



LEGAL AND INSTITUTIONAL DETERMINANTS OF MEDICAL SOLID WASTE MANAGEMENT IN INDONESIA'S FIRST-LEVEL HEALTH FACILITIES

Musdaleni

Universitas Riau, Pekanbaru, Indonesia

musdaleni368@gmail.com

ARTICLE INFO

Keywords:

First-Level Healthcare Facilities; Infrastructure Constraints; Medical Solid Waste; Regulatory Compliance; Waste Management Regulation.

ABSTRACT

The management of medical solid waste in first-level healthcare facilities is a critical component of public health and environmental protection in Indonesia. This study examines the adequacy of the regulatory framework, the implementation of waste management practices, and strategies for improving compliance in primary healthcare settings. Using a normative juridical and policy-oriented approach, the research analyzes key legal instruments governing medical solid waste, including environmental, health, and waste management regulations. The findings indicate that Indonesia has established a comprehensive legal framework that clearly regulates waste segregation, storage, transportation, treatment, and disposal. However, empirical evidence from prior studies shows that implementation at the facility level remains inconsistent. Limited infrastructure, financial constraints, inadequate human resource capacity, and uneven regulatory enforcement hinder effective compliance, particularly in rural and resource-constrained areas. Many facilities depend on third-party waste providers, weakening accountability for proper segregation at the source. The study highlights the need for integrated strategies, including stronger regulation, capacity building, infrastructure investment, and better coordination between health and environmental authorities. The study concludes that aligning regulatory standards with institutional and operational capacities is crucial for achieving safe and sustainable medical solid waste management in first-level healthcare facilities in Indonesia.

A. INTRODUCTION

Medical solid waste management has become a critical environmental and public health issue in Indonesia, particularly in first-level healthcare facilities such as public health centers (*Pusat Kesehatan Masyarakat*/Puskesmas) and clinics. These facilities represent the frontline of healthcare services and contribute significantly to the daily generation of infectious and hazardous medical waste. Inadequate handling of such waste not only threatens environmental sustainability but also poses serious risks to

healthcare workers, patients, and surrounding communities. Despite the existence of regulatory frameworks governing medical waste management, persistent gaps between regulation and practice indicate structural and implementation challenges that require systematic examination.¹

Indonesia has established specific regulations to govern the management of medical solid waste, notably the Regulation of the Minister of Environment and Forestry Number P56 of 2015, which outlines standards for waste reduction, segregation, collection, storage, transportation, and final treatment. However, compliance with these regulations remains uneven across healthcare facilities. While certain hospitals demonstrate relatively high levels of adherence, many first-level service facilities struggle to implement standardized waste management procedures consistently. Studies indicate that weaknesses frequently occur at the stages of waste segregation, internal transportation, and temporary storage, leading to increased risks of contamination and regulatory violations.²

One of the most significant barriers to effective implementation lies in infrastructural and capacity limitations. The total capacity of licensed medical waste treatment facilities in Indonesia is insufficient to accommodate the volume of waste generated daily, particularly from decentralized primary healthcare units. As a result, facilities often resort to improper disposal practices, including open-air burning and uncontrolled dumping, especially in areas with limited access to treatment facilities.³ These practices undermine environmental protection efforts and contradict national waste management standards. The reliance on third-party waste management vendors further complicates implementation, as collection schedules are often infrequent and subject to logistical constraints. In Surabaya, for instance, medical waste is collected only once a month, requiring facilities to comply with a 14-day

¹ F. F. Al-Fikri, R. A. Nugroho, and Sudarmo, "Evaluation of implementation about Covid-19 medical waste management policies in health care facilities," In *IOP Conference Series: Earth and Environmental Science* 905, no.1, IOP Publishing, 2021, 12124. See too, Ratih Enggal Siswanti, "Tanggung Gugat Rumah Sakit Atas Pelanggaran Pengelolaan Limbah Medis B3 yang dikerjasamakan dengan Pihak Lain," *Jurnal Hukum Dan Etika Kesehatan* (2022): 149.

² Silvia Khansa, Agustin Kusumayati, Dewi Susanna, and Uli Tiarna Sinaga, "Evaluation of solid medical waste management in Bogor regional public hospitals," 6, no. 1 (2023): 133. See too, Mehdi Kabiri Naein, and Zeynab Elahi, "Sustainable Waste Management in Healthcare: Application of Fuzzy Determination Method to Prioritize Key Influencing Factors," *Journal of Advances in Environmental Health Research* 13, no. 3 (2025): 201; Arifah Wulansari, Sudarno, and Fuad Muhammad, "Medical waste management at community health center: a literature review." In *E3S Web of Conferences* 202, EDP Sciences, 2020, 06017.

³ Mehdi Kabiri Naein, and Zeynab Elahi, "Sustainable Waste Management in Healthcare: Application of Fuzzy Determination Method to Prioritize Key Influencing Factors," *Journal of Advances in Environmental Health Research* 13, no. 3 (2025): 202. See too, Arifah Wulansari, Sudarno, and Fuad Muhammad, "Medical waste management at community health center: a literature review." In *E3S Web of Conferences* 202, EDP Sciences, 2020, 06018.

storage limit to prevent waste accumulation, a requirement that is not always met in practice.⁴

Technological and financial constraints also play a decisive role in shaping waste management practices.⁵ Incineration remains a dominant method for treating hazardous medical waste due to its effectiveness in reducing volume and eliminating pathogens. However, the high costs associated with constructing, operating, and maintaining incinerators make this option inaccessible for many first-level healthcare facilities. Alternative technologies, such as chemical disinfection using chlorine and innovations like the MWT-P system that reduces bacterial content in medical waste, offer lower-cost solutions but have not been widely adopted due to limited awareness, technical capacity, and institutional support.⁶

Geographical conditions further exacerbate disparities in implementation. In archipelagic regions such as Maluku and Papua, limited infrastructure and transportation networks significantly hinder access to centralized waste treatment facilities. In response, conceptual designs for floating medical waste treatment facilities have been proposed as context-sensitive solutions to address regional constraints. While such innovations demonstrate adaptive potential, their implementation remains largely conceptual, underscoring the gap between policy ideas and operational realities.

Given these challenges, there is growing recognition of the need for integrated and scalable improvement strategies. Strengthening infrastructure through targeted investment in waste treatment facilities and digital management systems, such as the adoption of Odoo Enterprise Resource Planning for integrated monitoring and reporting, has been suggested as a means to enhance compliance and transparency.⁷ Equally important is the role

⁴ Maria Anityasari, Hilmi Cahya Rinardi, and I. D. A. A. Warmadewanthi, "Analysing medical waste transportation using periodic vehicle routing problem for Surabaya public health facilities," *Journal of Material Cycles and Waste Management* 27, no. 2 (2025): 836. See too, Fikri Naufal Uyun, Frency Siska, and Nurul Chotidjah, "Pengawasan pemerintah daerah terhadap pengelolaan limbah B3 internal rumah sakit," *Jurnal Riset Ilmu Hukum* 2, no. 1 (2022): 59.

⁵ Syukra Alhamda, Abdul Khair, And Noraida, "Evaluation of solid medical waste management at Pasaman Barat Regional Hospital, Indonesia: Challenges and environmental impact solutions," *Journal of Sustainability Science and Management* 20, no. 8 (2025): 1579. See too, Absori, and Muhamad Latif, "Kebijakan hukum dalam pengelolaan limbah bahan berbahaya dan beracun (B3): Studi implementasi pengelolaan limbah medis di rumah sakit Salatiga," *JIL: Journal of Indonesian Law* 1, no. 1 (2020): 94.

⁶ Verawaty Simarmata, Setiaty Pandia, and Herman Mawengkang, "Model statistic with program LISREL for medical solid infectious waste hazardous hospital Type B management in Medan City," In *IOP Conference Series: Earth and Environmental Science* 205, no. 1, IOP Publishing, 2018, 12002.

