



Developing a Sustainable Strategy for Solid Hazardous Waste Management in Healthcare Facilities: A Case Study from Batam City, Indonesia

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<https://doi.org/10.18280/ijspd.210119>

ABSTRACT

Received: 14 October 2025

Revised: 8 January 2026

Accepted: 15 January 2026

Available online: 31 January 2026

Keywords:

hazardous solid waste management, healthcare facilities, sustainable strategy, SWOT analysis, waste policy

Healthcare facilities generate hazardous solid waste with substantial volume and high exposure risk, requiring a sustainable management system. This study aimed to develop a sustainable B3 solid waste management strategy that is relevant to local conditions in healthcare facilities. A qualitative approach was employed through in-depth interviews with nine informants drawn from three type-B hospitals in Batam City. Data were analyzed using triangulation techniques and SWOT analysis by constructing the Internal Factors Analysis Summary (IFAS) and External Factors Analysis Summary (EFAS) matrices. The analytical process was further enhanced by a Focus Group Discussion that included both internal and external stakeholders to confirm the results and reach an initial strategic agreement. The results revealed an IFAS score of 1.34 and an EFAS score of 1.46, positioning the B3 solid waste management system in Quadrant I (aggressive strategy), indicating the dominance of internal strengths and external opportunities despite existing technical and human resource limitations. It can be concluded that B3 solid waste management in healthcare facilities has strong strategic potential; however, strengthening technical systems, enhancing human resource capacity, and consistently implementing the 5R principles (reduce, reuse, recycle, recovery, repair) are essential to ensure sustainability and regulatory compliance.

1. INTRODUCTION

Managing hazardous and toxic waste in healthcare facilities presents a serious environmental and public health challenge in many developing countries, including Indonesia. Solid hazardous waste encompasses infectious, sharp, and chemically hazardous materials, which, if improperly handled, can result in contamination, occupational injuries, and disease transmission [1]. Hospitals are among the highest generators of solid hazardous waste, and their output surged dramatically during events such as the COVID-19 pandemic, compounding the risks to environmental and human health [2]. In this context, adherence to national waste management regulations is crucial to mitigate environmental and health risks [3].

Effective solid hazardous waste management requires a systematic approach, including waste segregation, safe storage, collection, transportation, and treatment using appropriate methods such as autoclaving or incineration [4, 5]. Hospital policies must include standard operating procedures (SOPs) and regular staff training to ensure protocol compliance and enhance awareness of safe handling practices.

The consistent use of personal protective equipment (PPE) and the correct labelling of waste containers are integral to occupational safety [6]. However, national data from the Ministry of Environment and Forestry (2018) show that only 95 hospitals in Indonesia had licensed incinerators with a combined daily capacity of 45 tonnes, while e-monitoring by the Ministry of Health in 2019 revealed that merely 42% of hospitals met the required medical waste management standards. Furthermore, limited access to authorized waste treatment companies has contributed to waste accumulation in numerous healthcare facilities [7].

Accumulated infectious waste presents a serious threat to patients, healthcare workers, and surrounding communities, exacerbated by the absence of robust waste treatment infrastructure across regions [8, 9]. Poor waste management practices, including overfilled safety boxes and improper segregation, have led to needle-stick injuries and increased nosocomial infections [10]. Although some hospitals have started implementing the 5R principles (reduce, reuse, recycle, recovery, repair), full-scale adoption remains limited due to resource constraints [11, 12].

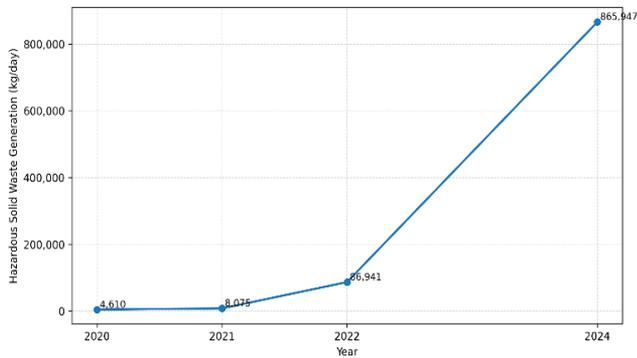


Figure 1. Hazardous solid waste generation in healthcare facilities at Batam City

Batam City exemplifies these challenges. According to the Provincial Health Office in Riau Islands (2023), of 42 healthcare facilities practicing waste segregation, only 15 had permits for temporary solid hazardous waste storage. The solid hazardous waste generation in Batam has shown a significant increase over the years, with health facilities such as community health centers and hospitals being the main contributors. This trend is depicted in Figure 1 [13].

