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The Implementation of Solid Waste Management Policies in Southeast Asia: The Present Situations and Future Recommendations

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Abstract

Solid waste management (SWM) is a challenge for urban cities in most of the globe, including Southeast Asia. The weak implementation of effective policies, mainly due to increasing solid waste (SW) generation, changing lifestyles, increasing demand for products and services, rapid urbanisation, and multiplication of various waste compositions, have affected the capacity of the authorities to secure financial budget, adequate human resources, and development of infrastructures in managing SW. The ineffective SWM causes severe health hazards and environmental degradation. Most Southeast Asian cities lack efficient SWM programmes. In aiming to provide a SW dataset for the Southeast Asian region, each country's waste generation and composition are profiled. Southeast Asia generated about 137.4 million tonnes of SW in 2016. Organic waste is the highest fraction of total SW generated, which accounted for 52 percent. The country's income level influences the waste composition of each country. Landfilling and open dumpsites are the standard methods of waste disposal in the region, accounting for 55 percent of the region's SW disposal method. Further, to support the policy implementation, this paper analysed gaps and SWOT (strengths, weaknesses, opportunities, and threats) and provided recommendations to incorporate into the action plans

for effective SWM policy implementation in Southeast Asia.

Keywords: Policy implementation, solid waste management, solid waste composition, gap analysis, SWOT analysis, Southeast Asia.

Introduction

Individuals, commercials, and industries-related activities contribute to a substantial amount of SW generation and cause pollution that is deteriorating environmental sustainability and the quality of public health. Economic development resulting from the industrial revolution, population growth from millions to billions, increasing purchasing power and demand for goods and services, shorter travelling time across the globe, globalisation of the economy, and technological advancements has significantly influenced the generation and composition of SW. The World Bank reported in their publication 'What A Waste 2.0', revealed that a total of 2.01 billion tonnes of SW was generated by the world's cities in 2016, equivalent to 0.74 kilograms of SW per capita per day (Kaza et al., 2018). It is anticipated that SW generation will increase to 3.40 billion tonnes in 2050 due to growth in urbanisation rate and income level posing another primary concern to any government (Iyamu et al., 2020; Rupani et al., 2019; Serge Kubanza & Simatele, 2020). Adequate designated legislation and developing comprehensive control programmes can support the efficiency and effectiveness of SWM (Das et al., 2019; Ferronato & Torretta, 2019). Studies revealed that countries with designated legislation significantly improved SWM while improving the environmental condition and maintaining the quality of public health (Das et al., 2019).

This study examines the implementation of policies for SWM. As the world grows into a future urban, more than half of the population lives in the major cities in the world. Urbanisation has influenced the migration of the population from rural to major cities. World Bank (2018) reported that the urban population has steadily increased from 751 million people in 1950 to 4.2 billion people in 2018. They also revealed that Asia accounts for 54 percent of the world's urban population, increasing demand for municipality services. Effective SWM is a significant concern in developing economies, mainly due to increasing population and urbanisation (Iyamu et al., 2020; Rupani et al., 2019; Serge Kubanza & Simatele, 2020). SWM is also significantly influenced by contextual factors such as politics, economy, society, and culture due to the implementation and the outcomes of SWM vary across countries depending

on SW characteristics and the capacity of the governments (Abdel-Shafy & Mansour, 2018). Governments at national and local levels need to plan, implement, and execute SWM effectively and anticipate its impact.

Literature Review

Global scenario of solid waste generation

Industrialisation, economic growth, population growth, urbanisation rate and climate conditions influence solid waste (SW). Proper SWM is essential to any country, as ineffective SWM may harm the environment and public health. Conventional waste disposal methods such as landfilling and open burning may result in greenhouse gas emissions, giving rise to potential environmental pollution and health hazards. Despite the growing awareness of SWM, several studies show that the planning, implementation, and execution of SWM in different countries is proportionate to their economic growth (Abdel-Shafy & Mansour, 2018; Das et al., 2019; Kaza et al., 2018). Table 1 shows the comparison of SWM by different levels of income in countries.