⁷ Rizky Syahriani Putri, Owildan Wisudawan, Haslinah Ahmad, Masnilam Hasibuan, Anto J. Hadi, and Nayodi Permayasa, "Efektivitas Kebijakan Kesehatan dalam Meningkatkan Pengelolaan

of continuous training and education for healthcare workers to improve knowledge, attitudes, and practices related to medical waste handling.⁸ Furthermore, more consistent policy enforcement, coupled with technical and financial support mechanisms, is essential to ensure that first-level healthcare facilities are capable of meeting regulatory standards.⁹

Although previous studies have examined various aspects of medical waste management in Indonesia, most have focused on specific operational stages such as segregation, transportation, or storage, as well as technological alternatives and policy enforcement issues.¹⁰ However, there remains a lack of comprehensive research that systematically integrates regulatory analysis, on-the-ground implementation in first-level healthcare facilities, and context-sensitive improvement strategies within a single framework.¹¹ This gap indicates the need for a more holistic approach to better understand the disconnect between policy and practice and to formulate scalable and sustainable solutions.

The main problem in this study is the gap between the regulatory framework and the implementation of solid medical waste management in primary healthcare facilities in Indonesia, which is influenced by limited infrastructure, technical capacity, and geographical conditions, thus hindering the achievement of safe, effective, and sustainable waste management. Against this background, this study seeks to systematically examine the

Limbah Medis di Puskesmas Labuhan Rasoki Kota Padangsidempuan," *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 7, no. 4 (2024): 1047.

⁸ Meng Zhang, Wei Cui, Qi Jiang, Nengmin Wang, and Yuan Shang, "Vehicle routing for infectious healthcare waste collection with transit points: a problem incorporating multiple types of risks and two solution methods from different perspectives," *IEEE Access* 8, no. 1 (2025): 536. See too, Micaela Ines Castillo Ulloa, Diego Alexis Ramos Huarachi, Vinicius Moretti, Cleiton Hluszko, Fabio Neves Puglieri, Thalita Monteiro Obal, and Antonio Carlos de Francisco, "Sustainability and Algorithmic Comparison of Segmented PVRP for Healthcare Waste Collection: A Brazilian Case Study," *Sustainability* 17, no. 19 (2025): 8536; Arifah Wulansari, Sudarno, and Fuad Muhammad, "Medical waste management at community health center: a literature review." In *E3S Web of Conferences* 202, EDP Sciences, 2020, 06019.

⁹ Erwin Sondang Siagian, Asep Sumaryana, Ida Widianingsih, and Heru Nurasa, "Public-private partnerships in solid waste management in Indonesia: the need for technical regulation," *Asia Pacific Journal of Public Administration* 41, no. 4 (2019): 249.

¹⁰ Silvia Khansa, Agustin Kusumayati, Dewi Susanna, and Uli Tiarma Sinaga, "Evaluation of solid medical waste management in Bogor regional public hospitals," 6, no. 1 (2023): 134. See too, Erwin Sondang Siagian, Asep Sumaryana, Ida Widianingsih, and Heru Nurasa, "Public-private partnerships in solid waste management: arrangements in Indonesia," *Asia Pacific Journal of Public Administration* 41, no. 1 (2019): 59; Mehdi Kabiri Naein, and Zeynab Elahi, "Sustainable Waste Management in Healthcare: Application of Fuzzy Determination Method to Prioritize Key Influencing Factors," *Journal of Advances in Environmental Health Research* 13, no. 3 (2025): 204.

¹¹ Verawaty Simarmata, Setiaty Pandia, and Herman Mawengkang, "Model statistic with program LISREL for medical solid infectious waste hazardous hospital Type B management in Medan City," In *IOP Conference Series: Earth and Environmental Science* 205, no. 1, IOP Publishing, 2018, 12003.

regulatory framework governing medical solid waste management in first-level healthcare facilities in Indonesia; analyze the actual implementation practices of medical waste segregation and handling at the facility level; and, formulate evidence-based recommendations to improve medical solid waste management in a sustainable and context-sensitive manner. By addressing these interconnected dimensions, the study aims to contribute to the strengthening of environmental governance and public health protection within Indonesia's primary healthcare system.

1. How is the regulatory framework governing medical solid waste management in Indonesia structured, particularly for first-level healthcare facilities?
2. How is medical solid waste management implemented in practice at first-level healthcare facilities?
3. What strategies can be developed to improve the effectiveness and sustainability of medical solid waste management in first-level healthcare facilities in Indonesia?

B. RESEARCH METHODS

This study employs a normative juridical research method using a statutory and policy-oriented approach to examine the regulation and management of medical solid waste in first-level healthcare facilities in Indonesia. This method is appropriate because the study focuses on analyzing legal norms, regulatory frameworks, and policy implementation related to medical waste management rather than collecting primary empirical data from the field.

The statutory approach is used to analyze key legal instruments governing medical solid waste management. Primary legal materials include Minister of Environment and Forestry Regulation Number P.56/Menlhk-Setjen/2015, Government Regulation Number 101 of 2014 on Hazardous and Toxic Waste Management, Minister of Health Regulation Number 1204 of 2004, and Solid Waste Management Act Number 18 of 2008. These regulations are examined to identify regulatory standards, institutional responsibilities, and compliance obligations imposed on first-level healthcare facilities, including public health centers and clinics. The analysis emphasizes the coherence of these regulations and their alignment with public health and environmental protection objectives.

To complement the statutory analysis, the study incorporates a policy analysis approach by reviewing secondary sources such as peer-reviewed journal articles, policy reports, and relevant academic studies. These materials are used to assess how regulatory provisions are implemented in practice and to identify common challenges faced by healthcare facilities in managing

medical solid waste. Secondary empirical findings are treated as supporting data that provide contextual understanding of compliance levels, operational practices, and enforcement dynamics without transforming the study into empirical research.

The analytical technique applied is qualitative descriptive analysis. This technique is used to systematically describe regulatory requirements and compare them with documented implementation practices, particularly in relation to waste segregation, temporary storage, transportation, and final disposal.

C. DISCUSSION

1. Regulations for Managing Medical Solid Waste in First-Level Healthcare Facilities in Indonesia

The management of medical solid waste in first-level healthcare facilities in Indonesia is regulated through a layered legal framework that integrates environmental protection, public health safeguards, and national waste management principles. These facilities, which include public health centers and clinics, generate various categories of medical solid waste that are potentially hazardous to human health and the environment.¹² Consequently, the regulatory framework aims to ensure that such waste is managed in a manner that minimizes risks of contamination, infection, and ecological damage.

One of the most central legal instruments governing medical solid waste management is the Minister of Environment and Forestry Regulation No. P.56/Menlhk-Setjen/2015. This regulation provides detailed technical procedures for managing hazardous and toxic waste (B3) generated by healthcare facilities.¹³ It mandates waste segregation at the point of generation, secure packaging and labeling, controlled temporary storage, licensed transportation, and environmentally sound treatment and disposal. The regulation is designed to create a standardized chain of responsibility,

¹² Welem Tandilolok Sitohang, Djoko Imbawani, and Inge Hartini, "The Effectiveness of Law on the Obligation of B3 Medical Waste Management by Healthcare Facilities in Tana Toraja Regency," *Locus: Jurnal Konsep Ilmu Hukum* 6, no. 1 (2026): 123.

¹³ Franky Yusuf, "Pertanggungjawaban hukum terkait pengelolaan limbah b3 dalam fasilitas kesehatan," *Journal iuris scientia* 2, no. 1 (2024): 18. See too, Egi Agfira Noor, "Pertanggungjawaban rumah sakit terhadap limbah bahan beracun berbahaya (B3)," *Jurnal Penegakan Hukum Indonesia* 1, no. 1 (2020): 235; Suroto, "Pertanggungjawaban Hukum Terkait Pengelolaan Limbah B3 (Bahan Berbahaya dan Beracun) dalam Fasilitas Kesehatan," *Majelis: Jurnal Hukum Indonesia Учредители: Asosiasi Seni Desain dan Komunikasi Visual Indonesia* 1, no. 3 (2024): 11; Absori, and Muhamad Latif, "Kebijakan hukum dalam pengelolaan limbah bahan berbahaya dan beracun (B3): Studi implementasi pengelolaan limbah medis di rumah sakit Salatiga," *JIL: Journal of Indonesian Law* 1, no. 1 (2020): 95.

ensuring that medical waste does not pose risks during handling or disposal.¹⁴ For first-level healthcare facilities, this regulation establishes a minimum compliance threshold, even though their operational capacity is often more limited than that of hospitals.