Despite some hospitals operating internal waste systems, the majority still rely on third-party services. Observations reveal persistent challenges in segregation, labelling, PPE usage, and the operation of treatment facilities such as incinerators and autoclaves [14, 15].

Theoretical insights emphasize that waste management strategies must integrate regulatory compliance, institutional behavior, and circular economy innovations, such as waste recycling and cleaner production [16]. In many low-resource contexts, insufficient education, limited infrastructure, and weak enforcement further hinder implementation [17].

This study fills a significant gap in the literature by focusing specifically on the development of a sustainable, locally responsive strategy for hazardous solid waste management in healthcare facilities. Unlike prior research that primarily focuses on regulatory compliance or technological aspects, this study adopts a systemic approach that incorporates stakeholder perspectives, institutional practices, and behavioral dimensions. The research applies SWOT analysis and qualitative data triangulation to design an integrated waste management framework aligned with the 5R principles (reduce, reuse, recycle, recovery, repair) and the SDGs. The originality of this work lies in its context-specific, participatory strategy development model [18].

This study aims to develop a sustainable and locally appropriate strategy for the management of hazardous solid waste in healthcare facilities in Batam City. The research contributes practical recommendations for institutional strengthening and environmental health policy reform in urban Indonesia, thus offering a replicable model for other regions facing similar challenges.

2. LITERATURE REVIEW

2.1 Hazardous solid waste management

Various studies show that substandard management of hazardous medical waste can lead to occupational injuries, disease transmission, and soil, water, and air pollution,

especially in healthcare facilities with suboptimal control systems [19]. The increasing volume of healthcare waste in recent years has further amplified the challenges of hazardous waste management and placed additional strain on existing waste management systems. Although international guidelines on the management of hazardous medical waste are available, their implementation remains inconsistent, particularly in developing countries, due to limitations in sorting practices, processing capacity, and institutional management [20].

2.2 Determinants of sustainable hazardous solid waste management

The increase in medical waste generation needs to be balanced with safe and education-based management, as human resource behavior and understanding play an important role in preventing health risks and environmental pollution [21]. This is often caused by a lack of education, training, and resources for safe waste management [22]. Management of hazardous waste in healthcare facilities is influenced by policies, facility availability, and human resource behavior [23, 24]. Some studies emphasize the importance of regulatory compliance, training, and technical evaluation in reducing environmental and health risks, but most are still partial and focus on problem identification without producing integrated and actionable policy recommendations tailored to the local context. Studies in post-mining environments show conceptual relevance to the management of hazardous waste in healthcare facilities due to the similarity of potential heavy metal and toxic compound residues, while also confirming the limited research integrating factor analysis, management strategies, and comprehensive policy formulation in healthcare facilities [25].

2.3 Sustainable strategy approaches in hazardous solid waste management

Sustainability practices integrated into the organizational system are a key element in supporting effective and long-term environmental management [26, 27]. Various studies indicate that effective hazardous waste management strategies cannot solely focus on end-of-life treatment technology, but must be supported by strong governance, regulatory compliance, and the active involvement of healthcare professionals at every stage of waste management [28]. The principle of sustainability through the 5R principles (reduce, reuse, recycle, recovery, repair) is considered capable of reducing the generation of hazardous waste, improving resource utilization efficiency, and minimizing environmental impact when applied systematically and controllably in healthcare facilities [29, 30]. Additionally, strategic approaches based on internal and external condition analysis, such as SWOT, are widely used to formulate adaptive and contextual hazardous waste management strategies, particularly in developing countries with limited resources and institutional capacity [31].