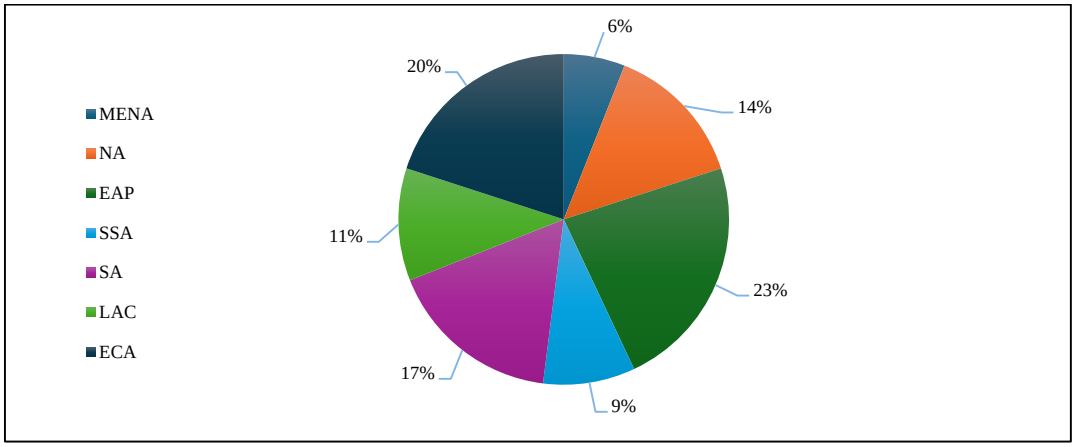
Meanwhile, Table 2 represents the world's demography and SW generation on a regional basis. The world is divided into several regions, such as East Asia and Pacific (EAP), Europe and Central Asia (ECA), Latin America and the Caribbean (LAC), Middle East and North Africa (MENA), North America (NA), South Asia (SA), and Sub-Saharan Africa (SSA). As the world moves to the future, urbanisation and population will continue to grow. East Asia and the Pacific (EAP) region has the largest population, with 2,298 million people in 2016. The SA total population is 1,766 million, followed by ECA, which accounts for 908 million people, LAC with 638 million people, MENA with 437 million people, and NA, which accounts for 359 million people. The world will witness a massive growth in population during the next three decades. More than 2,000 million people will live in the EAP, SSA, and SA regions by 2050.

There is a positive correlation between urbanisation and the generation of SW (Chen, 2018). A total of 1,316 million people lived in metropolitan areas in EAP in 2016, the highest among other regions. The urban population in Europe and Central Asia (ECA) accounts for 651 million people, followed by SA with 585 million people, Latin America, and the Caribbean with 511 million people, SSA accounts for 403 million people, NA with 293 million people, and MENA accounts for 282 million people. The SSA, MENA, and SA are anticipated

to have triple, twice, and double their present urban populations in 2050. Apart from that, the urban population of other regions is expected to increase by 10-30% in 2050. Figure 1 illustrates global waste generation on a regional basis.

