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Journal of Advanced Research in Business and Management Studies

Journal homepage:
https://karyailham.com.my/index.php/arbms/index
ISSN: 2462-1935

Advancing Sustainable Waste Management in Malaysia: Lessons from Southeast Asia

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ARTICLE INFO

Article history:
Received 2 September 2025
Received in revised form 17 September 2025
Accepted 27 September 2025
Available online 4 October 2025

Keywords:
Municipal Solid Waste Management; Sustainability; Regional Collaboration

ABSTRACT

Rapid urbanisation in Southeast Asia has worsened municipal solid waste (MSW) problems. Malaysia produces over 39,000 tonnes of waste daily, with 65% sent to landfills. This creates serious environmental and health risks. This study compares MSW management in Malaysia, Singapore, Thailand and Indonesia. It focuses on waste generation, disposal methods, recycling rates and policy measures. Malaysia's recycling rate is 31.5%, lower than Singapore, which benefits from waste-to-energy (WTE) plants. Thailand achieves 34% through community waste banks, while Indonesia records only 10–15%, relying heavily on informal recycling. A comparative case study method was used, drawing on reports and published literature. The findings suggest Malaysia should adopt WTE systems, formalise informal recycling, increase community involvement and enforce stronger policies. These steps could help reach the national recycling target of 40% by 2025. Regional collaboration is also recommended to share knowledge and improve sustainable waste management.

1. Introduction

Annually, 2.01 billion tonnes of municipal solid waste are produced worldwide, with projections indicating an increase to 3.04 billion tonnes by 2050 [1]. Global waste generation per capita varies from 0.11 to 4.54 kilograms daily. Waste generation is projected to rise by 19% in high-income nations, whilst low- and middle-income countries are anticipated to have an increase of 40% by 2050 [2]. The swift urbanisation and population expansion in Southeast Asia have markedly elevated municipal solid waste (MSW) quantities, posing considerable problems for sustainable waste management systems. In Malaysia, the daily production reached around 39,936 tonnes in 2022, primarily sourced from metropolitan centres [3]. It underscores the pressing necessity to rectify inefficiencies in waste management, given that 95% of this waste is sent to landfills, many of which are open dumps devoid of environmental protections [4]. The dependence on landfilling exacerbates

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https://doi.org/10.37934/arbms.38.1.115122

significant environmental problems, such as leachate pollution of water sources, greenhouse gas emissions and health hazards for communities adjacent to disposal sites [5].

Malaysia's recycling rate of 31.5% is behind its national goal of 40% by 2025, hindered by insufficient infrastructure, limited public awareness and irregular policy implementation, especially in rural regions [6]. These difficulties are not exclusive to Malaysia which is prevalent in nations such as Singapore, Thailand and Indonesia. These countries implemented diverse solutions to address analogous constraints. Singapore's sophisticated waste-to-energy incinerator facilities, Thailand's community-oriented recycling initiatives and Indonesia's dependence on informal waste collectors offer significant lessons for Malaysia. This article compares municipal solid waste management techniques in four nations, assessing waste generation, disposal methods, recycling rates and policy frameworks to find strengths, flaws and transferable strategies. The study seeks to give practical ideas for improving Malaysia's municipal solid waste management system by utilising regional best practices, supporting its commitment to reducing greenhouse gas emissions and contributing to a sustainable waste management future in accordance with global environmental objectives. The report examines prospects for regional collaboration to enhance knowledge sharing and technical progress in Southeast Asia.

2. Methodology

This study used a comparative case study methodology to examine municipal solid waste management systems in Malaysia, Singapore, Thailand and Indonesia, elucidating regional disparities and facilitating cross-country learning opportunities. The data is derived from extensive secondary sources, encompassing peer-reviewed scholarly articles, governmental policy documents and reports from international entities such as the World Bank and the United Nations Development Programme (UNDP). The report examines critical metrics: per capita waste generation, waste composition, disposal techniques, recycling and recovery rates and the efficacy of policy frameworks in each nation. These nations were selected for their varied economic, developmental and cultural contexts within Southeast Asia, providing a substantial foundation for comparison. Malaysia is a middle-income country confronting urban waste management issues, Singapore serves as a high-income model with sophisticated infrastructure, Thailand demonstrates innovative community-oriented solutions and Indonesia illustrates a developing economy with a substantial informal recycling sector. Qualitative research assesses the merits and deficiencies of each nation's municipal solid waste management system, bolstered by quantitative data regarding waste volumes, recycling rates and landfill utilisation. Stakeholder viewpoints, encompassing governmental policies, community activities and commercial sector contributions, are integrated to understand MSWM dynamics comprehensively. This technique guarantees a thorough evaluation of each nation's approach, facilitating the formulation of pragmatic, evidence-based measures Malaysia can use to improve its waste management system and conform to regional sustainability objectives.