3. MATERIALS AND METHODS

3.1 Location and objects study

This research was conducted at the Batam City Health Service Facilities, Riau Islands Province, Indonesia. The study was carried out in three Type B hospitals in Batam

representing different ownership statuses, namely a ministry-owned hospital, a municipal government hospital, and a corporate-owned hospital. This study focuses on developing sustainable strategies for managing hazardous and toxic solid waste in healthcare facilities by integrating internal and external barriers into empirical findings and stakeholder perspectives.

3.2 Data collection

Participants were selected through purposive sampling to ensure inclusion of informants with practical experience and knowledge in hazardous solid waste management. A total of nine key informants were recruited, including hospital sanitation officers, personnel responsible for waste management, cleaning staff, and operational staff from affiliated waste treatment service providers. Data collection involved qualitative methods such as in-depth interviews, non-participant observation, and document analysis. Semi-structured interviews were conducted face-to-face in Bahasa Indonesia, recorded with consent, and transcribed for further analysis. Observations were used to validate interview responses and assess real-time waste handling practices. Triangulation was applied by cross-verifying information from interviews, document reviews (SOPs, hospital waste logs, regulatory permits), and direct observations.

3.3 Research procedures

The study was carried out in two phases. The first phase involved qualitative data collection and thematic analysis, including coding to identify recurring themes, categories, and subcategories aligned with the research questions. These themes were mapped into a SWOT framework (Strengths, Weaknesses, Opportunities, and Threats) to contextualize internal and external factors affecting current waste management systems. Further analysis used Internal Factors Analysis Summary (IFAS) and External Factors Analysis Summary (EFAS) matrices, where factors identified were scored based on significance and weight through team consensus. The SWOT quadrant outcomes informed the development of strategic alternatives. To validate and refine these strategies, a focus group discussion with internal and external stakeholders was held, including representatives from the Batam City Health Office, the Environmental Agency, hospital managers, and licensed waste treatment companies. The second phase focused on developing a policy brief, synthesizing SWOT and focus group discussion findings, and integrating the 5R principles (reduce, reuse, recycle, recovery, repair) to present tailored technical, managerial, and policy recommendations for healthcare facilities.

3.4 Data analysis

Data analysis involved manual thematic coding to identify key themes, categories, and subcategories relevant to the study's research questions. Thematic findings were organized within the SWOT framework to distinguish internal and external influencing factors. The IFAS and EFAS matrices were employed to evaluate each factor's relative importance and impact, as rated by the research team via consensus. These analyses provided a strategic positioning of hazardous waste management within Batam's healthcare system and supported the formulation of context-sensitive strategic alternatives.

4. RESULTS AND DISCUSSIONS

The results of this study present a detailed overview of the input, process, and output dimensions of hazardous solid waste management practices across selected healthcare facilities in Batam City. The analysis integrates data obtained through in-depth interviews, document reviews, and field observations. Findings are structured according to the systems framework, covering human resources, policy, infrastructure, process compliance, and sustainable waste handling initiatives. Each dimension reveals varying degrees of conformity with regulatory standards and operational effectiveness.

4.1 Human resources

Most healthcare facilities in Batam City have established functional organizational structures for managing hazardous solid waste. Key personnel include environmental health officers, cleaning service staff, and waste operators, each with defined roles and responsibilities. Field observations confirmed the presence of duty rosters, organizational charts, and job descriptions at each facility. Training efforts have been initiated through internal workshops, external webinars, and partial certification (e.g., PLB3) among operational staff. Despite these efforts, training coverage remains uneven across institutions. Disparities exist in the frequency and scope of medical check-ups, which depend on each hospital's internal policy.