Complementing this regulation, Government Regulation No. 101 of 2014 serves as the overarching framework for hazardous and toxic waste management in Indonesia. This regulation emphasizes waste minimization, pollution prevention, and the obligation to apply safe treatment methods, including incineration and residue solidification. Its relevance to medical solid waste lies in reinforcing the principle that waste management is not solely a technical obligation but also a preventive environmental policy measure. For first-level healthcare facilities, this regulation provides the legal basis for requiring licensed treatment and disposal processes, even when such facilities do not operate their own treatment units.

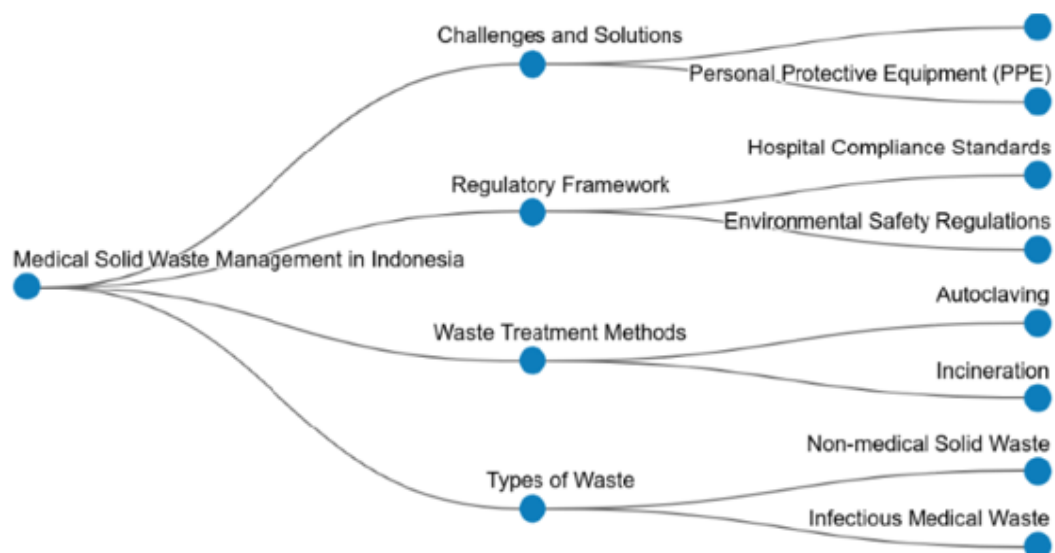


Figure 1. Medical Solid Waste Management Issues

As illustrated in Figure 1, the management of medical solid waste in Indonesia is conceptualized through several interconnected components. The

¹⁴ Silvia Khansa, Agustin Kusumayati, Dewi Susanna, and Uli Tiarna Sinaga, "Evaluation of solid medical waste management in Bogor regional public hospitals," 6, no. 1 (2023): 135. See too, Rizky Syahrani Putri, Owildan Wisudawan, Haslinah Ahmad, Masnilam Hasibuan, Anto J. Hadi, and Nayodi Permayasa, "Efektivitas Kebijakan Kesehatan dalam Meningkatkan Pengelolaan Limbah Medis di Puskesmas Labuhan Rasoki Kota Padangsidimpuan," *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 7, no. 4 (2024): 1048; Jenni Ria Rajagukguk, "B3-Medical waste management Fas Yankes Bogor district health office in 2018," In *IOP Conference Series: Materials Science and Engineering* 725, no. 1, IOP Publishing, 2020, 12083; Mehdi Kabiri Naein, and Zeynab Elahi, "Sustainable Waste Management in Healthcare: Application of Fuzzy Determination Method to Prioritize Key Influencing Factors," *Journal of Advances in Environmental Health Research* 13, no. 3 (2025): 206.

diagram highlights four main aspects: challenges and solutions, regulatory framework, waste treatment methods, and types of waste. Under challenges and solutions, emphasis is placed on the use of personal protective equipment (PPE), reflecting safety concerns in waste handling. The regulatory framework branch underscores the importance of hospital compliance standards and environmental safety regulations. Meanwhile, waste treatment methods are represented by processes such as autoclaving and incineration, which are essential for reducing hazardous risks. Lastly, the classification of waste distinguishes between non-medical solid waste and infectious medical waste. Overall, Figure 1 demonstrates that effective medical waste management requires an integrated approach combining regulation, safety measures, proper treatment technologies, and clear waste categorization.

From the health sector perspective, Minister of Health Regulation No. 1204 of 2004 specifically addresses the technical requirements for managing medical waste within healthcare service facilities. This regulation governs internal operational processes, including segregation, on-site transportation, temporary storage, and coordination for final disposal. It places direct responsibility on healthcare providers to ensure that medical waste handling does not endanger patients, healthcare workers, or surrounding communities.¹⁵ Although enacted earlier than environmental regulations, this instrument remains a key reference for operational compliance within first-level healthcare facilities.

In addition to sector-specific regulations, the Solid Waste Management Act No. 18 of 2008 provides a broader normative framework for waste management in Indonesia.¹⁶ This law prioritizes waste reduction through the principles of Reduce, Reuse, and Recycle (3Rs) and emphasizes environmentally sound waste handling. While medical solid waste requires specialized treatment that limits recycling options, the law reinforces the importance of waste reduction and responsible management as part of national environmental policy.¹⁷ For healthcare facilities, this act situates

¹⁵ Roza Seilkassymova, Daniya Nurmukhankyzy, Aktoty Rzabay, Zhangali Baktykhozhayev, and Indira Nessipbayeva, "Environmental safety and legal regulation of medical waste management: international experience," *Journal of Environmental Management & Tourism* 13, no. 7 (2022): 1820. See too, Fikri Naufal Uyun, Frency Siska, and Nurul Chotidjah, "Pengawasan pemerintah daerah terhadap pengelolaan limbah B3 internal rumah sakit," *Jurnal Riset Ilmu Hukum* 2, no. 1 (2022): 54.

¹⁶ Lisa Lamusul Afiah, "Implementasi PERMENKES Nomor 18 Tahun 2020 Terhadap Pengolahan Limbah Medis Rumah Sakit," *UNES Law Review* 6, no. 2 (2023): 6149.

¹⁷ Enri Damanhuri, Widhi Handoko, and Tri Padmi, "Municipal solid waste management in Indonesia," In *Municipal solid waste management in Asia and the Pacific Islands: challenges and strategic solutions*, Singapore: Springer Singapore, 2013, 142. See too, Verani Dwitarsari, Adriano Adriano, and M. Tauchid Noor, "Tanggung Jawab Hukum Klinik Pratama dalam Pengelolaan Limbah Medis: Legal Responsibility of Primary Healthcare Clinics in Medical Waste Management," *Jurnal Hukum dan Etika Kesehatan* (2025): 144.

medical waste management within a wider commitment to sustainable waste governance.

Despite the existence of these regulations, their implementation in first-level healthcare facilities reveals notable regulatory challenges. Compliance levels vary significantly across facilities, reflecting differences in institutional capacity, access to infrastructure, and administrative oversight. Some facilities have established structured waste management systems and collaborate with licensed third-party vendors for waste transportation and disposal, indicating partial regulatory alignment.¹⁸ However, such practices are not uniformly adopted, particularly in facilities located in rural or resource-constrained areas.

Regulatory enforcement also remains uneven. While legal obligations are clearly articulated, monitoring and supervision mechanisms are often insufficient to ensure consistent compliance. Weak enforcement undermines the effectiveness of regulatory instruments, allowing deviations from prescribed standards to persist without adequate corrective measures.¹⁹ This situation highlights a structural gap between normative legal provisions and their operational realization in first-level healthcare settings.

Financial constraints further affect regulatory compliance. The management of medical solid waste requires sustained funding for segregation materials, storage facilities, transportation services, and treatment costs. Delays in operational budget disbursement and limited financial allocations hinder the ability of healthcare facilities to fully comply with regulatory requirements, particularly during periods of increased waste generation such as public health emergencies.²⁰ These constraints illustrate that regulatory effectiveness is closely linked to fiscal capacity.