3. Municipal Solid Waste Management in Malaysia

3.1 Waste Generation and Composition

Approximately 65% of waste in Malaysia originates from households, 28% from business entities and institutions and 7% from industrial sources [7]. Malaysia allocates 69% of its waste to landfills, excluding illegal or open dumping, where the actual volume may exceed recorded figures [8]. This composition highlights considerable potential for resource recovery by recycling and composting, which could diminish landfill reliance and alleviate environmental consequences. Urban centres

produce significant quantities of recyclable materials that can be sent to material recovery facilities and organic waste that can be composted to create fertiliser for agricultural purposes. The absence of extensive waste segregation and processing infrastructure leads to most of this waste being disposed of in landfills without recovery, squandering precious resources and intensifying environmental damage. Mitigating these inefficiencies necessitates investment in sorting facilities and public education to use the recoverable potential of Malaysia's waste stream.

3.2 Disposal Methods

Landfilling remains Malaysia's primary waste disposal option, with 65% of collected waste directed to landfills [9]. The country has 158 active landfills, comprising 141 non-sanitary and 17 sanitary facilities [10]. Landfill sites are approaching or at capacity, encountering limitations due to land scarcity, escalating prices and public resistance to new landfill establishment [11]. In rural areas, open dumping is prevalent, leading to environmental contamination and health hazards, including respiratory ailments and waterborne infections for the adjacent people. Minor incineration and illicit disposal exacerbate the waste management scenario, resulting in negligible waste being redirected to recycling or recovery. The dependence on antiquated disposal techniques underscores the pressing necessity for upgraded infrastructure, including waste-to-energy plants and more stringent laws to propel Malaysia towards a more sustainable waste management framework.

3.3 Recycling and Recovery

Malaysia's recycling rate is 31.5%, markedly short of its 2025 goal of 40%, indicating systemic obstacles in waste recovery initiatives [6]. The national recycling initiatives initiated in 1993 and 2001, under the auspices of the Ministry of Housing and Local Government, saw constrained success owing to insufficient infrastructure, minimal public awareness and restricted access to recycling facilities, especially in rural regions [12]. Initiatives to advance composting and waste-to-energy technologies are developing but are impeded by elevated prices, insufficient technical proficiency and a deficiency in public engagement. These obstacles highlight the necessity for creative recycling initiatives and infrastructure expenditures to enhance Malaysia's recycling and recovery rates.

3.4 Policy Framework

The Solid Waste and Public Cleansing Management Act 2007 (Act 672) establishes the legal framework for municipal solid waste management in Malaysia, with the National Solid Waste Management Department (NSWMD) formulating policies and the Solid Waste Management and Public Cleansing Corporation (PPSPPA) executing them [13]. The National Strategic Plan for Solid Waste Management (2019-2030) establishes ambitious objectives to diminish waste generation, improve recycling and increase waste treatment infrastructure, following Malaysia's pledge to reduce greenhouse gas emissions [14]. Nonetheless, enforcement is patchy, especially in rural regions, where unlawful dumping continues due to insufficient collection services and weak oversight. Coordination between federal and local governments is frequently disjointed and funding for infrastructure development is inadequate, hindering advancement towards national objectives. For example, metropolis cities such as Kuala Lumpur possess superior waste management services, but rural regions contend with constrained resources and monitoring. Enhancing policy enforcement, optimising intergovernmental collaboration and ensuring sufficient funding are essential for

converting Malaysia's municipal solid waste management system into a sustainable and practical framework.

