage, and disposal processes. Additionally, waste collection schedules and transport logistics must be optimized to prevent backlogs and inefficiencies. Expert recommendations emphasize the importance of designing a step-by-step implementation roadmap with clear milestones and performance evaluations to ensure that the transition to improved waste management practices is structured, measurable, and sustainable.

A cross-group comparison between naval engineers, cadets, policymakers, and environmental specialists revealed commonalities and distinctions in perspectives on waste management effectiveness. All groups agreed on the necessity of improving regulatory enforcement and training, but differences emerged regarding implementation priorities. Naval engineers and maintenance officers prioritized technological improvements, such as better waste separation equipment and recycling systems, whereas policymakers focused on regulatory alignment and cost-benefit analysis. Cadets, on the other hand, emphasized the need for more practical training opportunities to enhance their environmental competence before entering professional maritime roles. These findings suggest that a holistic approach—balancing regulatory enforcement, technological upgrades, and training initiatives—is necessary to ensure a well-rounded waste management strategy.

The broader implications of this study extend beyond Poltekpel SULUT and its naval engineering operations. The research highlights that effective waste management and pollution prevention strategies are integral to achieving global maritime sustainability goals. The findings can be applied to other maritime training institutions, commercial shipping operations, and naval fleets, where structured waste management models are needed to ensure regulatory compliance and environmental responsibility. The study also emphasizes that sustainability must be embedded into maritime engineering curricula, equipping the next generation of naval professionals with the knowledge and skills required to implement pollution prevention initiatives across the industry (Albayrak & Ziarati, 2012).

The study confirms that waste management and pollution prevention strategies at Poltekpel SULUT are effective, but improvements are necessary to enhance regulatory enforcement, training, and operational efficiency. The high scores across all evaluation

criteria—ranging from 85/100 to 92/100—indicate that the institution has a strong foundation in environmental sustainability, yet opportunities exist to further optimize performance. The study's findings provide valuable insights into the practical and economic feasibility of implementing an optimized waste management model, reinforcing the need for structured policy enhancements, technological investments, and education-driven sustainability programs. By addressing these key areas, naval engineering institutions can strengthen their commitment to environmental stewardship, ensure compliance with maritime regulations, and set a new standard for sustainable naval operations in the years to come.

5. CONCLUSION

This research confirms that waste management and pollution prevention strategies in naval engineering operations at Poltekpel SULUT are effective but require targeted enhancements to improve regulatory enforcement, cadet training, and operational efficiency. The findings demonstrate that while existing waste disposal frameworks align with basic regulatory requirements, inconsistencies in monitoring, enforcement gaps, and limited hands-on training opportunities must be addressed. The study highlights that cadet awareness and engagement in environmental sustainability are strong, yet practical implementation remains a challenge, emphasizing the need for curriculum improvements that integrate real-world waste management exercises. The research also underscores that pollution prevention measures, such as oil-water separation and hazardous waste containment, have been successful in minimizing environmental risks, with further potential for optimization through investment in advanced waste processing technologies. The proposed waste management model is both feasible and cost-effective, as it aligns operational sustainability with economic efficiency, reducing long-term disposal costs and enhancing regulatory compliance. However, financial constraints and logistical barriers must be mitigated through phased implementation, strategic partnerships, and external funding opportunities. Ultimately, this study provides empirical evidence supporting structured policy improvements, technological advancements, and enhanced training initiatives to ensure that waste management in naval engineering operations meets the highest environmental and operational standards. These recommendations offer a sustainable,

scalable framework for reducing the environmental footprint of naval activities while strengthening maritime education and regulatory compliance.

REFERENCES

Alamoush, A. S., Ballini, F., & Ölçer, A. I. (2020). Ports' technical and operational measures to reduce greenhouse gas emission and improve energy efficiency: A review. *Marine Pollution Bulletin*, *160*, 111508.

Albayrak, T., & Ziarati, R. (2012). Encouraging research in maritime education & training. *Journal of Maritime Transport and Engineering*, *1*(1), 4–9.

Creswell, J. W., & Clark, V. L. P. (2011). Choosing a mixed methods design. In *Designing and Conducting Mixed Methods Research* (pp. 53–106). Sage Publications, Inc.

Das, A. P., Mohanty, A. K., van Hullebusch, E. D., & Figueiredo, G. (2023). Bioremediation as an emerging technology for the removal of synthetic microplastic pollutants from marine ecosystem. In *Marine Pollution Bulletin* (Vol. 194, p. 115297). Elsevier.

Dyagileva, O., Goridko, N., Popova, H., Voloshynov, S., & Yurzhenko, A. (2020). *Ensuring sustainable development of education of future maritime transport professionals by means of network interaction*.

Fang, S., Wang, Y., Gou, B., & Xu, Y. (2019). Toward future green maritime transportation: An overview of seaport microgrids and all-electric ships. *IEEE Transactions on Vehicular Technology*, *69*(1), 207–219.

Kidd, R., & McCarthy, E. (2019). Maritime education in the age of autonomy. *WIT Transactions on The Built Environment*, *187*, 221–230.

Li, X., Zhou, Y., & Yuen, K. F. (2024). Blockchain implementation in the maritime industry: critical success factors and strategy formulation. *Maritime Policy & Management*, *51*(2), 304–322.

Manuel, M. E. (2017). Vocational and academic approaches to maritime education and training (MET): Trends, challenges and opportunities. *WMU Journal of Maritime Affairs*, *16*, 473–483.

Pu, S., & Lam, J. S. L. (2021). Blockchain adoptions in the maritime industry: a conceptual framework. *Maritime Policy & Management*, *48*(6), 777–794.

Sæther, S. R., & Moe, E. (2021). A green maritime shift: Lessons from the electrification of ferries in Norway. *Energy Research & Social Science*, *81*, 102282.

Saldana, J. (2014). *Thinking qualitatively: Methods of mind*. SAGE publications.

Sharma, A. (2023). *Potential of technology supported competence development for Maritime Education and Training*.

Siedlecki, S. L. (2020). Understanding descriptive research designs and methods. *Clinical Nurse Specialist*, *34*(1), 8–12.

Bureaucracy Journal: Indonesia Journal of Law and Social-Political Governance
p-ISSN: 2797-9598 | e-ISSN: 2777-0621
Vol. 5 No. 1 Januari - April 2025