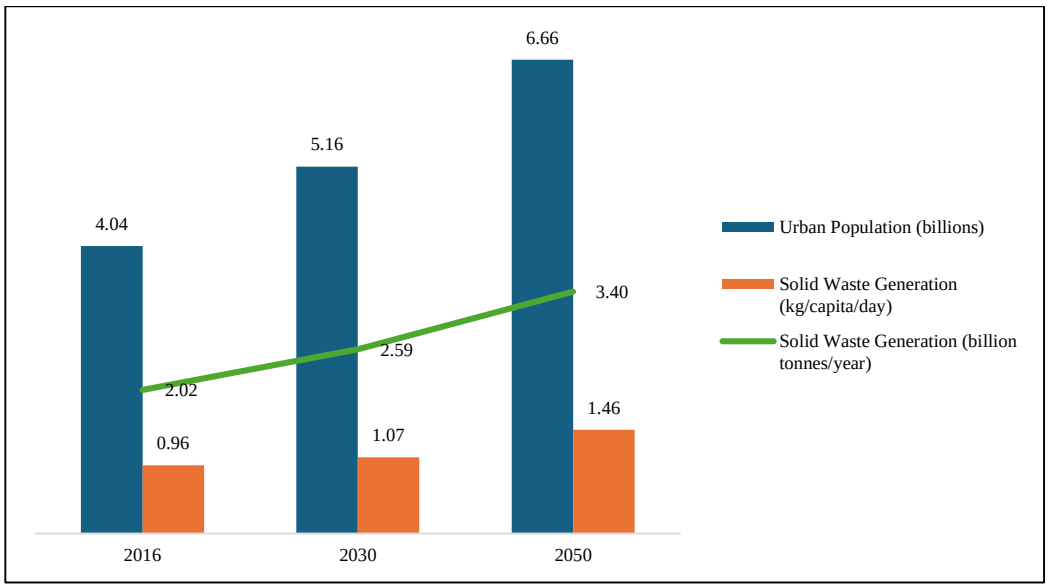
The East Asia and Pacific and the Europe and Central Asia regions accounted for 43 percent of the world's total waste generation in 2016. Table 2 represents the demography and SW generation on a regional basis. Figure 2 also illustrates the projection of global waste generation by 2050.

As the globe moves closer to an urban future, the SW generation will increase more than urbanisation. EAP has produced the most significant SW (23%) worldwide, followed by ECA (20%), SA (17%), NA (14%), LAC (11%), SSA (9%) and MENA (6%) (Kaza et al., 2018). However, by 2050, the expected growth rate of SW generation is 197 percent for SSA, 98 percent for SA, 75 percent for MENA, 60 percent for LAC, 53 percent for EAP, 37 percent for NA, and 25 percent for ECA, as shown in Table 2. In the case of per capita waste generation, the average waste generation rate in the NA was much higher (2.21 kilograms/capita/day) compared to ECA (1.18 kilograms), LAC (0.99 kilograms), MENA (0.81 kilograms), EAP (0.56 kilograms), SA (0.52 kilograms), and SSA (0.46 kilograms) (Kaza et al., 2018).



Source: Kaza et al. (2018).

Figure 1 Share of Waste Generated by Region



Source: Kaza et al. (2018)

Figure 2 Global waste generation by 2050

Table 1 Comparison of SWM by Different Level Incomes Countries

Activity	Low income	Lower middle income	Upper middle income	High income
Composition	The organic waste stream accounts for more than 50% of total SW generated. The percentage of recyclable material is low, with an average of 10%.	There is a significant quantity of recyclable material, with an average of 20%. However, organic waste dominates, accounting for more than half of the total SW produced.	There is a significant quantity of recyclable material, with an average of 20%. However, organic waste dominates, accounting for more than half of the total SW produced.	Recyclable materials are more dominant, accounting for 42% of the total SW generated. On average, organic waste accounts for less than 30% of the total generated SW.
Disposition	Lower incomes countries generally rely on open dumping; 93% of waste is dumped.	The most common method of waste disposal is open dumping (66%), followed by landfills (18%), and 28% of waste diversion to recycling and composting.	Waste is majorly being disposed of at landfills (54%). Waste is diverted through recycling and composting (6%) and incineration (10%).	Waste recovery is a priority. 35% of waste is diverted in recycling and composting. 22% of waste disposed of through incineration.

