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RESEARCH ARTICLE

Implementation of a Smart Marine Debris Governance System for Marine Debris Management in Indonesia

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ABSTRACT

This study aims to examine the regulatory framework and implementation of marine debris management in Indonesia and to propose a smart marine debris governance system. The research employs a normative legal method using statutory and conceptual approaches, supported by literature review and qualitative normative analysis. The findings indicate that, despite an existing regulatory framework, marine debris management in Indonesia continues to face significant challenges. Existing regulations lack integrated implementation mechanisms, while fragmented institutional authority, weak coordination, and disconnected data and monitoring systems hinder effective policy implementation. Fragmented responsibilities and non-integrated monitoring and reporting systems further limit coordination, transparency, and accountability. To address these issues, this study proposes an integrated monitoring application, the use of the Internet of Things (IoT) and artificial intelligence, and cross-sector collaboration supported by performance-based accountability. This model is expected to improve data integration, strengthen institutional coordination, and enhance policy implementation. In conclusion, effective marine debris management requires integrated digital governance that connects institutions, data, technology, and accountability to support sustainable management.

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1. Introduction

Indonesia, as an archipelagic state with extensive marine waters and a long coastline, is highly vulnerable to marine debris. These geographical conditions create a close link between land-based activities and marine ecosystems, so that waste that is poorly managed on land is very likely to end up in the sea. In this context, Indonesia is even recorded as one of the world's largest contributors of plastic waste, ranking second after China, with an estimated 3.22 million tons of plastic waste discarded into the sea every year (Kementerian Lingkungan Hidup dan Kehutanan & KLHK, 2020). However, not all of this waste enters the sea directly; research by the Indonesian Institute of Sciences (Lembaga Ilmu Pengetahuan Indonesia, LIPI) in 2018 showed that the amount of plastic waste that actually leaks into Indonesian marine waters ranges from 0.27 to 0.59 million tons per year. This situation is further aggravated by the fact that four rivers in Indonesia, namely the Brantas, Solo, Serayu, and Progo Rivers, are among the 20 most polluted rivers in the world (KLHK, 2020).

Globally, marine debris has developed into a serious environmental issue. A report by the United Nations Environment Programme (UNEP) indicates that around 11 million tons of plastic waste enter the ocean every year, most of it originating from land-based activities (UNEP, 2021). At the national level, high waste generation that is not matched by an adequate management system is the main factor aggravating marine pollution. Data show that the plastic recycling rate in Indonesia reaches only 7%, while around 47% of all plastic waste generated is burned by households as a way of reducing waste volume without adequate control (World Bank, 2021). This practice not only causes health impacts through air pollution but also reflects the weakness of the integrated waste management systems available to the public.

In response to these problems, the Indonesian Government has established various strategic policies, including Presidential Regulation Number 97 of 2017 on the National Policy and Strategy for the Management of Household Waste and Waste Similar to Household Waste (JAKSTRANAS) and Presidential

Regulation Number 83 of 2018 on Marine Debris Management. These policies target a 30% reduction and 70% handling of waste by 2025, as well as a 70% reduction in marine debris compared with 2017 levels (Kementerian Lingkungan Hidup/Badan Pengendalian Lingkungan Hidup [KLH/BPLH], 2025). Nevertheless, the implementation of these policies still faces various obstacles, particularly in cross-sector coordination, data integration, and the effectiveness of existing management systems. The reduction of marine debris achieved up to 2022 was only 28%, still far from the set target (Environment Institute, 2023). Based on these conditions, it can be concluded that the marine debris problem in Indonesia is not only a matter of the technical aspects of waste management but also reflects weaknesses in a governance system that is not yet integrated, adaptive, and transparent.

In the development of marine debris management, approaches that rely on policy and administrative coordination still face limitations in integrating data, strengthening inter-agency accountability, and supporting responsive decision-making. The *governance* approach offers a perspective different from *government*, which centers on the sole role of the state, because it emphasizes multi-stakeholder collaboration involving central and regional governments, the private sector (including plastic packaging producers and retailers), civil society, academics, and informal sectors such as waste pickers and waste banks, all of which play crucial roles in the marine debris management chain (Sangprasert & Inthavisas, 2025).

In this context, a *smart marine debris governance system* is a marine debris management approach that integrates information technology, data-based monitoring systems, and cross-sector institutional coordination to create governance that is transparent, adaptive, and evidence-based (*evidence-based policy*). Opportunities to implement this approach are increasingly open as the government pursues digital transformation through the Electronic-Based Government System (Sistem Pemerintahan Berbasis Elektronik, SPBE) and the development of GovTech Indonesia, which encourage the integration of technology-based data and public services. This approach has the potential to overcome the weaknesses of the existing system by strengthening data integration, improving inter-agency accountability, and enabling decision-making that is more responsive to the dynamics of the marine debris problem (Pemerintah Kabupaten Rejang Lebong, 2025).