These findings indicate that although organizational structures for hazardous waste management are formally established, institutional support for human resource development remains inconsistent. In terms of human resources, the presence of environmental health officers, cleaning service staff, and waste handlers aligns with Article 32 of national regulatory requirements (PermenLHK No. P.56/2015). Staff responsibilities are distributed in a manner that reflects institutional awareness of the technical and regulatory requirements for hazardous waste handling [32]. However, disparities in training coverage and irregular medical check-ups indicate weaknesses in occupational health monitoring. Although training has been conducted via internal sessions, webinars, and some PLB3 certifications, these efforts remain fragmented. The findings are consistent in reporting that while human resource components are frequently recognized, they often lack institutional support in terms of policy enforcement and routine evaluation [33, 34]. The absence of systematic health checks, despite the stipulation in Article 33 and its annex, underscores the need for comprehensive implementation of occupational health standards. Standardizing health protection protocols and investing in continuous professional development are critical for ensuring a competent and protected workforce.

4.2 Cost and financial management

Efforts to optimize operational costs are evident through waste source reduction strategies and the partial implementation of reuse, reduce, recycle. For example, some hospitals reuse non-infectious items such as infusion bottles and convert used detergent containers into flower pots. Observations support the availability of separated containers for medical and non-medical waste, reflecting an awareness of segregation protocols. However, the lack of formal documentation or internal policy supporting these practices

indicates the absence of institutionalization. Monthly hazardous solid waste management costs vary widely, ranging from IDR 16 million to IDR 40 million per hospital. The differences are attributed to waste volume, internal policy, and the scope of outsourcing arrangements with licensed third-party waste processors.

These findings indicate that cost considerations represent another central theme in this study. The financial allocation for hazardous solid waste management in Batam varies widely from IDR 16 million to IDR 40 million per month, depending on waste volume, internal processing capacities, and the extent of third-party involvement. Several facilities have adopted cost-saving measures, including early-stage waste sorting, reuse of non-infectious materials, and small-scale recycling initiatives. These practices reflect partial alignment with Article 24 of national regulatory requirements (PermenLHK No. P.56/2015), which mandates specific budget allocations for each waste management stage. Several studies have identified insufficient funding as a critical factor limiting the integration of environmentally sustainable initiatives within hospitals [35]. In Batam, the reuse of detergent containers and infusion bottles demonstrates innovative local responses to budgetary constraints, although they lack formal policy backing. Thus, while financial creativity exists, the absence of a strategic framework linking budgetary planning and environmental targets impedes the scalability and consistency of such practices [36].

4.3 Facilities and infrastructure

The physical infrastructure for hazardous solid waste management generally meets safety and technical standards. Most hospitals have dedicated waste storage buildings located away from clinical service areas, equipped with adequate ventilation, secure doors, hazard signs, and access control mechanisms. Emergency preparedness equipment, such as fire extinguishers, first aid kits, eyewash stations, and emergency showers, was present and regularly inspected. Waste containers such as drums, Sulo bins, and jumbo bags were available in sufficient quantities and appropriately labelled based on waste type. Documentation revealed routine maintenance activities and inspection logs, indicating ongoing infrastructure upkeep. However, variation in infrastructure quality and inspection frequency was observed between facilities.

These findings indicate that, although infrastructure and equipment across facilities generally meet the technical criteria outlined in Articles 14 to 18 of national regulatory requirements (PermenLHK No. P.56/2015). Most hospitals maintain standardized temporary storage facilities equipped with ventilation, signage, and emergency safety tools such as Portable Fire extinguishers, first-aid kits, and eyewash stations. Containers for specific waste types are available and labelled correctly, supporting waste segregation efforts. However, disparities in infrastructure quality and usage patterns persist. Observations in several facilities show inconsistent PPE use and suboptimal waste segregation in certain departments, aligning with previous research indicating that infrastructure alone cannot ensure effectiveness without sustained supervision, continuous training, and strengthened compliance mechanisms [37]. The implementation of green technologies such as autoclaves remains limited, further underscoring the need for investment in modern, environmentally friendly processing options [38].