¹⁸ Maria Anityasari, Hilmi Cahya Rinardi, and I. D. A. A. Warmadewanthi, "Analysing medical waste transportation using periodic vehicle routing problem for Surabaya public health facilities," *Journal of Material Cycles and Waste Management* 27, no. 2 (2025): 837. See too, Silvia Khansa, Agustin Kusumayati, Dewi Susanna, and Uli Tiarna Sinaga, "Evaluation of solid medical waste management in Bogor regional public hospitals," 6, no. 1 (2023): 136; Rizky Syahriani Putri, Owildan Wisudawan, Haslinah Ahmad, Masnilam Hasibuan, Anto J. Hadi, and Nayodi Permayasa, "Efektivitas Kebijakan Kesehatan dalam Meningkatkan Pengelolaan Limbah Medis di Puskesmas Labuhan Rasoki Kota Padangsidempuan," *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 7, no. 4 (2024): 1048; I. R. Rahim, M. Selintung, I. Jamaluddin, M. Ihsan, and E. Y. Tiranda, "Performance of Covid-19 Waste Management at Health Service Facilities in North Toraja Regency," In *IOP Conference Series: Earth and Environmental Science* 1117, no. 1, IOP Publishing, 2022, 12051.

¹⁹ Oktavia Dewi, Novita Rany, Herniwanti Herniwanti, and Mitra, M, "Application of SWOT analysis as a strategy for medical waste management in the independent practice of dentists in Pekanbaru City, Indonesia," *Multidisciplinary Science Journal* 6, no. 3 (2026): 236. See too, Edward Kurnia Setiawan Limijadi, and Katrin Setio Devi, "Medical Waste Management and Environmental Impact in Independent Healthcare Practices: A Systematic Review," In *E3S Web of Conferences*, vol. 655, EDP Sciences, 2025, 1013.

²⁰ I. R. Rahim, M. Selintung, I. Jamaluddin, M. Ihsan, and E. Y. Tiranda, "Performance of Covid-19 Waste Management at Health Service Facilities in North Toraja Regency," In *IOP Conference Series: Earth and Environmental Science* 1117, no. 1, IOP Publishing, 2022, 12053.

Human resource capacity is another critical regulatory dimension. Regulations implicitly assume the availability of trained personnel capable of implementing technical waste management procedures. In practice, insufficient training limits the ability of healthcare workers to comply with regulatory standards. Evidence indicates that trained staff demonstrate higher adherence to waste management protocols, thereby reducing health and environmental risks.²¹ However, training programs remain inconsistent, weakening the practical enforcement of existing regulations.

Overall, Indonesia's regulatory framework for managing medical solid waste in first-level healthcare facilities is comprehensive in scope and reflects a strong legal commitment to public health and environmental protection. Nevertheless, the persistence of compliance gaps indicates that regulatory effectiveness is constrained by institutional capacity, financial limitations, and uneven enforcement. Strengthening regulatory implementation requires not only clear legal norms but also adequate resources, effective supervision, and sustained capacity-building to ensure that first-level healthcare facilities can meet the standards set by existing regulations.²²

2. Implementation Practices in First-Level Healthcare Facilities Handling Medical Solid Waste Segregation in Indonesia

The implementation of medical solid waste segregation in first-level healthcare facilities in Indonesia remains a critical challenge, despite the existence of comprehensive regulatory frameworks. Public health centers and clinics are the primary generators of medical solid waste at the community level, yet empirical evidence shows that segregation practices are frequently inconsistent and incomplete.²³ The effectiveness of waste management at this level is largely determined by daily operational practices, human resource capacity, infrastructure availability, and coordination with external waste management services.

Several studies highlight that waste segregation at the point of generation is often inadequately implemented. In Bogor District, for example,

See too, Myrna Asnawati Safitri, "Establishing the link between law, culture and infrastructure for pandemic waste management," *UUM Journal of Legal Studies* 16, no. 2 (2025): 88.

²¹ Setia Megawati Hutajulu, and Arifah Devi Fitriani, "Nurse Compliance with Medical Waste Management Protocols: An Observational Study at Indonesian Hospitals," *The Open Public Health Journal* 18, no. 1 (2025): 346.

²² Silvia Khansa, Agustin Kusumayati, Dewi Susanna, and Uli Tiarna Sinaga, "Evaluation of solid medical waste management in Bogor regional public hospitals," 6, no. 1 (2023): 137. See too, Rizky Syahriani Putri, Owildan Wisudawan, Haslinah Ahmad, Masnilam Hasibuan, Anto J. Hadi, and Nayodi Permayasa, "Efektivitas Kebijakan Kesehatan dalam Meningkatkan Pengelolaan Limbah Medis di Puskesmas Labuhan Rasoki Kota Padangsidimpuan," *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 7, no. 4 (2024): 1049.

²³ Annisa Hartami, Lego Karjoko, and Fatma Ulfatun Najicha, "Optimalisasi Peran Pemerintah Dalam Kebijakan Penanganan Limbah Medis," *PLEDOI (Jurnal Hukum dan Keadilan)* 2, no. 1 (2023): 14.

public hospitals demonstrated compliance rates ranging from 77% to 86.48% with applicable regulations. However, these figures mask persistent weaknesses in segregation practices, particularly in distinguishing infectious waste from non-hazardous waste and ensuring proper on-site transport procedures. Similar patterns are observed in first-level healthcare facilities, where segregation is formally required but operationally compromised by limited supervision and inconsistent staff practices.

In other regions, such as North Toraja Regency, first-level healthcare facilities frequently rely on third-party vendors to handle hazardous medical waste.²⁴ While outsourcing waste management may reduce immediate operational burdens, it often reflects the absence of effective in-house segregation and treatment capabilities. Facilities tend to store mixed waste before collection, increasing the risk of cross-contamination and occupational exposure.²⁵ This practice indicates that segregation is not fully internalized as part of routine clinical operations.

Compliance with waste segregation standards is further constrained by human resource limitations. Many healthcare facilities lack designated waste management officers with adequate training and authority. As a result, segregation responsibilities are often assigned informally to clinical or cleaning staff who may not fully understand waste classification requirements. Studies show that deficiencies in human resource quality directly affect segregation accuracy, temporary storage practices, and record-keeping.²⁶ This situation is particularly evident in independent clinics and rural health centers, where staffing levels are minimal.

Financial constraints also play a significant role in shaping segregation practices. Limited operational budgets restrict the procurement of essential segregation tools, such as color-coded bins, secure containers for sharps, and appropriate labeling systems. Delays in the disbursement of operational funds exacerbate these constraints, leading facilities to adopt ad hoc waste handling

²⁴ Suroto, "Pertanggungjawaban Hukum Terkait Pengelolaan Limbah B3 (Bahan Berbahaya dan Beracun) dalam Fasilitas Kesehatan," *Majelis: Jurnal Hukum Indonesia Учредители: Asosiasi Seni Desain dan Komunikasi Visual Indonesia* 1, no. 3 (2024): 12. See too, Lintang Aprilia, Rahayu Subekti, and Sapto Hermawan, "Kajian Precautionary Principle Terhadap Pengelolaan Limbah Medis B3 Pada Fasilitas Layanan Kesehatan," *Indonesian Journal of Social Sciences and Humanities* 5, no. 1 (2025): 128.

²⁵ Annisa Hartami, Lego Karjoko, and Fatma Ulfatun Najicha, "Optimalisasi Peran Pemerintah Dalam Kebijakan Penanganan Limbah Medis," *PLEDOI (Jurnal Hukum dan Keadilan)* 2, no. 1 (2023): 15.

²⁶ Verani Dwitasari, Adriano Adriano, and M. Tauchid Noor, "Tanggung Jawab Hukum Klinik Pratama dalam Pengelolaan Limbah Medis: Legal Responsibility of Primary Healthcare Clinics in Medical Waste Management," *Jurnal Hukum dan Etika Kesehatan* (2025): 146. See too, Nuril Hikam Efendi, Dominikus Rato, and Iwan Rachmad Soetijono, "Prinsip kehati-hatian dalam pengelolaan limbah medis untuk mewujudkan kehidupan yang berkelanjutan," *DIH: Jurnal Ilmu Hukum* (2023): 149.

practices that prioritize immediate disposal over proper segregation.²⁷ During periods of increased waste generation, such as the COVID-19 pandemic, these limitations became more pronounced, further undermining segregation compliance.