Based on the above, the main gap in marine debris management in Indonesia lies in the lack of integration of regulations, institutions, data, and infrastructure into a single adaptive and transparent governance system. Conventional approaches that rely on administrative coordination are inadequate for dealing with the complexity of problems that cut across sectors and regions. Accordingly, the state of the art of this research lies in developing a marine debris governance approach that integrates information technology, data-based monitoring, and cross-sector institutional coordination. The novelty of this research lies in formulating an implementation model of a *smart marine debris governance system* as a governance approach that integrates digitalization, multi-stakeholder collaboration, and accountability in marine debris management in Indonesia. Therefore, implementing a *smart marine debris governance system* is a strategic urgency for bridging the gap between policy and practice in the field by strengthening data integration, multi-stakeholder collaboration, and system transparency. The aim of this research is to analyze the regulation and implementation of marine debris management in Indonesia and to formulate an implementation model of a *smart marine debris governance system* that suits Indonesia's institutional conditions, infrastructure, and technological capacity.

2. Methodology

This research is normative juridical research, namely legal research that examines primary, secondary, and tertiary legal materials through the following approaches: the statute approach, to analyze the regulations on marine debris management and SPBE, and the conceptual approach, to examine the concepts of *governance* and *smart governance* (Marzuki, 2005, p. 35). The data used are secondary data, comprising primary legal materials, namely the 1945 Constitution of the Republic of

Indonesia, Law Number 18 of 2008 on Waste Management, Law Number 32 of 2009 on Environmental Protection and Management, Presidential Regulation Number 97 of 2017 on the National Policy and Strategy for the Management of Household Waste and Waste Similar to Household Waste, Presidential Regulation Number 83 of 2018 on Marine Debris Management, Presidential Regulation Number 95 of 2018 on the Electronic-Based Government System, as well as relevant ministerial regulations and regional regulations. Secondary legal materials include textbooks, scientific journals, and reports by the World Bank and the United Nations Environment Programme (UNEP), while tertiary legal materials include legal dictionaries and encyclopedias. Legal materials were collected through library research and then analyzed using qualitative normative analysis, namely legal interpretation and systematization, a gap analysis between *das sollen* and *das sein*, and an institutional analysis to examine authority and inter-agency coordination (Soekanto & Mamudji, 2011).

3. Results and discussion

3.1 Regulation and Implementation of Marine Debris Management in Indonesia

The regulation of marine debris management in Indonesia does not stand as an independent legal regime but forms part of the national waste management system. The main foundation of this regulation lies in Law Number 18 of 2008 on Waste Management, which comprehensively regulates management from upstream to downstream, from source reduction to final handling at final disposal sites (*tempat pemrosesan akhir*, TPA). Thus, the existing legal framework has in fact provided a sufficient normative basis for controlling waste flows, including those that end up in the sea.

In addition, Law Number 18 of 2008 also recognizes the principle of *extended producer responsibility* (EPR), which was subsequently reinforced through Minister of Environment and Forestry Regulation Number P.75 of 2019 (Direktorat Pengurangan Sampah, 2024, p. 1). This principle conceptually places producers as the party responsible for the life cycle of their products and packaging, including post-consumption management. In practice, however, the implementation of this principle has not run optimally because it is not supported by strong oversight mechanisms and effective sanctions, so that producer compliance tends to be administrative rather than substantive.

Furthermore, the Government issued Presidential Regulation Number 97 of 2017 on JAKSTRANAS, which targets a 30% waste reduction and 70% waste handling by 2025 (KLH/BPLH, 2025). These targets reflect a progressive national commitment to integrated waste management. However, limitations in implementation instruments, such as economic incentives and operational control, have meant that the targets have not been optimally achieved to date. In the specific context of marine debris, Presidential Regulation Number 83 of 2018 on Marine Debris Management (2018) serves as the main legal basis for the integrated regulation of marine debris handling. Through this regulation, Indonesia established the National Coordination Team for Marine Debris Management (TKN PSL), involving various ministries and agencies, including the Ministry of Marine Affairs and Fisheries (KKP), which plays a role in Working Group 3 on Marine and Coastal Debris Management. Nevertheless, although it adopted a cross-sector coordinative approach, the mechanism that has been built still tends to be administrative and is not yet fully accompanied by a strong operational integration system, so its effectiveness in implementation in the field remains limited (Ismadi, 2022).

Marine debris management in Indonesia is carried out within a decentralization framework as regulated in Law Number 23 of 2014 on Regional Government. Under this system, waste management is a concurrent government affair shared among the central, provincial, and regency/city governments. This division is normatively intended to ensure a proportional distribution of authority in line with the capacity of each level of government (Andiriana, 2023, p. 2).