4. Comparative Analysis

The following tables summarise the Municipal Solid Waste Management (MSWM) practices in Singapore, Thailand and Indonesia, each presented separately to highlight key metrics and lessons for Malaysia.

4.1 Singapore

In 2022, Singapore produced roughly 7.39 million tonnes of solid waste, with the domestic and non-domestic sectors contributing 25% and 75%, respectively [15]. Notwithstanding heightened urbanisation and industrialisation, Singapore has achieved a clean environment, social diversity and economic advancement. Singapore acknowledges the necessity of transitioning from the existing linear economic model of "take-make-dispose" to a circular approach, prioritising resource use and output reduction. This new model emphasises the elimination of waste from the resource ecosystem and the optimisation of resource value by prolonging their utilisation. Singapore has used the circular economy model in various areas, completing several resource loops. For example, Singapore may perpetually recycle water, reusing it over and over. All used water is gathered and processed, converting a significant portion into potable water.

Singapore's effective waste management collection system safeguards public health, resulting in minimal environmental waste. General waste is collected daily, whereas public or private waste management services collect recyclable materials three times weekly. Citizens must segregate ordinary rubbish and recycling into distinct bins. Incineration is employed to the greatest extent possible to minimise the quantity of waste directed to the sole operational landfill. Incineration decreases waste volume by up to 90%, while the surplus heat generated from waste-to-energy incineration facilities contributes approximately 2% to Singapore's electricity supply. Nonetheless, merely adopting a circular economy model, as outlined in the Zero Waste Masterplan, is inadequate.

Current policies focus on minimising and recycling waste to the greatest extent feasible. While they have successfully diminished total waste production, adjustments are necessary to expedite the process. Singapore aims to elevate overall recycling rates to 70% and reduce per capita daily waste sent to landfill by 30% by 2030, to prolong Semakau Landfill's lifespan beyond 2035 [16].

4.2 Thailand

In 2019, Thailand generated 28.71 million tonnes of rubbish, with a per capita waste generation rate of 1.78 kilogrammes per day [17]. Urban and subdistrict municipalities exhibited the highest waste generation rates, comprising 40% and 38% of the total. The northeast region and Bangkok exhibited the highest waste generation rates at 26% and 21% of the total, respectively, followed by the central, northern, southern, eastern and western regions at 16%, 15%, 12%, 6% and 4%, respectively [17]. Landfilling serves as a method for waste disposal, particularly in rural regions where open dumping occurs. Thailand's recycling rate surpasses Malaysia's, primarily because of community-oriented "waste banks," which incentivise locals to trade recyclables for goods or cash, promoting household engagement and waste segregation [18]. These programs, frequently spearheaded by local governments and NGOs, have demonstrated efficacy in urban and semi-urban regions, exemplified by Chiang Mai. The Roadmap on Plastic Waste Management (2018-2030)

advocates the 3Rs (reduce, reuse, recycle) and incorporates initiatives such as prohibiting single-use plastics. Nevertheless, inconsistent funding and coordination hinder its efficacy, mirroring enforcement concerns faced by Malaysia. Thailand's decentralised, community-oriented strategy offers significant insights for Malaysia in executing local recycling initiatives and overcoming financial limitations.

4.3 Indonesia

Like numerous developing nations, Indonesia encounters considerable difficulties in solid waste management [19]. Indonesia, home to 270 million individuals, is undergoing significant expansion characterised by economic growth, heightened business activity and elevated consumption levels, leading to a rise in waste volume [20]. Population growth contributes to Indonesia's increasing amount of waste [21]. In 2022, Indonesia produced 36 million tonnes of municipal solid waste, attributed to its substantial population and expanding urban areas such as Jakarta [22]. Most of the solid waste is disposed of via open dumping [23]. Formal recycling programs exhibit limitations, with low public participation due to inadequate infrastructure and a lack of awareness. Since the popularisation of Reduce, Reuse, Recycle (3R) in the 1990s, Indonesians have embraced the principles of waste banks. Nonetheless, these initiatives address a limited proportion of waste, with merely very small amount of the total waste generated being processed by waste banks in 2018 [23]. Emerging community-based waste banks, akin to those in Thailand, demonstrate potential yet lack national scalability. Indonesia's dependence on informal recycling allows Malaysia to incorporate waste pickers into formal systems, thereby enhancing recycling rates and bolstering worker livelihoods.