Cont. Table 1

Activity	Low income	Lower middle income	Upper middle income	High income
SWM cost and financing	The average cost of SWM accounts for 19% of the municipal budget. Some municipalities regulate SW fees. Operational expenditures (e.g., labour, facilities maintenance) dominate the total SWM cost. Budgets are often funded by external sources, primarily the private sector.	The average cost of SWM accounts for 11% of the municipal budget. National and local governments regulate waste fees. Investment in SWM infrastructure made the most significant one-off expenditure (e.g., sanitary landfill, waste collection trucks). The budget is usually financed by external financing (e.g., national government, financial institutions).	The average cost of SWM accounts for 11% of the municipal budget. National and local governments regulate waste fees. Investment in SWM infrastructure made the most significant one-off expenditure (e.g., sanitary landfill, waste collection trucks). The budget is usually financed by external financing (e.g., national government, financial institutions).	Lower SWM cost is less than 5% of the municipal budget due to public awareness and participation in SWM, such as recycling and composting. Substantial allocation of budget for SWM treatment facilities. Investment is sourced from both the public and private sectors.
Regulations	There is inadequate designated legislation on SWM due to the region's SWM system not being well developed.	There is a significant number of designated legislations on SWM. Availability of proper legislative frameworks. The primary concern is on the aspect of implementation.	Legislations on SWM are extensive. The legislations are comprehensive and cover the waste stream flow (e.g., from generation to disposal). Implementation is still a prevalent challenge.	The legislations on SWM are better regulated and implemented. The laws are more comprehensive with high compliance.

Source: Kaza et al. (2018).

Table 2 Population, SW Generation, Collection, Treatment, and Disposal on Regional Basis

Region	Current available data					Estimation in 2050				
	Total population (million)[a]	Total urban population (million)[b]	Urbanisation rate (percent)[c]	SW generation		Projected population		Urbanisation rate (percent)[c]	Projected SW generation	
				Per capita (kg/capita/day)[d]	Total (million tons/year)[d]	Total population (thousand)[a]	Total urban population (thousand)[b]		Per capita (kg/capita/day)[d]	Total (million tons/year)[d]
EAP	2,298	1,316	62	0.56	468	2,414	1,839	62	2.50	714
ECA	908	651	31	1.18	392	924	751	50	1.45	490
LAC	638	511	34	0.99	231	778	684	47	1.30	369
MENA	437	282	45	0.81	129	656	497	32	1.06	255
NA	359	293	11	2.21	289	435	387	16	2.50	396
SA	1,766	585	130	0.52	334	2,288	1,201	133	0.79	661
SSA	1,033	403	119	0.46	174	2,245	1,298	102	0.63	516
Total	**7,439**	**4,043**	**62**	**0.96**	**2,017**	**9,741**	**6,656**	**63**	**1.46**	**3401**

Source: [a] United Nations (2017); [b]United Nations (2018c); [c]United Nations (2018a); [d]Kaza et al. (2018)

The East Asia and Pacific (EAP) region has a higher urban population than other regions, and it is projected to reach 1,838 million in 2050, an increase from 1,316 million in 2016 (see Table 2). Although the region's per capita waste generation rate was lower than in other regions in 2016, it is expected to increase by 34 percent in 2050. Furthermore, Table 2 also shows that EAP generated 468 million tonnes of SW in 2016 and that this amount will be increased to 714 million tonnes in 2050.

SW is broadly classified into organic and inorganic. This study categorises SW into different compositions such as organic, paper, plastic, glass, metals, and 'other'. Table 3 represents the sources of the by-products generated under each category.

Table 3 SW Generation Category

Types	Sources
Organic	Food scraps, garden waste, animal food, biodegradable material, horticultural residual, poultry
Glass	Bottles, broken glassware, bulbs
Metal	Cans, foil, tin, appliances, vehicles spare
Paper	Paper scraps, cardboard, newspaper, magazines, bags, boxes, wrapping paper, shredded paper, and paper beverage cups
Plastic	Bottles, packaging containers, bags, lids, cups
Rubber	Rubber tires, footwear, clothing
Textile	Clothing, carpets, textile-based products (furniture, footwear, towels etc.)
Wood	Wood packaging, wood pallets, crates, wooden containers, dunnage
Other	Construction debris, glue, residual waste, special waste, stone, ceramic, ash, and sludge