The central government holds authority over the determination of national policy and standards, as well as guidance and supervision of the regions. Provincial governments play a role in cross-regency/city

coordination, while regency/city governments are the main implementers of operational management. Conceptually, this division shows a structured and systematic institutional design.

In practice, however, this institutional structure has actually produced fragmented authority. Yuwono (2025) found overlapping authority involving at least 12 agencies in waste management at fishing ports. This condition shows that normative clarity does not always translate into effective implementation in the field.

Such fragmentation ultimately has various implications, such as unclear responsibilities, duplication of programs, and inefficient use of resources. In addition, weak coordination among agencies often causes the resulting policies to be unsynchronized and to proceed in a partial manner. These conditions result in less-than-optimal implementation of marine debris management policies, as reflected in the gap between the set targets and implementation outcomes.

The implementation of marine debris management policies shows a significant gap between targets and realization. The reduction in marine debris achieved up to 2022 reached only 28%, while the target set is 70% by 2025 (Environment Institute, 2023). This gap shows that existing policies have not been accompanied by an effective implementation strategy.

The low plastic recycling rate of only 7% and the high rate of household burning at 47% reflect weaknesses in the available management system (World Bank, 2021, p. 35). This condition relates not only to public behavior but also shows limited infrastructure and incentives within the waste management system. In other words, the failure is structural rather than merely individual.

Furthermore, the high leakage of plastic waste into the sea, reaching 346.5 kilotons per year, along with the continued dominance of *open dumping* at final disposal sites, shows that waste management from upstream to downstream has not run in an integrated manner (World Bank, 2021, pp. 1–2). This indicates that the existing management system has not been able to effectively cut the flow of waste from land to sea. Therefore, the achievement gap reflects not only implementation failure but also systemic problems in governance.

The gap between legal norms (*das sollen*) and implementation reality (*das sein*) can be identified in several main aspects. First, a normative gap, in which the principle of *extended producer responsibility* has not been fully operationalized effectively. This is caused, among other things, by suboptimal support from law enforcement instruments, particularly regarding sanction mechanisms that have not been firmly formulated (ANTARA News, 2025). This condition implies a limited coercive power of legal norms in driving changes in business actors' behavior.

Second, an institutional gap characterized by fragmented authority and weak inter-agency coordination. Although a National Coordination Team involving various ministries and agencies has formally been established, its implementation is still not optimal (MPR RI, 2025). This shows that formal coordination has not been able to meet the need for operational integration in the field. Third, a data and information gap related to the limitations of the National Waste Management Information System (*Sistem Informasi Pengelolaan Sampah Nasional*, SIPSN). The system has not been able to provide accurate, real-time data, so decision-making is not based on actual conditions in the field (KLH/BPLH, 2025).

Overall, these gaps show that the main problem in marine debris management lies not in the absence of regulation but in the weak integration of regulations, institutions, data, and infrastructure. This condition reflects that a system connected from upstream to downstream has not yet been built. Therefore, an approach is needed that is able to integrate all of these elements into a single unified system.

3.2 Weaknesses in the Monitoring and Management System

Cross-sector fragmentation of authority is one of the main weaknesses in Indonesia's marine debris management system. Overlapping authority among agencies results in unclear responsibility for waste

handling, particularly in waters (Yuwono, 2025, p. 8). This condition hampers the effectiveness of action because each agency tends to work within its own sectoral boundaries.

The impact of this condition can be seen in the form of responsibility vacuums, program duplication, and wasted resources. In addition, weak coordination also means that oversight does not run optimally because there is no clear accountability mechanism (Yuwono, 2025). Thus, fragmentation of authority is not merely an administrative matter but also directly affects the effectiveness of management in the field.

Another significant problem is that the data systems and digital applications used by various stakeholders are not yet synchronized. The various systems that have been developed operate sectorally and are not interconnected, producing fragmented data. This condition hinders the integration of information needed for comprehensive decision-making. SIPSN, as the national system, still has limitations because it depends on manual input and is not yet able to provide data in real time (Firmansyah, 2025). As a result, the available data often do not reflect actual conditions in the field. In the context of dynamic marine debris management, this information delay directly leads to an ineffective response.

Weak inter-agency coordination is further aggravated by the absence of binding accountability mechanisms. Although a National Coordination Team has been established, its implementation remains administrative, without a performance-based evaluation system. This causes coordination not to run effectively in practice (Repository IPB, 2022). As a result, most of the national waste is still not well managed and waste leakage into the sea remains high (Mongabay Indonesia, 2020). Evaluations tend to be formal and are not based on real achievements in the field. Thus, weak accountability is a factor that reinforces the failure of policy implementation.