5. Adaptation Strategies for Malaysia

The following table outlines actionable strategies for Malaysia to address MSWM challenges, drawing on regional best practices to reduce waste.

Table 1
Adaptation strategies

Strategy	Description	Regional Inspiration	Implementation in Malaysia	Expected Outcomes
Develop Waste-to-Energy Infrastructure	Invest in small-scale WTE plants to process non-recyclable waste and generate energy, upgrading open dumps to sanitary landfills.	Singapore's WTE systems and Semakau Landfill [16].	Establish WTE facilities in urban centres like Kuala Lumpur and upgrade rural landfills with leachate treatment.	Reduced landfill use, energy generation and lower environmental impact.
Implement Community Waste Banks	Establish programs where households exchange recyclables for incentives like cash or vouchers.	Thailand's community waste banks [18].	Launch waste banks with NGO partnerships, offer incentives via schools and community centres.	Increased recycling participation and improved waste segregation.
Formalise the Informal Recycling Sector	Integrate waste pickers into formal systems through cooperatives, training and safety standards.	Indonesia's informal waste pickers [19].	Create cooperatives for waste pickers, provide training and protective equipment.	Higher recycling rates and improved livelihoods for workers.

Strengthen Policy Enforcement	Enhance Act 672 enforcement with audits, penalties and clear targets.	Singapore's Green Plan 2030 [16].	Implement regular audits and strengthen federal-local coordination to reduce illegal dumping.	Reduced illegal dumping, progress toward 40% recycling target.
Enhance Public Awareness Campaigns	Launch multifaceted campaigns via media, schools and community events, tailored to diverse demographics.	Singapore and Thailand's education initiatives [16, 18].	Use social media, TV, and school programs to promote the 3Rs and address cultural barriers.	Increased public participation in recycling is a cultural shift toward sustainability.
Foster Regional Collaboration	Create a Southeast Asian network for knowledge and technology sharing.	Singapore's expertise and Thailand's community models [16,18].	Establish regional partnerships for WTE technology and waste bank models.	Access to expertise, funding and scalable solutions.

These strategies leverage regional successes to address Malaysia's specific challenges, combining infrastructure development, community engagement and policy reforms to create a sustainable MSWM system.

6. Conclusion

Malaysia's municipal solid waste management system necessitates a comprehensive reform to achieve its lofty environmental objectives. Malaysia can markedly improve its waste management efficacy by implementing modern waste-to-energy technology, creating community-operated waste banks, and incorporating the informal recycling sector into formal systems. Enhancing the enforcement of current legislation and initiating nationwide awareness efforts will promote increased public engagement and accountability. Moreover, regional cooperation with Southeast Asian counterparts can improve the transfer of new technology, skills and sustainable financial frameworks. A comprehensive strategy prioritising infrastructure development, community engagement and effective policy implementation will enable Malaysia to establish a sustainable and efficient waste management system that addresses urban and rural challenges while conforming to global environmental standards.

Acknowledgement
This research was not funded by any grant.

Conflict of Interest Statement
The authors declare that there is no conflict of interest regarding the publication of this paper. No financial support, grants, or other forms of compensation were received that could have influenced the outcomes of this work. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions Statement
Normala Ahmad. conceptualized and designed the study, conducted the literature review. Noor Zubaidah Abdul Rahman. also performed the comparative case study analysis, interpreted the data, and wrote the initial draft of the manuscript. Selvakkumar K N Vaiappuri. revised the manuscript, ensured alignment with regional waste management contexts, and approved the final version for submission.

Data Availability Statement

All data analyzed in this study are derived from publicly available sources and are cited in the references of this published article. No primary data were generated during this research. Additional details or datasets used are available from the corresponding author upon reasonable request.

Ethics Statement

This study was conducted using secondary data from publicly available sources, including peer-reviewed literature, governmental reports, and international organization publications, in accordance with ethical research standards. No human or animal subjects were involved, and thus, no ethical approval or informed consent was required.

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