Marine Pollution Prevention and Response Effectiveness: MARPOL Implementation in Indonesian Territorial Waters and Strategic Straits

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Abstract. Indonesia's territorial waters, encompassing the world's most strategically significant maritime chokepoints including the Malacca, Sunda, and Lombok Straits, face acute and escalating marine pollution threats from the dense vessel traffic that transits these corridors daily. This study evaluates the effectiveness of MARPOL Annex I–VI compliance enforcement in Indonesian waters, identifying systemic implementation gaps and proposing an optimized enforcement and early warning response model. Employing a qualitative research design with thematic analysis and documentary review, the study engaged marine environmental inspectors, port state control officers, maritime law academics, and environmental scientists as primary respondents. Findings reveal an overall MARPOL implementation effectiveness composite score of 3.89 out of 5.00, with Annex I (oil pollution) and Annex VI (air pollution) enforcement identified as the most critically deficient implementation domains. The research demonstrates that Indonesian MARPOL enforcement is constrained by inspection capacity limitations, inter-agency coordination failures, and inadequate pollution response infrastructure across outer island port jurisdictions. The study contributes an enforcement optimization model and early warning pollution response system framework for Indonesian maritime environmental governance, with direct implications for maritime professional education at STIP Jakarta.

Keywords: MARPOL; marine pollution; Indonesian waters; environmental enforcement; maritime sustainability

1. INTRODUCTION

The seas surrounding Indonesia are among the most ecologically rich and economically vital marine environments on the planet — home to the Coral Triangle's extraordinary biodiversity, artisanal fishing communities whose livelihoods depend on pristine coastal ecosystems, and strategic waterways through which an estimated 40% of global seaborne trade transits annually. Yet these same waters are subjected to relentless pollution pressure from the vessel traffic that makes Indonesia's maritime corridors so economically indispensable. Oil discharge, sewage, garbage, noxious liquid substances, and atmospheric emissions from the thousands of vessels navigating Indonesian waters daily constitute a chronic and compounding threat to marine ecosystem integrity, coastal community health, and the long-term sustainability of Indonesia's blue economy. The International Convention for the Prevention of Pollution from Ships — universally known as MARPOL — represents the primary international legal instrument through which these pollution threats are supposed to be governed, yet the gap between MARPOL's regulatory ambitions and the operational realities of enforcement in Indonesia's vast and geographically dispersed maritime jurisdiction has never been more urgently in need of systematic scholarly examination.

The scholarly literature on MARPOL implementation has increasingly documented the disparity between convention ratification and effective enforcement operationalization, particularly in developing maritime nations where inspection capacity, inter-agency

coordination mechanisms, and pollution response infrastructure have not kept pace with the escalating volume and complexity of vessel pollution risks. Jian-ping et al. (2021) demonstrated in their analysis of marine plastic waste in the South China Sea that regional cooperation frameworks are essential for addressing transboundary pollution challenges that individual national enforcement systems cannot manage in isolation — a finding with direct relevance to Indonesia's MARPOL enforcement challenges given the transboundary nature of pollution incidents in the Malacca and Lombok Straits. Amorim et al. (2024) revealed that microplastic pollution patterns in oceanic island contexts reflect both local pollution sources and distant transportation pathways, illustrating the systemic character of marine pollution that MARPOL's multi-annex structure attempts to address but that fragmented national enforcement systems frequently fail to govern adequately. These scholarly contributions frame the analytical context within which this study examines Indonesian MARPOL implementation effectiveness.

The central research problem is the persistent and documented gap between Indonesia's formal ratification of MARPOL annexes and the operational effectiveness of its enforcement mechanisms across its vast territorial water jurisdiction. While Indonesia has ratified all six MARPOL annexes and incorporated their requirements into national maritime law through Government Regulation No. 21 of 2010 on Ship Environmental Protection, the practical enforcement of these requirements — particularly Annex I oil pollution controls and Annex VI atmospheric emission standards — is severely constrained by the limited inspection capacity of the Directorate General of Sea Transportation, the absence of coordinated inter-agency pollution monitoring frameworks, and the inadequacy of pollution response infrastructure at ports beyond Java's major urban centers. Paridaens and Notteboom (2021) argued that effective maritime environmental policy requires not merely regulatory ratification but the institutional embeddedness of enforcement cultures and the inter-agency coordination mechanisms capable of translating legal obligations into operational compliance realities. The specific research questions are: How effectively are MARPOL Annex I–VI requirements being enforced in Indonesian territorial waters? What are the primary institutional and operational constraints limiting MARPOL enforcement effectiveness? And what enforcement optimization and early warning response mechanisms would most significantly improve marine pollution prevention outcomes? These questions are addressed through three specific objectives: to assess current MARPOL enforcement effectiveness across all six annexes in Indonesian waters; to identify and prioritize institutional and operational constraints on enforcement capacity; and to develop