These various weaknesses show that the main problem in marine debris management lies not only in policy or institutional aspects but in the absence of a system able to integrate data, coordination, and decision-making in real time. Conventional approaches that rely on administrative coordination have proven inadequate for dealing with the complexity of problems that cut across sectors and regions. Therefore, a new approach is needed that can overcome these limitations systemically.

3.3 Implementation of a Smart Marine Debris Governance System as a Solution

3.3.1 Concept and Urgency of a Smart Marine Debris Governance System

A *smart marine debris governance system* is a marine debris management approach that focuses on the integration of information technology, data-based monitoring systems, and cross-sector institutional coordination. This approach is oriented not only toward improving technical efficiency but also toward transforming governance into a system that is more transparent, adaptive, and evidence-based (*evidence-based policy*) (INCA, 2025). Thus, the proposed solution is not partial but targets the root of the problems identified in the previous sections. The urgency of applying this approach cannot be separated from the failure of conventional approaches that have relied on administrative coordination without adequate integration systems. The significant gap between targets and realization shows that policy improvement alone is not enough without changes in implementation mechanisms. Therefore, digitalization and system integration are a structural need, not merely an additional innovation.

In addition, the governance approach promoted here emphasizes a shift from a hierarchical *government* model toward a multi-stakeholder collaborative model (Lestari & Afrilia, 2025). In this context, marine debris management is no longer positioned as the sole responsibility of the government but as the result of interaction among the government, the private sector, society, and informal actors. Thus, the effectiveness of policy depends greatly on the system's ability to orchestrate this collaboration in an integrated manner.

3.3.2 Integrated Application as a Monitoring Control Center

The implementation of a *smart marine debris governance system* is realized through an integrated application serving as a marine debris monitoring control center that connects SIPSN, regional information systems, and private-sector platforms in a single data ecosystem. The application functions as a *decision support system* to address data fragmentation and reporting delays through digital *dashboard* features, automatic notifications, *geotagging*, *crowdsourcing*, and cross-sector data integration. The use of *Internet of Things* (IoT) technology and artificial intelligence also enables real-time monitoring, early detection of waste accumulation, prediction of vulnerable points, and optimization of resource allocation (Matondang et al., 2025). Thus, marine debris management can shift from a reactive approach to a predictive and participatory system.

3.3.3 Stages of Integrated System Implementation

The system is implemented in stages, beginning with data integration through the harmonization of standards and the development of an *application programming interface* (API) to connect the various platforms that are already available. The next stage is the development of IoT-based real-time monitoring through the installation of sensors at strategic points, such as river mouths and ports, to detect waste accumulation early. Subsequently, strengthening human resource capacity through technical training, improved data literacy, and operational assistance needs to be carried out to overcome human resource limitations, particularly in the regions (Putri et al., 2025). Once this foundation is established, artificial intelligence can be developed to predict the distribution of waste and optimize its handling.

3.3.4 Cross-Sector Synergy in Implementation

The success of the system depends on cross-sector synergy, with the central government responsible for establishing regulations, technical standards, and funding, while regional governments carry out operations in the field. The private sector and academics support technology development and policy evaluation, while communities, waste pickers, and waste bank managers are involved in monitoring and managing waste inclusively (Syalluna et al., 2026). This synergy needs to be supported by a clear and binding coordination mechanism, with the Coordinating Ministry for Maritime Affairs and Investment as the national coordinator to ensure coherence between policy and implementation. Without strong coordination, the system risks becoming fragmented again.

Thus, the implementation of a *smart marine debris governance system* needs to be understood as an effort to transform governance that integrates technology, institutions, and multi-stakeholder participation, not merely the digitalization of a monitoring system. Its success depends on infrastructure readiness, human resource capacity, and clear coordination and accountability among stakeholders. Through such integration, the system is expected to overcome fragmented management, improve the accuracy of decision-making, and strengthen the effectiveness of marine debris management policies in a sustainable manner.

4. Conclusion

Marine debris management in Indonesia basically already has an adequate legal foundation, but its implementation still faces a gap between targets and realization. This problem is caused by fragmented authority, weak coordination and accountability, and suboptimal integration of data and monitoring systems, which shows that the main issue lies not in the absence of regulation but in the weak integration of policy implementation. The weaknesses of conventional monitoring systems that depend on manual reporting and administrative coordination hinder fast and accurate decision-making, and data systems that are not yet integrated also mean that the available information does not fully reflect actual conditions in the field. Therefore, an approach is needed that connects data, institutions, and oversight

in a single integrated management system. The application of a *smart marine debris governance system* is proposed as a solution through an integrated monitoring application, the use of *Internet of Things* (IoT) technology and artificial intelligence, and the strengthening of cross-sector collaboration. Its implementation needs to be carried out in stages through data integration, human resource capacity building, and the establishment of clear coordination and accountability mechanisms. Thus, this system is expected to realize marine debris governance that is more effective, adaptive, transparent, and sustainable.

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