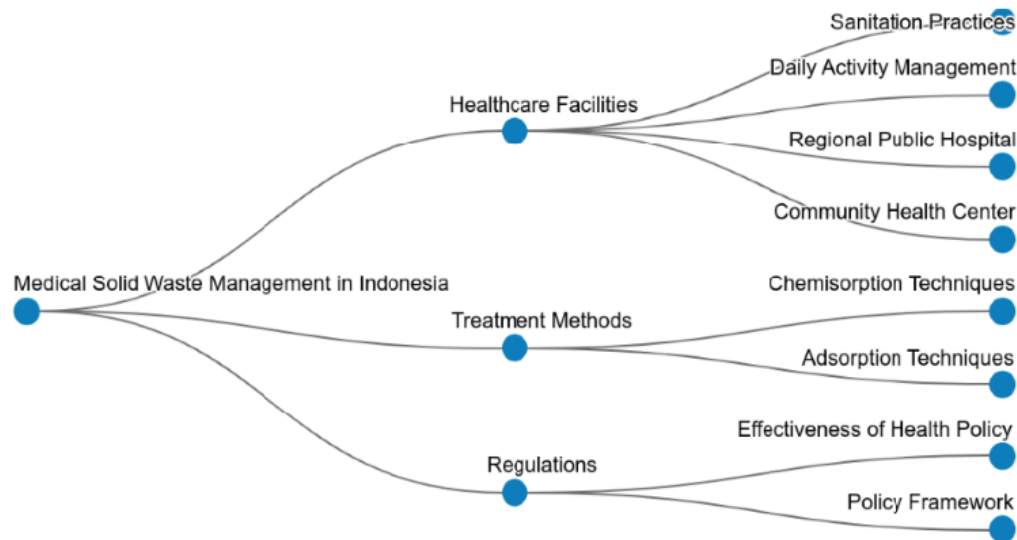


Figure 2. Implementation Practices of Medical Solid Waste Management

As illustrated in Figure 2, the management of medical solid waste in Indonesia is structured around three main components: healthcare facilities, treatment methods, and regulatory aspects. The diagram shows that healthcare facilities such as regional public hospitals and community health centers are closely linked to daily activity management and sanitation practices, highlighting the operational dimension of waste segregation. In terms of treatment methods, approaches such as chemisorption and adsorption techniques are presented as key processes for handling waste. Meanwhile, the regulatory branch emphasizes the importance of policy frameworks and the effectiveness of health policies in guiding waste management practices. Figure 2 conveys that medical waste management is not solely dependent on regulations, but also on the integration of facility-level practices, appropriate treatment technologies, and the effectiveness of policy implementation in ensuring proper waste segregation and handling.

²⁷ Edward Kurnia Setiawan Limijadi, and Katrin Setio Devi, "Medical Waste Management and Environmental Impact in Independent Healthcare Practices: A Systematic Review," In *E3S Web of Conferences*, vol. 655, EDP Sciences, 2025, 1014. See too, Rizky Syahrani Putri, Owildan Wisudawan, Haslinah Ahmad, Masnilam Hasibuan, Anto J. Hadi, and Nayodi Permayasa, "Efektivitas Kebijakan Kesehatan dalam Meningkatkan Pengelolaan Limbah Medis di Puskesmas Labuhan Rasoki Kota Padangsidimpuan," *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 7, no. 4 (2024): 1050.

The treatment and disposal stage also reflects weaknesses in segregation implementation. Incineration remains the dominant treatment method for hazardous medical waste, yet its effectiveness depends heavily on proper segregation upstream.²⁸ Evidence from a national infection center hospital indicates that incinerators sometimes operate below recommended temperatures, resulting in incomplete waste treatment.²⁹ In first-level healthcare facilities lacking direct access to compliant incinerators, improperly segregated waste may be temporarily stored or disposed of through unsafe practices, including open burning or mixing with domestic waste streams.³⁰

A significant gap between policy and practice is particularly visible in rural and remote areas. Weak regulatory enforcement, combined with limited monitoring capacity, allows unsafe segregation practices to persist with minimal accountability. Facilities may lack adequate temporary storage spaces and fail to use personal protective equipment consistently, increasing occupational and environmental risks.³¹ These conditions illustrate how segregation practices are shaped not only by formal rules but also by local institutional realities.

Current implementation practices also reveal heavy dependence on third-party waste management vendors. While collaboration with licensed vendors is intended to ensure safe disposal, it can lead to fragmented accountability when segregation responsibilities are unclear. In some cases, healthcare facilities assume that waste management compliance begins only at the point of collection, neglecting segregation responsibilities at the source.³² This reliance complicates oversight and weakens internal quality control mechanisms.

²⁸ Ratih Enggal Siswanti, "Tanggung Gugat Rumah Sakit Atas Pelanggaran Pengelolaan Limbah Medis B3 yang dikerjasamakan dengan Pihak Lain," *Jurnal Hukum Dan Etika Kesehatan* (2022): 150.

²⁹ D. Curie, I. Warmadewanthi, E. Haryadi, and M. Tiardjiono, "Evaluation of medical waste management in national infection center hospital," In *AIP Conference Proceedings* 3098, no. 1, AIP Publishing LLC, 2024, 40071. See too, Yosef Stefan Sutanto, and Kortensi Karianga, "Hukum Terkait Pengelolaan Limbah Bahan Berbahaya Dan Beracun Medis Rumah Sakit," *Jurnal Hukum Kesehatan Indonesia* 3, no. 02 (2023): 104.

³⁰ Edward Kurnia Setiawan Limijadi, and Katrin Setio Devi, "Medical Waste Management and Environmental Impact in Independent Healthcare Practices: A Systematic Review," In *E3S Web of Conferences*, vol. 655, EDP Sciences, 2025, 1015.

³¹ D. Curie, I. Warmadewanthi, E. Haryadi, and M. Tiardjiono, "Evaluation of medical waste management in national infection center hospital," In *AIP Conference Proceedings* 3098, no. 1, AIP Publishing LLC, 2024, 40073. See too, Edward Kurnia Setiawan Limijadi, and Katrin Setio Devi, "Medical Waste Management and Environmental Impact in Independent Healthcare Practices: A Systematic Review," In *E3S Web of Conferences*, vol. 655, EDP Sciences, 2025, 1016.

³² Maria Anityasari, Hilmi Cahya Rinardi, and I. D. A. A. Warmadewanthi, "Analysing medical waste transportation using periodic vehicle routing problem for Surabaya public health facilities," *Journal of Material Cycles and Waste Management* 27, no. 2 (2025): 839. See too, Oktavia Dewi, Novita Rany, Herniwanti Herniwanti, and Mitra, M, "Application of SWOT

The health and environmental consequences of inadequate segregation practices are well documented. Improper handling of medical waste increases the risk of needlestick injuries, exposure to infectious materials, and environmental contamination affecting surrounding communities. Estimates suggest that Indonesia has accumulated approximately 8,000 tons of untreated medical waste, underscoring the systemic implications of ineffective segregation practices. These risks are magnified when segregation failures occur consistently at the primary healthcare level.

Overall, the implementation of medical solid waste segregation in first-level healthcare facilities in Indonesia is characterized by partial compliance, operational inconsistencies, and structural constraints. While some facilities demonstrate moderate levels of adherence, segregation practices remain vulnerable to financial limitations, insufficient training, infrastructural gaps, and weak enforcement mechanisms. These findings suggest that effective segregation is not merely a technical issue but an organizational and institutional challenge embedded within daily healthcare service delivery.³³

3. Strategies for Improving Medical Solid Waste Management in First-Level Healthcare Facilities in Indonesia

Although Indonesia has established a relatively comprehensive regulatory framework governing medical solid waste management, persistent challenges in compliance, enforcement, and resource availability indicate the need for systematic improvements that address both institutional capacity and operational practices.³⁴ One of the most critical areas for improvement is training and education for healthcare workers and supporting staff. Empirical studies consistently demonstrate that inadequate knowledge and limited technical competence significantly contribute to improper waste segregation and handling practices. In many first-level healthcare facilities, staff

analysis as a strategy for medical waste management in the independent practice of dentists in Pekanbaru City, Indonesia," *Multidisciplinary Science Journal* 6, no. 3 (2026): 237.