an enforcement optimization model and early warning pollution response framework for Indonesian maritime environmental governance.

The rationale for this research is grounded in the convergence of ecological urgency and economic imperative. Caldeirinha et al. (2024) established that port sustainability performance is fundamentally conditioned by the quality of environmental governance frameworks within which ports operate, creating a direct link between MARPOL enforcement effectiveness and the long-term sustainability of Indonesian port and coastal economies. Zhou et al. (2024) demonstrated that green port policy implementation in Chinese coastal regions produced measurable improvements in both marine environmental quality and port operational efficiency, illustrating the compound benefits of rigorous environmental enforcement that Indonesian maritime governance must seek to replicate. The significance of this research extends beyond regulatory compliance to encompass Indonesia's international maritime reputation, its obligations under the United Nations Convention on the Law of the Sea as a coastal state with sovereign rights over its exclusive economic zone, and its responsibility as the world's largest archipelagic nation to protect marine biodiversity of global ecological significance. For STIP Jakarta, this research creates a direct professional education mandate: maritime officers trained at the institution must graduate with a thorough understanding of MARPOL requirements and pollution prevention procedures, equipped to serve as frontline ambassadors of marine environmental protection aboard Indonesian and international vessels.

2. RESEARCH METHOD

This study adopted a qualitative research design integrating thematic analysis with systematic documentary review, appropriate for examining the complex regulatory, institutional, and operational dynamics of MARPOL implementation across Indonesia's geographically dispersed maritime jurisdiction. The methodological approach drew from the environmental governance analytical framework established by Jian-ping et al. (2021) in their South China Sea marine pollution study, adapting it to the MARPOL compliance context by evaluating enforcement effectiveness across the six annexes through a multi-stakeholder analytical lens that captures regulatory, operational, and scientific perspectives.

The population comprised MARPOL implementation stakeholders operating across Indonesia's principal maritime jurisdictions. Purposive sampling selected 47 respondents distributed across four groups: 12 marine environmental inspectors and pollution response officers from the Ministry of Environment and Forestry and the Directorate General of Sea Transportation, 11 Port State Control officers and maritime safety inspectors with MARPOL

enforcement responsibilities, 12 maritime law academics and marine environmental scientists from STIP Jakarta, the Institut Pertanian Bogor, and the Indonesian Institute of Sciences, and 12 shipping company designated persons ashore and environmental compliance officers from Indonesian domestic and international shipping companies operating through Indonesian waters. The inclusion of marine environmental scientists alongside maritime regulatory and industry respondents represents a distinctive interdisciplinary methodological contribution, enabling the study to triangulate regulatory enforcement assessments with scientific evidence of pollution incidence and ecosystem impact.

The research instrument comprised a semi-structured interview protocol organized around two independent variables: MARPOL regulatory implementation capacity, encompassing inspection frequency, deficiency detection rates, enforcement action consistency, and inter-agency coordination effectiveness across Annexes I through VI; and pollution response infrastructure adequacy, encompassing reception facility availability at Indonesian ports, oil spill response equipment deployment, pollution incident reporting systems, and early warning monitoring technology coverage. The dependent variable was MARPOL implementation effectiveness, operationalized through indicators including annex-specific compliance rates, pollution incident response time, reception facility utilization rates, and ecosystem impact mitigation effectiveness. Supporting instruments included systematic review of MARPOL inspection records from Indonesian Port State Control authorities (2021–2024), Ministry of Environment pollution incident databases, and comparative analysis of MARPOL implementation effectiveness assessments from comparable ASEAN jurisdictions. Zhou et al. (2024) provided methodological precedent for combining regulatory document analysis with stakeholder interviews in maritime environmental governance research.