4.4 Policy and regulatory alignment

Hospitals reported using government regulations and internal SOPs to guide waste management activities. Interviews and document reviews confirmed the presence of written procedures covering segregation, temporary storage, transportation, and treatment using technologies such as incinerators and sterilwave. SOPs were displayed in waste processing areas, and their implementation was generally consistent with policy requirements. Nonetheless, deficiencies in licensing compliance, lack of formal partnerships with third-party processors, and incomplete segregation practices were common. These gaps highlight opportunities for improving regulatory alignment and operational efficiency.

From a policy perspective, the majority of facilities have internal documents supporting waste management SOPs, staff training plans, and reporting systems to the Ministry of Environment and Forestry through the KLHK online portal, reflecting compliance with national regulatory requirements (PermenLHK No. P.56/2015). However, interviews revealed gaps in consistent enforcement, particularly in periodic monitoring, medical surveillance, and the availability of licensed waste treatment partners. These operational inconsistencies mirror findings in previous studies, which indicate that internal policies often exist without adequate mechanisms for implementation and oversight. Therefore, policy frameworks must be complemented by routine evaluation and internal audits to ensure effective implementation [33]. Therefore, the presence of policy frameworks must be complemented by routine evaluation and internal audits to ensure their effectiveness.

4.5 Waste segregation and reduction

All facilities implemented basic waste segregation according to regulatory categories: infectious, sharp, chemical, organic, and non-organic. Visual assessments confirmed the correct placement and labelling of containers in most locations. Written SOPs outlining segregation protocols were available at all sites. However, non-compliance was observed in some clinical units, where non-medical waste was disposed of in infectious waste bins. Inconsistent implementation by healthcare workers, patients, and visitors poses a challenge to systemic waste sorting. These lapses indicate the need for reinforced behavioral protocols and ongoing internal supervision.

The findings on waste segregation indicate strong procedural adherence in terms of container labelling and SOP availability. Sorting at the source, conducted by sanitation staff and operators, complies with the categorization of waste types as defined in national regulations. Effective source segregation is critical, as it reduces the proportion of waste requiring specialized treatment and lowers the costs of transportation and final disposal [39]. In Batam, despite these procedural strengths, minor non-compliance was observed in some clinical units, particularly regarding input from healthcare workers and patients' families. This suggests that sustained education and strict internal supervision are essential to maintain good waste management practices across service areas [40].

4.6 Temporary storage of waste

Healthcare facilities possessed designated temporary

storage facilities for hazardous solid waste, in compliance with national guidelines. In general, the temporary storage infrastructure was separate from clinical areas, well-ventilated, lockable, and equipped with warning signs. Differences were noted in the completeness of the temporary storage infrastructure, such as lighting, drainage, and flooring materials, across hospitals.

These findings underscore the need for infrastructure standardization to ensure consistent waste containment and environmental safety. With respect to temporary storage, Batam's healthcare facilities generally comply with construction and safety requirements. Most temporary storage structures are lockable, separated from high-traffic areas, and equipped with standard hazard signage. However, some technical weaknesses, such as insufficient ventilation or gaps in documentation regarding waste movement, were observed. These shortcomings indicate a lack of systematic operational control, particularly in scheduling waste rotation and recording internal transfers. Emphasize the importance of robust documentation systems and consistent ventilation design for effective waste handling [41]. Therefore, reinforcing administrative routines and physical inspections should be prioritized to support sustainable practices [42].

4.7 Transportation of hazardous solid waste

Waste transportation occurred through two mechanisms: internal and external. In-situ transfers, from healthcare units to temporary storage facilities or treatment facilities, were typically conducted two to three times daily by trained cleaning service or waste staff. Transportation used closed trolleys or adapted motorbikes and complied with PPE requirements. External transport was conducted by licensed third-party operators using specially designated vehicles. This process included manifest documentation to track waste flow and verify the chain of custody. The presence of manifests at each facility confirmed compliance with national waste transport regulations.