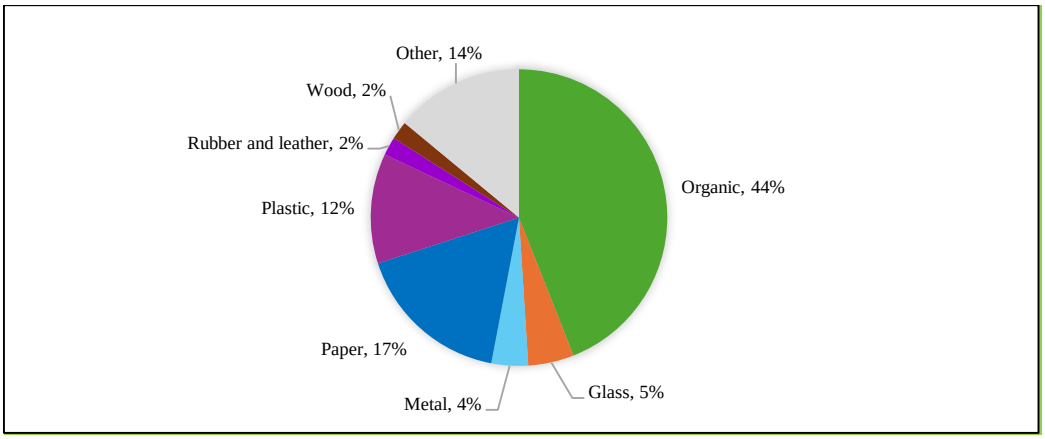
Source: United States EPA (2022); United Nations Environment Programme (2017a).

Figure 3 represents the percentage of different categories of waste generated globally. Organic waste accounts for the bulk of SW generated compared to non-organic waste. Organic waste accounts for 44 percent of global waste generation, followed by paper and cardboard (17%), plastic (12%), metal (5%), glass (5%), rubber and leather (2%), wood (2%), and others waste account for 14 percent. Theoretically, it is evident that as a country becomes more urbanised and prosperous, the consumption of inorganic materials (such

as paper, plastic, and aluminium) grows while organic and inert volume declines. Various factors, such as geographical location, cultural norms, and climate, may influence a country's waste composition. Understanding waste composition is essential as it will affect the efficiency of the SWM system in terms of collection, transportation, treatment, and disposal (United Nation Environment Programme, 2015).

Waste management in ASEAN

In developing countries, environmental issues-particularly in SWM, have become a significant concern. Southeast Asia is a sub-region of Asia. The region covers about 10.5 percent of the Asia continent or 3 percent of the entire planet. It has around 625 million people, which accounts for 8.8 percent of the world's population (United Nation Environment Programme, 2017b). In terms of international politics, the governments in the region have formed to establish the Association of Southeast Asian Nations (ASEAN), an economic union consisting of ten Southeast Asian nations: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam (Erdiwansyah et al., 2019). ASEAN's mission is to foster intergovernmental cooperation in various fields, such as economic, political, defence, education, social, and environmental, among its members and other nations worldwide (Association of Southeast Asian Nations, 2008).



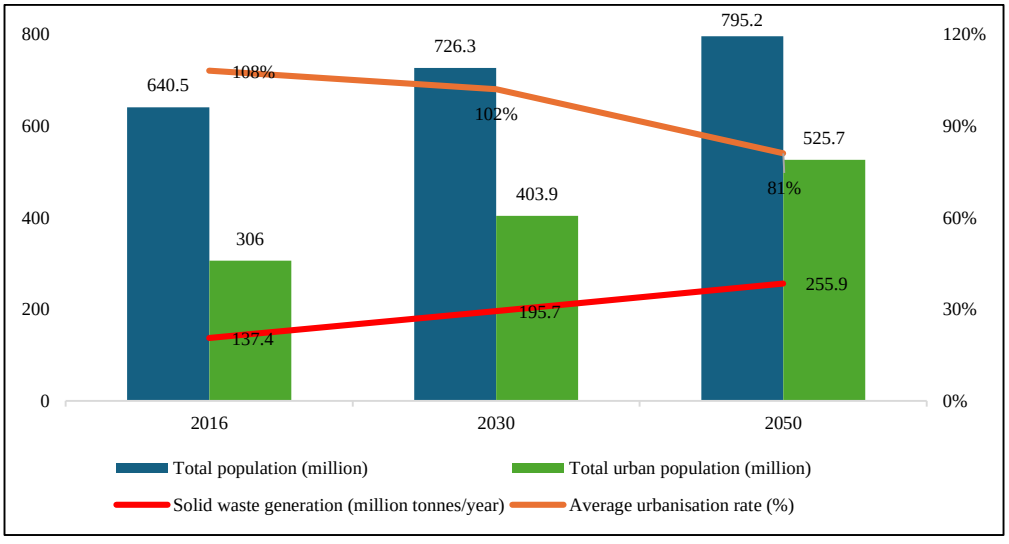
Source: World Bank (2018)