Data collection proceeded through recorded semi-structured interviews conducted across Jakarta, Surabaya, Batam, and Makassar — representing Indonesia's four principal maritime governance centers — supplemented by documentary analysis of MARPOL enforcement records and pollution incident data over a twelve-week field research period. Thematic analysis proceeded through open coding of interview transcripts to identify MARPOL enforcement barrier and enabler themes, categorical aggregation into regulatory capacity and response infrastructure themes, and cross-group comparative analysis to distinguish the perspectives of inspectors, PSC officers, academics, and industry compliance officers on the most critical implementation constraints and improvement priorities. Narrative synthesis then integrated these themes with documentary evidence to produce a coherent

institutional account of Indonesian MARPOL implementation dynamics and strategic improvement pathways.

3. RESULTS AND DISCUSSION

3.1 Results

The thematic analysis yielded an overall MARPOL implementation effectiveness composite score of 3.89 out of 5.00, indicating moderate-to-good overall implementation with significant annex-specific and geographic variation in enforcement quality and compliance rates.

Table 1: MARPOL Annex Implementation Effectiveness Scores — By Respondent Group

MARPOL Annex	Environmental Inspectors (n=12)	PSC Officers (n=11)	Maritime Academics (n=12)	Industry Compliance Officers (n=12)	Mean Score
Annex I — Oil Pollution	3.42	3.58	4.08	3.75	3.71
Annex II — Noxious Liquid Substances	3.75	3.83	4.17	4.00	3.94
Annex III — Harmful Substances in Packages	4.08	4.17	4.33	4.25	4.21
Annex IV — Sewage	3.92	4.00	4.25	4.08	4.06
Annex V — Garbage	3.67	3.75	4.17	3.83	3.86
Annex VI — Air Pollution	3.17	3.33	3.92	3.58	3.50
Composite Effectiveness Score	3.67	3.78	4.15	3.92	3.88

Table 2: MARPOL Enforcement Constraint Analysis and Optimization Priority Matrix

Enforcement Constraint	Severity Score (/5)	Geographic Impact	Improvement Feasibility	Priority Ranking
Inspection Capacity Limitations	4.50	National — all regions	Moderate	1
Inter-Agency Coordination Failures	4.33	National — systemic	High	2
Reception Facility Inadequacy	4.25	Severe in outer islands	Moderate	3
Annex VI Monitoring Technology Gaps	4.17	All major ports	High	4

Pollution Incident Reporting Culture	3.92	Industry-wide	High	5
Early Warning System Coverage	3.83	Eastern Indonesia	Moderate	6
Legal Enforcement Action Consistency	3.75	National — court system	Low	7

Table 1 reveals that Annex VI (air pollution) enforcement scores lowest across all respondent groups (3.50 mean), reflecting the absence of vessel emissions monitoring technology at most Indonesian ports and the very limited capacity of Indonesian PSC officers to conduct NOx, SOx, and particulate matter compliance assessments without specialized measurement equipment. Annex I (oil pollution) also scores critically low (3.71), despite being the most globally recognized and institutionally established MARPOL requirement — a finding that interviews attribute to the insufficient frequency of oil record book inspections outside major ports and the inadequacy of oil reception facilities at provincial and outer island ports that force vessels into illegal discharge practices. Annex III (harmful substances in packages) scores highest (4.21), reflecting the relatively straightforward documentation-based nature of its compliance requirements compared to the technical monitoring demands of Annexes I and VI.

Table 2 identifies inspection capacity limitations as the most severe enforcement constraint (4.50), followed closely by inter-agency coordination failures (4.33) — findings that collectively point to a systemic governance architecture problem rather than a merely technical resource deficiency. The geographic distribution column reveals that reception facility inadequacy is most severely concentrated in outer island regions, creating enforcement voids in precisely the maritime areas where vessel pollution risks are least monitored and most ecologically damaging given the exceptional biodiversity of Indonesia's eastern marine environments.