³³ D. Curie, I. Warmadewanthi, E. Haryadi, and M. Tiardjiono, "Evaluation of medical waste management in national infection center hospital," In *AIP Conference Proceedings* 3098, no. 1, AIP Publishing LLC, 2024, 40075. See too, Silvia Khansa, Agustin Kusumayati, Dewi Susanna, and Uli Tiarma Sinaga, "Evaluation of solid medical waste management in Bogor regional public hospitals," 6, no. 1 (2023): 139; Edward Kurnia Setiawan Limijadi, and Katrin Setio Devi, "Medical Waste Management and Environmental Impact in Independent Healthcare Practices: A Systematic Review," In *E3S Web of Conferences*, vol. 655, EDP Sciences, 2025, 1018; Rizky Syahrani Putri, Owildan Wisudawan, Haslinah Ahmad, Masnilam Hasibuan, Anto J. Hadi, and Nayodi Permayasa, "Efektivitas Kebijakan Kesehatan dalam Meningkatkan Pengelolaan Limbah Medis di Puskesmas Labuhan Rasoki Kota Padangsidempuan," *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 7, no. 4 (2024): 1050; Arifah Wulansari, Sudarno, and Fuad Muhammad, "Medical waste management at community health center: a literature review," In *E3S Web of Conferences* 202, EDP Sciences, 2020, 06020.

³⁴ Fikri Naufal Uyun, Frency Siska, and Nurul Chotidjah, "Pengawasan pemerintah daerah terhadap pengelolaan limbah B3 internal rumah sakit," *Jurnal Riset Ilmu Hukum* 2, no. 1 (2022): 57.

responsible for waste management have not received formal or regular training, resulting in frequent mixing of infectious and non-hazardous waste streams and unsafe handling procedures. The absence of structured training programs undermines the effectiveness of existing regulations and increases occupational health risks for healthcare workers, including exposure to infectious materials and needlestick injuries. Evidence from previous studies suggests that regular, targeted training programs can substantially improve compliance with waste management protocols and reduce environmental contamination and infection risks.³⁵ Therefore, strengthening training and education initiatives is essential to ensure that regulatory requirements are translated into consistent operational practices.

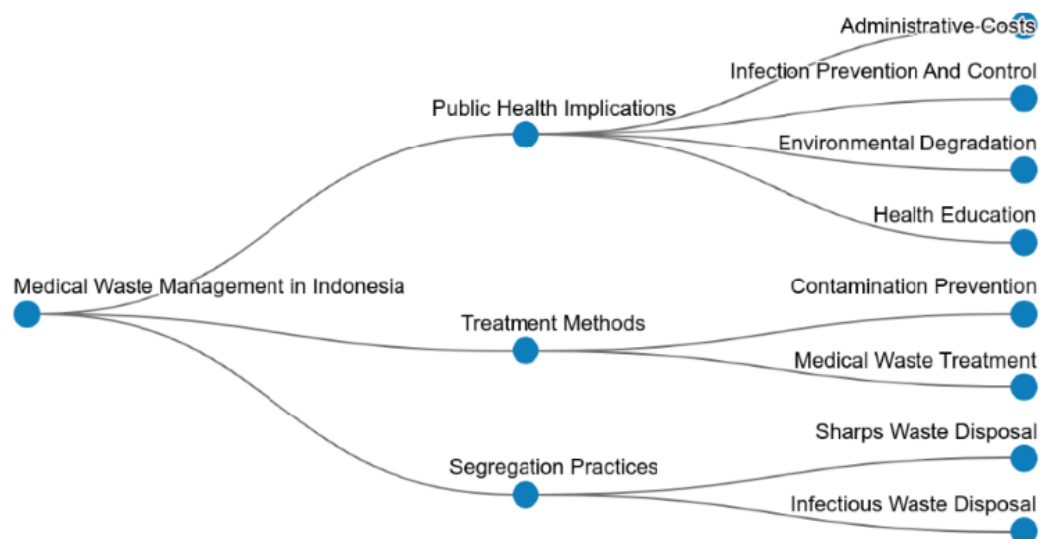


Figure 3. Strategies for Improving Medical Solid Waste Management

As illustrated in Figure 3, medical waste management in Indonesia is framed through an integrated structure consisting of public health implications, treatment methods, and segregation practices. The diagram emphasizes that ineffective waste management has direct consequences for public health, including increased administrative costs, challenges in infection prevention and control, environmental degradation, and the need for broader health education. These elements highlight that improper handling of medical waste extends beyond technical issues, affecting both healthcare systems and

³⁵ M. Irfa'i, Arifin Arifin, Ferry Kriswandana, and Imam Thohari, "The design of medical waste treatment in Public Health Center (MWT-P) for reducing total bacteria count in Banjarbaru," (2020): 258. See too, Andreas S. Miamiliotis, and Michael A. Talias, "Healthcare workers' knowledge about the segregation process of infectious medical waste management in a hospital," In *Healthcare*, vol. 12, no. 1, MDPI, 2023, 94.

community well-being. In parallel, the treatment methods branch underscores the importance of contamination prevention and appropriate medical waste treatment processes, indicating that safe and effective handling requires not only regulatory compliance but also the application of suitable technologies. Furthermore, the segregation practices component focuses on specific operational aspects, such as the proper disposal of sharps waste and infectious waste, which are critical in minimizing risks of injury and disease transmission. Overall, Figure 3 conveys that improving medical solid waste management requires a comprehensive approach that integrates preventive health measures, effective treatment systems, and strict segregation practices, supported by adequate training, education, and institutional capacity at the healthcare facility level.

Infrastructure and resource availability represent another major constraint affecting medical solid waste management in first-level healthcare facilities.³⁶ Many facilities lack adequate physical infrastructure, such as designated temporary storage areas, color-coded segregation bins, and appropriate waste treatment equipment. This limitation is particularly evident in rural and independent healthcare facilities, where budgetary constraints restrict access to compliant waste management systems.³⁷ The reliance on outdated or substandard equipment, including incinerators operating below recommended temperatures, compromises the effectiveness of waste treatment and contributes to environmental pollution. Studies highlight that investment in proper infrastructure such as standardized segregation facilities and high-temperature incineration or alternative treatment technologies is crucial for ensuring safe and environmentally sound waste management.³⁸ Without adequate infrastructure, regulatory compliance remains largely procedural and fails to achieve substantive health and environmental protection.

Regulatory enforcement and monitoring also require significant strengthening to improve medical solid waste management outcomes.

³⁶ Sandra Aparcana, "Approaches to formalization of the informal waste sector into municipal solid waste management systems in low-and middle-income countries: Review of barriers and success factors," *Waste management* 61 (2017): 594. See too, Feriany Said, Christine Wulandari, Samsul Bakri, Asep Sukohar, and Diyah Sumekar, "Tinjauan Hukum Strategi Optimalisasi Kebijakan untuk Mengatasi Tantangan Dalam Pengelolaan Limbah Padat Medis," *Justicia Sains: Jurnal Ilmu Hukum* 9, no. 2 (2024): 378.

³⁷ Endang Wahyati Yustina, "Aspek hukum pengelolaan limbah medis pada fasilitas pelayanan kesehatan dan perlindungan terhadap kesehatan lingkungan," *Jurnal Paradigma Hukum dan Pembangunan* 6, no. 1 (2021): 99.

³⁸ D. Curie, I. Warmadewanthi, E. Haryadi, and M. Tiardjiono, "Evaluation of medical waste management in national infection center hospital," In *AIP Conference Proceedings* 3098, no. 1, AIP Publishing LLC, 2024, 40076. See too, Jan-Gerd Kühling, and Ute Pieper, "Management of healthcare waste: developments in Southeast Asia in the twenty-first century," *Waste management & research* 30, no. 9 (2012): 101.

Although regulations such as Minister of Environment and Forestry Regulation Number P.56 of 2015 provide clear technical standards, enforcement remains uneven across regions. Weak supervision, limited inspection frequency, and insufficient sanctions for non-compliance allow unsafe practices such as open burning or mixing medical waste with household waste to persist, particularly in rural areas. Empirical evidence indicates that stronger regulatory oversight, including regular inspections and consistent application of penalties, can improve compliance and accountability among healthcare facilities.³⁹ Enhanced enforcement mechanisms are therefore necessary to bridge the gap between policy formulation and practical implementation.

Community involvement is increasingly recognized as an important complementary strategy for improving medical solid waste management.⁴⁰ While waste management is primarily a technical and institutional responsibility, community awareness and participation can support monitoring efforts and promote safer disposal practices. Involving local communities in education campaigns and reporting mechanisms can increase transparency and encourage healthcare facilities to adhere more closely to regulatory standards. Empirical studies suggest that community engagement can enhance social accountability and contribute to improved environmental outcomes, particularly in areas where formal regulatory enforcement is weak.⁴¹ Community-based approaches may also help reduce improper disposal practices that directly affect surrounding populations.