These findings indicate that, in terms of transport, both in-situ and ex-situ mechanisms are in place across all surveyed facilities. In-situ transport from clinical units to temporary storage facilities generally involves staff using enclosed carts or motorized tricycles. These activities occur two to three times daily, using PPE and adhering to routine schedules. External transport, managed by third-party vendors, is performed in compliance with regulatory standards using licensed vehicles and documented with manifest reports. While these practices align with national regulatory requirements (PermenLHK No. P.56/2015). The study identifies a need for more standardized equipment for in-situ transport and increased hospital oversight of third-party compliance. The findings emphasize the need for secure and well-controlled waste management systems supported by robust institutional monitoring and continuous quality control mechanisms to ensure compliance and sustainability [43].

4.8 Treatment and disposal

Treatment methods varied across facilities. Some hospitals conducted on-site treatment using incinerators or sterilwave systems, supported by documented SOPs, scheduled operations, and trained operators. Others outsourced treatment to licensed companies, with regular pick-ups documented through official manifests.

These findings indicate that the level of independence in treatment operations depends on the availability of appropriate technology, infrastructure, and financial capacity, as demonstrated in system-level analyses of healthcare waste management in resource-constrained settings [44]. Facilities with in-house treatment displayed greater control but also faced high maintenance costs and technical limitations. Those using external services expressed concerns about dependency, pricing, and scheduling flexibility.

4.9 Implementation of sustainable waste management

All healthcare facilities in the study had begun implementing basic elements of sustainable waste management, particularly the principles of reduce and reuse. Examples include the segregation of reusable materials and the repurposing of non-infectious waste. One facility had initiated recycling efforts through collaboration with a third-party recycler. However, no facility had operationalized the principles of recovery or repair. This indicates that the application of the full 5R principles (reduce, reuse, recycle, recover, and repair) remains limited to the initial stages and lacks comprehensive integration into facility-wide waste management systems.

These findings indicate that the study also explores the diverse methods of waste processing in Batam. Facilities utilize on-site treatment technologies such as incinerators and sterilwave units or rely on licensed external partners. Internal treatment provides autonomy but is hindered by high operational costs, particularly related to equipment maintenance. External partnerships, while logistically convenient, pose challenges such as delays in waste pick-up during public holidays. Moreover, the study found that facilities rarely maximize the utilization of non-hazardous solid waste residual waste (e.g., sterilized plastic flakes), which could potentially be repurposed. Although the systems meet technical standards, they fall short in terms of cost-efficiency and resource recovery. These findings are consistent with the literature, which identifies financial and logistical constraints as common barriers to the sustainability of hospital waste systems [45].

4.10 SWOT analysis, Internal Factors Analysis Summary and External Factors Analysis Summary

The identification of internal factors is the first step in analyzing the facility's waste management system.

Based on Table 1, the facility's waste management strengths include licensed incinerator/autoclave equipment, strong management commitment, non-hazardous waste utilization programs, and budgetary support. Weaknesses consist of high operational costs, limited certified staff, a lack of routine medical check-ups, and incomplete application of the 5R principles (reduce, reuse, recycle, recovery, repair). While a solid foundation for sustainable waste management exists, addressing these gaps is essential to ensure compliance and long-term sustainability. Following the identification of strengths and weaknesses in Table 1, the IFAS was developed to quantify their relative importance. This analysis assigns weights, ratings, and scores to each factor to provide a comprehensive assessment of the facility's internal conditions.

Based on Table 2, the IFAS indicates that the total strength score is 3.59, while the total weakness score is 2.25, resulting in an overall IFAS matrix value of 1.34. The main strengths

identified include the availability of licensed incinerator/autoclave equipment (score 1.41) and budgetary allocations from management (score 0.94). Meanwhile, the key weaknesses consist of the limited number of certified personnel (score 0.57) and the incomplete implementation of the 5R principles (score 0.55). These results suggest that internal strengths outweigh weaknesses, positioning the facility in a relatively favorable condition to pursue aggressive strategies for improving its waste management system.

The external analysis focuses on identifying opportunities and threats that arise from the broader regulatory, environmental, and social context of waste management.