3.2 Discussion

The findings directly address the central research questions by demonstrating that Indonesian MARPOL implementation is characterized by a multi-layered enforcement deficit: inadequate inspection frequency, severe inter-agency coordination failures, critical reception facility gaps in outer island regions, and the near-total absence of Annex VI atmospheric monitoring technology. This diagnostic portrait confirms and extends the theoretical framework of Paridaens and Notteboom (2021), who identified institutional coordination failure as the primary impediment to effective maritime environmental policy integration — a diagnosis that the inter-agency coordination failure severity score of 4.33 (Table 2) powerfully validates in the Indonesian MARPOL context. The finding that Indonesia's Annex VI

enforcement is its weakest implementation domain fills a significant gap in the ASEAN maritime environmental literature, which has focused predominantly on oil pollution and plastic waste while the atmospheric emission compliance challenge has received comparatively little scholarly attention despite its escalating regulatory significance following IMO's 2020 sulfur cap implementation.

The critically low Annex I enforcement score (3.71, Table 1) is particularly troubling given that oil pollution represents the most immediately catastrophic marine pollution risk in Indonesia's ecologically sensitive waters. Jian-ping et al. (2021) established that regional cooperation is essential for managing South China Sea marine pollution challenges, implying that Indonesia must pursue bilateral and multilateral enforcement cooperation agreements with Singapore, Malaysia, and other ASEAN maritime neighbors to address the transboundary oil pollution risks that its limited unilateral enforcement capacity cannot manage adequately. Amorim et al. (2024) demonstrated that pollution distribution patterns in oceanic island environments reflect both local discharge sources and long-distance transport pathways — a finding that reinforces the necessity of Indonesia's MARPOL enforcement extending beyond its major ports to encompass the full geographic scope of its territorial water jurisdiction. This study fills a critical analytical gap by providing the first systematic cross-annex MARPOL implementation effectiveness assessment for Indonesian waters, extending the maritime environmental governance literature beyond the single-annex or single-pollutant focus that has characterized most existing Indonesian marine pollution scholarship.

The practical implications for Indonesian maritime governance are both urgent and institutionally demanding. Caldeirinha et al. (2024) demonstrated that sustainable port performance requires integrated environmental governance frameworks — supporting the recommendation that Indonesia's Ministry of Transportation, Ministry of Environment and Forestry, and Bakamla (Indonesian Coast Guard) must establish a formal Marine Environmental Enforcement Coordination Committee with the mandate, authority, and resources to develop and implement a unified MARPOL enforcement strategy. Zhou et al. (2024) established that green port policy produces compounding environmental and operational benefits when implemented through integrated governance frameworks, providing the theoretical and empirical rationale for Indonesia to invest in port reception facility expansion as both an environmental imperative and a port competitiveness enhancement measure. The early warning pollution response system framework proposed in this study — combining satellite-based vessel emission monitoring, drone-assisted pollution detection in outer island regions, and integrated incident reporting platforms — offers a technologically

feasible and cost-effective pathway for dramatically expanding Indonesia's MARPOL enforcement coverage without proportionally scaling inspection personnel. Future research should conduct geo-spatial analysis of pollution incident distributions relative to inspection coverage patterns across Indonesian waters, and should evaluate the effectiveness of inter-agency enforcement coordination mechanisms in pilot implementation jurisdictions before national rollout.

4. CONCLUSION

This study has provided a comprehensive, stakeholder-validated assessment of MARPOL implementation effectiveness in Indonesian territorial waters, revealing a moderate-to-good overall composite score of 3.89 that masks critical enforcement deficiencies in Annex I oil pollution and Annex VI atmospheric emission compliance — Indonesia's two most ecologically and internationally significant MARPOL implementation challenges. The research identifies inspection capacity limitations and inter-agency coordination failures as the most severely constraining governance deficits, while reception facility inadequacy in outer island regions emerges as the most geographically concentrated environmental governance vulnerability. The enforcement optimization model and early warning pollution response framework developed through this study offer Indonesian maritime environmental governance bodies a coherent and institutionally grounded strategic improvement agenda. STIP Jakarta occupies a critical educational role in this improvement ecosystem, with the responsibility to produce maritime officers whose MARPOL knowledge and pollution prevention commitment serve as the most fundamental and widely deployed enforcement mechanism across Indonesia's vast and ecologically irreplaceable marine environment.

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