Comparative evidence from other Southeast Asian countries further reinforces the importance of integrated improvements in training, infrastructure, and governance. Several countries in the region have adopted alternative treatment technologies, such as steam-based systems, and have implemented more coordinated waste management frameworks that reduce reliance on incineration alone. Indonesia's continued dependence on incineration, combined with limited technological diversification, highlights the need to learn from regional best practices. The experiences of neighboring

³⁹ Jan-Gerd Kühling, and Ute Pieper, "Management of healthcare waste: developments in Southeast Asia in the twenty-first century," *Waste management & research* 30, no. 9 (2012): 102. See too, Anindya Dwita, and Mohammad Zamroni, "Legal Responsibility of Waste Transportation Services in the Management of Hospital Solid Medical Waste," *Jurnal Hukum dan Etika Kesehatan* (2021): 47.

⁴⁰ Ramadhan Tosepu, Adius Kusnan, and Asnia Zainudin, "Analisis Faktor yang Berhubungan dengan Pengolahan Limbah Medis di Rumah Sakit Umum Aliyah Kota Kendari," *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 5, no. 8 (2022): 1028. See too, Roza Seilkassymova, Daniya Nurmukhankyzy, Aktoty Rzabay, Zhangali Baktykhozhayev, and Indira Nessipbayeva, "Environmental safety and legal regulation of medical waste management: international experience," *Journal of Environmental Management & Tourism* 13, no. 7 (2022): 1819.

⁴¹ Edward Kurnia Setiawan Limijadi, and Katrin Setio Devi, "Medical Waste Management and Environmental Impact in Independent Healthcare Practices: A Systematic Review," In *E3S Web of Conferences*, vol. 655, EDP Sciences, 2025, 1018.

countries demonstrate that sustained investment in human resources, infrastructure, and institutional coordination can significantly improve medical waste management performance.⁴²

In summary, improving the management of medical solid waste in first-level healthcare facilities in Indonesia requires a multidimensional approach that addresses human resource capacity, infrastructure adequacy, regulatory enforcement, and community participation. While existing regulations provide a solid normative foundation, their effectiveness is constrained by weak implementation and limited operational support. Strengthening training and education, investing in appropriate infrastructure, enhancing enforcement mechanisms, and involving local communities are essential steps toward achieving safer and more effective medical solid waste management. Without these improvements, regulatory frameworks will continue to fall short of their intended public health and environmental protection objectives, despite their formal comprehensiveness.

D. Conclusion

This study concludes that the management of medical solid waste in first-level healthcare facilities in Indonesia is formally supported by an adequate regulatory framework but remains constrained by significant implementation gaps. From a legal perspective, Indonesia has established clear and comprehensive regulations governing medical solid waste, including provisions on waste classification, segregation, storage, transportation, and final disposal. Regulations such as Minister of Environment and Forestry Regulation Number P.56/Menlhk-Setjen/2015, Government Regulation Number 101 of 2014, Minister of Health Regulation Number 1204 of 2004, and Solid Waste Management Act Number 18 of 2008 collectively demonstrate a strong normative commitment to protecting public health and the environment.

Nevertheless, the analysis of implementation practices reveals that compliance at the facility level remains inconsistent. Many first-level healthcare facilities continue to face operational constraints, particularly limited infrastructure, insufficient treatment capacity, financial barriers, and reliance on third-party waste management services. These conditions affect the effectiveness of waste segregation, temporary storage, and timely disposal. The challenges are more pronounced in rural and remote areas, where access to licensed waste treatment facilities and regulatory oversight is limited. As a

⁴² Jan-Gerd Kühling, and Ute Pieper, "Management of healthcare waste: developments in Southeast Asia in the twenty-first century," *Waste management & research* 30, no. 9 (2012): 103.

result, the gap between regulatory standards and daily practices persists, increasing environmental and occupational health risks.

In response to these challenges, the findings related to improvement strategies emphasize the need for an integrated and practical approach. Strengthening medical solid waste management requires not only regulatory enforcement but also supportive policies that enhance institutional capacity. Priority measures include regular training for healthcare workers to improve technical competence, increased investment in waste treatment infrastructure and affordable technologies, and improved coordination between central and local authorities. Additionally, consistent monitoring and clearer accountability mechanisms are essential to ensure uniform compliance across regions.

BIBLIOGRAPHY

Journals:

- Absori, Absori, and Muhamad Latif. "Kebijakan hukum dalam pengelolaan limbah bahan berbahaya dan beracun (B3): Studi implementasi pengelolaan limbah medis di rumah sakit Salatiga." *JIL: Journal of Indonesian Law* 1, no. 1 (2020): 91-117.
- Afiyah, Lisa Lamusul. "Implementasi PERMENKES Nomor 18 Tahun 2020 Terhadap Pengolahan Limbah Medis Rumah Sakit." *UNES Law Review* 6, no. 2 (2023): 6148-6154.
- Alhamda, Syukra, Abdul Khair, And Noraida. "Evaluation of solid medical waste management at Pasaman Barat Regional Hospital, Indonesia: Challenges and environmental impact solutions." *Journal of Sustainability Science and Management* 20, no. 8 (2025): 1577-1592.
- Anityasari, Maria, Hilmi Cahya Rinardi, and I. D. A. A. Warmadewanthi. "Analysing medical waste transportation using periodic vehicle routing problem for Surabaya public health facilities." *Journal of Material Cycles and Waste Management* 27, no. 2 (2025): 830-847.
- Aparcana, Sandra. "Approaches to formalization of the informal waste sector into municipal solid waste management systems in low-and middle-income countries: Review of barriers and success factors." *Waste management* 61 (2017): 593-607.
- Aprilia, Lintang, Rahayu Subekti, and Sapto Hermawan. "Kajian Precautionary Principle Terhadap Pengelolaan Limbah Medis B3 Pada Fasilitas Layanan Kesehatan." *Indonesian Journal of Social Sciences and Humanities* 5, no. 1 (2025): 127-137.
- Castillo Ulloa, Micaela Ines, Diego Alexis Ramos Huarachi, Vinicius Moretti, Cleiton Hluszko, Fabio Neves Puglieri, Thalita Monteiro Obal, and Antonio Carlos

- de Francisco. "Sustainability and Algorithmic Comparison of Segmented PVRP for Healthcare Waste Collection: A Brazilian Case Study." *Sustainability* 17, no. 19 (2025): 8536.
- Dewi, Oktavia., Novita Rany, Herniwanti Herniwanti, and Mitra, M. "Application of SWOT analysis as a strategy for medical waste management in the independent practice of dentists in Pekanbaru City, Indonesia." *Multidisciplinary Science Journal* 6, no. 3 (2026): 232-256.
- Dwita, Anindya, and Mohammad Zamroni. "Legal Responsibility of Waste Transportation Services in the Management of Hospital Solid Medical Waste." *Jurnal Hukum dan Etika Kesehatan* (2021): 45-63.
- Dwitasari, Verani, Adriano Adriano, and M. Tauchid Noor. "Tanggung Jawab Hukum Klinik Pratama dalam Pengelolaan Limbah Medis: Legal Responsibility of Primary Healthcare Clinics in Medical Waste Management." *Jurnal Hukum dan Etika Kesehatan* (2025): 141-157.
- Efendi, Nuril Hikam, Dominikus Rato, and Iwan Rachmad Soetijono. "Prinsip kehati-hatian dalam pengelolaan limbah medis untuk mewujudkan kehidupan yang berkelanjutan." *DiH: Jurnal Ilmu Hukum* (2023): 146-155.
- Hartami, Annisa, Lego Karjoko, and Fatma Ulfatun Najicha. "Optimalisasi Peran Pemerintah Dalam Kebijakan Penanganan Limbah Medis." *PLEDOI (Jurnal Hukum dan Keadilan)* 2, no. 1 (2023): 12-19.
- Hutajulu, Setia Megawati, and Arifah Devi Fitriani. "Nurse Compliance with Medical Waste Management Protocols: An Observational Study at Indonesian Hospitals." *The Open Public Health Journal* 18, no. 1 (2025): 343-367.
- Irfa'i, M., Arifin Arifin, Ferry Kriswandana, and Imam Thohari. "The design of medical waste treatment in Public Health Center (MWT-P) for reducing total bacteria count in Banjarbaru." (2020): 254-261.
- Kabiri Naeini, Mehdi, and Zeynab Elahi. "Sustainable Waste Management in Healthcare: Application of Fuzzy Determination Method to Prioritize Key Influencing Factors." *Journal of Advances in Environmental Health Research* 13, no. 3 (2025): 199-206.
- Khansa, Silvia, Agustin Kusumayati, Dewi Susanna, and Uli Tiarma Sinaga. "Evaluation of solid medical waste management in Bogor regional public hospitals." 6, no. 1 (2023): 131-153.
- Kühling, Jan-Gerd, and Ute Pieper. "Management of healthcare waste: developments in Southeast Asia in the twenty-first century." *Waste management & research* 30, no. 9_suppl (2012): 100-104.
- Noor, Egi Agfira. "Pertanggung jawaban rumah sakit terhadap limbah bahan beracun berbahaya (B3)." *Jurnal Penegakan Hukum Indonesia* 1, no. 1 (2020): 232-251.