Based on Table 3, the external analysis identified several opportunities and threats influencing the facility's waste management system. Key opportunities include regulatory support from central and local governments, the availability of licensed third parties for waste management, and the potential for cross-sector collaboration in health, environmental, and licensing aspects. In addition, the possibility of reducing the use of materials or equipment derived from hazardous waste

represents a further opportunity. On the other hand, significant threats were also noted, such as the high costs of third-party services, the risk of environmental pollution if facilities are inadequate, the limited number of certified personnel, and community complaints regarding the operation of incinerators or temporary storage facilities. These external factors demonstrate the dual role of external conditions, providing opportunities for improvement while also presenting challenges that must be carefully managed.

In continuation of the internal assessment, the EFAS was developed to evaluate opportunities and threats from the external environment.

Based on Table 4, the EFAS results show a total opportunities score of 3.73 and a threats score of 2.27, giving a matrix value of 1.46. Regulatory support and licensed third parties are the strongest opportunities, while high service costs and environmental risks are the main threats. Overall, external opportunities outweigh threats, placing the facility in a favorable position.

Table 1. Strengths, weaknesses

No.	Strength	Weaknesses
1.	The facility possesses licensed and operational Incinerator/Autoclave equipment for waste treatment.	High operational and maintenance costs associated with the use of Incinerator/Autoclave equipment.
2.	Strong management commitment to occupational health and safety (OHS) and environmental sustainability.	Limited number of personnel holding specialized certifications.
3.	Implement programs for limited utilization of non-hazardous waste (e.g., reuse of IV fluid bottles).	Absence of routine and periodic medical check-ups for waste management personnel.
4.	Availability of budgetary allocations from management for waste management activities.	Incomplete implementation of the 5R principles (reduce, reuse, recycle, recovery, repair).

Table 2. Internal Factors Analysis Summary (IFAS)

No.	Strength	Weight	Rating	Score
1.	The facility possesses licensed and operational Incinerator/Autoclave equipment for waste treatment.	0.35	4.00	1.41
2.	Strong management commitment to occupational health and safety (OHS) and environmental sustainability.	0.12	3.00	0.35
3.	Implement programs for limited utilization of non-hazardous waste (e.g., reuse of IV fluid bottles).	0.29	3.00	0.88
4.	Availability of budgetary allocations from management for waste management activities.	0.24	4.00	0.94
	Total Strength Score	1.00		3.59
No.	Weaknesses	Weight	Rating	Score
1.	High operational and maintenance costs associated with the use of Incinerator/Autoclave equipment.	0.27	2.50	0.68
2.	Limited number of personnel holding specialized certifications.	0.23	2.50	0.57
3.	Absence of routine and periodic <i>medical check-ups</i> for waste management personnel.	0.23	2.00	0.45
4.	Incomplete implementation of the 5R principles (reduce, reuse, recycle, recovery, repair).	0.27	2.00	0.55
	Total Weaknesses Score	1.00		2.25
	Total IFAS	2.00		5.84
	IFAS Matrix Value			1.34

Table 3. Opportunities, threats

No.	Opportunities	Threats
1.	Regulatory support from both central and local governments.	High costs associated with using third-party services.
2.	Availability of licensed third parties for waste management.	Risk of environmental pollution if facilities are inadequate.
3.	Cross-sector collaboration (Health, Environment, Licensing).	Limited number of personnel with certified competencies in hazardous waste management.
4.	Potential to reduce the use of materials or equipment derived from hazardous waste.	Complaints from nearby communities regarding the operation of incinerators or hazardous waste temporary storage facilities.

Table 4. External Factors Analysis Summary (EFAS)

No.	Opportunities	Weight	Rating	Score
1.	Regulatory support from both central and local governments.	0.23	5.00	1.14
2.	Availability of licensed third parties for waste management.	0.27	4.00	1.09
3.	Cross-sector collaboration (Health, Environment, Licensing).	0.27	3.00	0.82
4.	Potential to reduce the use of materials or equipment derived from hazardous waste.	0.23	3.00	0.68
	Total Opportunities Score	1.00		3.73
No.	Threats	Weight	Rating	Score
1.	High costs associated with using third-party services.	0.27	2.50	0.68
2.	Risk of environmental pollution if facilities are inadequate.	0.27	2.50	0.68
3.	Limited number of personnel with certified competencies in hazardous waste management.	0.27	2.00	0.55
4.	Complaints from nearby communities regarding the operation of incinerators or hazardous solid waste temporary storage facilities.	0.18	2.00	0.36
	Total Threats Score	1.00		2.27
	Total EFAS	2.00		6.00
	EFAS Matrix Value			1.46