- Putri, Rizky Syahrani, Owildan Wisudawan, Haslinah Ahmad, Masnilam Hasibuan, Anto J. Hadi, and Nayodi Permayasa. "Efektivitas Kebijakan Kesehatan dalam Meningkatkan Pengelolaan Limbah Medis di Puskesmas Labuhan Rasoki Kota Padangsidimpuan." *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 7, no. 4 (2024): 1044-1052.
- Safitri, Myrna Asnawati. "Establishing the link between law, culture and infrastructure for pandemic waste management." *UUM Journal of Legal Studies* 16, no. 2 (2025): 87-101.
- Said, Feriany, Christine Wulandari, Samsul Bakri, Asep Sukohar, and Diyah Sumekar. "Tinjauan Hukum Strategi Optimalisasi Kebijakan untuk Mengatasi Tantangan Dalam Pengelolaan Limbah Padat Medis." *Justicia Sains: Jurnal Ilmu Hukum* 9, no. 2 (2024): 377-389.
- Seilkassymova, Roza, Daniya Nurmukhankyzy, Aktoty Rzabay, Zhangali Baktykhozhayev, and Indira Nessipbayeva. "Environmental safety and legal regulation of medical waste management: international experience." *Journal of Environmental Management & Tourism* 13, no. 7 (2022): 1817-1824.
- Siagian, Erwin Sondang, Asep Sumaryana, Ida Widianingsih, and Heru Nurasa. "Public-private partnerships in solid waste management: arrangements in Indonesia." *Asia Pacific Journal of Public Administration* 41, no. 1 (2019): 56-62.
- Siswanti, Ratih Enggal. "Tanggung Gugat Rumah Sakit Atas Pelanggaran Pengelolaan Limbah Medis B3 yang dikerjasamakan dengan Pihak Lain." *Jurnal Hukum Dan Etika Kesehatan* (2022): 147-159.
- Sitohang, Welem Tandilolok, Djoko Imbawani, and Inge Hartini. "The Effectiveness of Law on the Obligation of B3 Medical Waste Management by Healthcare Facilities in Tana Toraja Regency." *Locus: Jurnal Konsep Ilmu Hukum* 6, no. 1 (2026): 120-128.
- Sondang Siagian, Erwin, Asep Sumaryana, Ida Widianingsih, and Heru Nurasa. "Public-private partnerships in solid waste management in Indonesia: the need for technical regulation." *Asia Pacific Journal of Public Administration* 41, no. 4 (2019): 246-250.
- Suroto, Suroto. "Pertanggungjawaban Hukum Terkait Pengelolaan Limbah B3 (Bahan Berbahaya dan Beracun) dalam Fasilitas Kesehatan." *Majelis: Jurnal Hukum Indonesia Учредители: Asosiasi Seni Desain dan Komunikasi Visual Indonesia* 1, no. 3 (2024): 01-16.
- Sutanto, Yosef Stefan, and Kortensi Karianga. "Hukum Terkait Pengelolaan Limbah Bahan Berbahaya Dan Beracun Medis Rumah Sakit." *Jurnal Hukum Kesehatan Indonesia* 3, no. 02 (2023): 103-115.
- Tosepu, Ramadhan, Adius Kusnan, and Asnia Zainudin. "Analisis Faktor yang Berhubungan dengan Pengolahan Limbah Medis di Rumah Sakit Umum

- Aliyah Kota Kendari." *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)* 5, no. 8 (2022): 1026-1031.
- Uyun, Fikri Naufal, Frency Siska, and Nurul Chotidjah. "Pengawasan pemerintah daerah terhadap pengelolaan limbah B3 internal rumah sakit." *Jurnal Riset Ilmu Hukum* 2, no. 1 (2022): 52-56.
- Yustina, Endang Wahyati. "Aspek hukum pengelolaan limbah medis pada fasilitas pelayanan kesehatan dan perlindungan terhadap kesehatan lingkungan." *Jurnal Paradigma Hukum dan Pembangunan* 6, no. 1 (2021): 98-115.
- Yusuf, Franky. "Pertanggungjawaban hukum terkait pengelolaan limbah b3 dalam fasilitas kesehatan." *Journal iuris scientia* 2, no. 1 (2024): 16-27.
- Zhang, Meng, Wei Cui, Qi Jiang, Nengmin Wang, and Yuan Shang. "Vehicle routing for infectious healthcare waste collection with transit points: a problem incorporating multiple types of risks and two solution methods from different perspectives." *IEEE Access* 8, no. 1 (2025): 533-561.

Books:

- Damanhuri, Enri, Widhi Handoko, and Tri Padmi. "Municipal solid waste management in Indonesia." In *Municipal solid waste management in Asia and the Pacific Islands: challenges and strategic solutions*, pp. 139-155. Singapore: Springer Singapore, 2013.
- Limijadi, Edward Kurnia Setiawan, and Katrin Setio Devi. "Medical Waste Management and Environmental Impact in Independent Healthcare Practices: A Systematic Review." In *E3S Web of Conferences*, vol. 655, p. 01013. EDP Sciences, 2025.
- Miamiliotis, Andreas S., and Michael A. Talias. "Healthcare workers' knowledge about the segregation process of infectious medical waste management in a hospital." In *Healthcare*, vol. 12, no. 1, p. 94. MAbsori, Absori, and Muhamad Latif. "Kebijakan hukum dalam pengelolaan limbah bahan berbahaya dan beracun (B3): Studi implementasi pengelolaan limbah medis di rumah sakit Salatiga." *JIL: Journal of Indonesian Law* 1, no. 1 (2020): 91-117.

Conference:

- Al-Fikri, F. F., R. A. Nugroho, and Sudarmo. "Evaluation of implementation about Covid-19 medical waste management policies in health care facilities." In *IOP Conference Series: Earth and Environmental Science*, vol. 905, no. 1, p. 012124. IOP Publishing, 2021.
- Curie, D., I. Warmadewanthi, E. Haryadi, and M. Tiardjiono. "Evaluation of medical waste management in national infection center hospital." In *AIP*

- Conference Proceedings*, vol. 3098, no. 1, p. 040071. AIP Publishing LLC, 2024.
- Rahim, I. R., M. Selintung, I. Jamaluddin, M. Ihsan, and E. Y. Tiranda. "Performance of Covid-19 Waste Management at Health Service Facilities in North Toraja Regency." In *IOP Conference Series: Earth and Environmental Science*, vol. 1117, no. 1, p. 012051. IOP Publishing, 2022.
- Rajagukguk, Jenni Ria. "B3-Medical waste management Fas Yankes Bogor district health office in 2018." In *IOP Conference Series: Materials Science and Engineering*, vol. 725, no. 1, p. 012083. IOP Publishing, 2020.
- Simarmata, Verawaty, Setiaty Pandia, and Herman Mawengkang. "Model statistic with program LISREL for medical solid infectious waste hazardous hospital Type B management in Medan City." In *IOP Conference Series: Earth and Environmental Science*, vol. 205, no. 1, p. 012002. IOP Publishing, 2018.
- Wulansari, Arifah, Sudarno, and Fuad Muhammad. "Medical waste management at community health center: a literature review." In *E3S Web of Conferences*, vol. 202, p. 06017. EDP Sciences, 2020.