The SWOT analysis provides a strategic overview of hazardous solid waste management in healthcare facilities in Batam City. With an IFAS score of 1.34 and an EFAS score of 1.46, the waste management system is positioned in Quadrant I of the SWOT matrix, indicating an aggressive strategic posture. The SWOT analysis diagram is presented in Figure 2.

still in a defensive phase due to limited infrastructure, weak policy support, or low institutional capacity, thus allowing for the more progressive implementation of sustainable waste management strategies.

5. CONCLUSIONS

This research confirms that the management of hazardous solid waste in healthcare facilities requires strengthening operational policies. This study recommends that policymakers and hospital management prioritize the standardization of human resource capacity thru certified training and periodic evaluation, the strengthening of internal oversight systems including documentation and routine audits, and the integration of the 5R principles (reduce, reuse, recycle, recover, repair) into SOPs and budgeting. Additionally, a more formal cross-sectoral coordination mechanism is needed between healthcare facilities, local governments, and licensed waste managers to ensure service consistency and cost efficiency. The implementation of these recommendations is expected not only to improve the performance of hazardous solid waste management but also to strengthen the healthcare system's resilience to future sustainability challenges.

Given the qualitative nature and local scope of this study, future research should consider employing mixed-methods or longitudinal designs to evaluate the impact of specific interventions, particularly in terms of cost-efficiency, staff safety, and waste volume reduction. Including rural or resource-limited areas in the study would also provide comparative insights and reinforce national policy recommendations for managing hazardous healthcare waste across diverse settings.

ACKNOWLEDGMENT

The author acknowledges Universitas Sriwijaya for the support and opportunity to conduct this study as part of the Doctoral Program in Environmental Science. Appreciation is also extended to the Faculty of Health Sciences, Universitas Ibnu Sina, for providing academic guidance and research facilities, as well as to all individuals and institutions who contributed through supervision, collaboration, and technical assistance during the study.

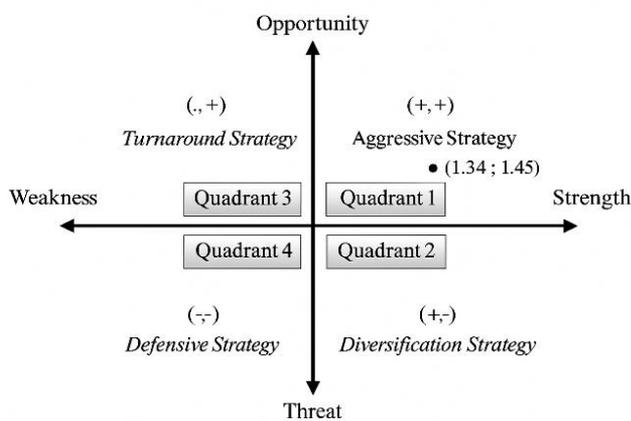


Figure 2. Diagram of SWOT analysis

The position of hazardous solid waste management in Quadrant I indicates a strategic condition where internal strengths and external opportunities outweigh weaknesses and threats, thus creating a favorable environment for the development of sustainable strategies. Aggressive strategy in this context is defined as accelerating system strengthening thru increased human resource capacity, infrastructure optimization, and consistent application of the 5R principles (reduce, reuse, recycle, recover, and repair) in daily operations.

This approach differs from defensive strategies that focus on meeting minimum standards and controlling risk without promoting system strengthening or sustainable innovation. Key internal strengths include the operation of incinerators and autoclaves, the existence of institutional SOPs, and proactive leadership support. Meanwhile, external opportunities include partnerships with third-party waste managers, integration with local government programs, and the development of public-private partnerships [36]. This strategic position is relatively distinct from other cities that are

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