Figure 3 Percentage Quantity of Global Waste Generation by Different Categories

The World Bank has estimated that the annual urban population of

ASEAN countries is expected to grow significantly by 2050 (Kaza et al., 2018). Hence, this situation may result in an increase in the annual SW generation in the future. The majority of countries in Southeast Asia are classified as lower-middle-income countries (LMICs), except for Malaysia and Thailand, which are classified as upper-middle-income countries (UMICs). Brunei Darussalam and Singapore are classified as high-income countries (HICs).

Figure 4 depicts statistics on ASEAN countries' demographics and SW generation. Southeast Asia had a population of 640.5 million people in 2016. The region's population will rise to 726.3 million in 2030 and 795.2 million in 2050. Urbanisation has become a significant trend, and the region's population has rapidly increased. In 2016, 306 million people were living in cities. In 2030, this figure is expected to rise to 403.9 million, with 525.7 million people in the region's major cities by 2050. In 2016, ASEAN generated 137.4 million tonnes of SW. The region is expected to continue to create more waste in the future. The region's SW generation growth rate from 2016 to 2050 is estimated at 86 percent. In 2030, SW generation is projected to increase to 195.7 million tonnes and 255.9 million tonnes in 2050.



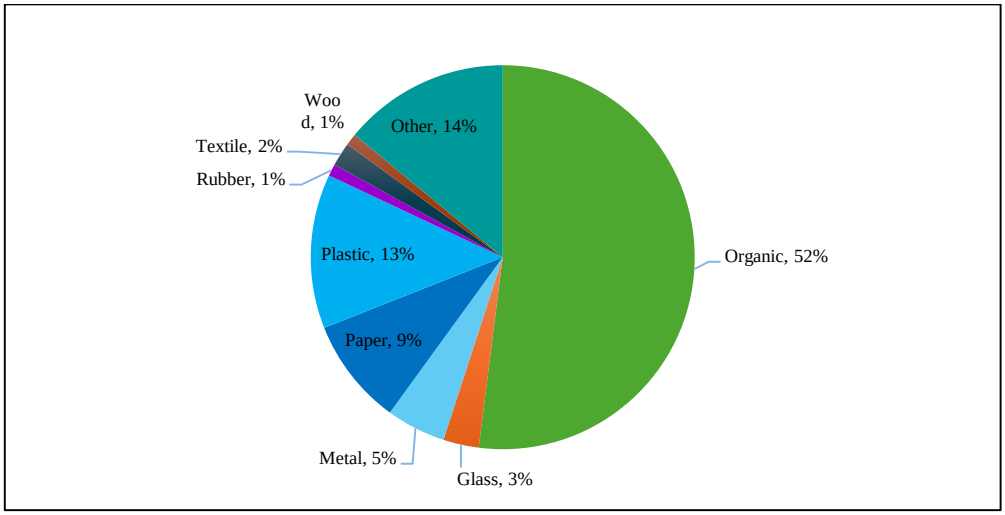
Source: Kaza et al. (2018)

Figure 4 Population and SW Generation in ASEAN, 2016 – 2050

Statistically, organic waste is the highest fraction of total SW generated in ASEAN, which accounted for 52 percent, followed by plastic at 13 percent, paper at 9 percent, metal at 5 percent, glass at 3 percent, textile at 2 percent,

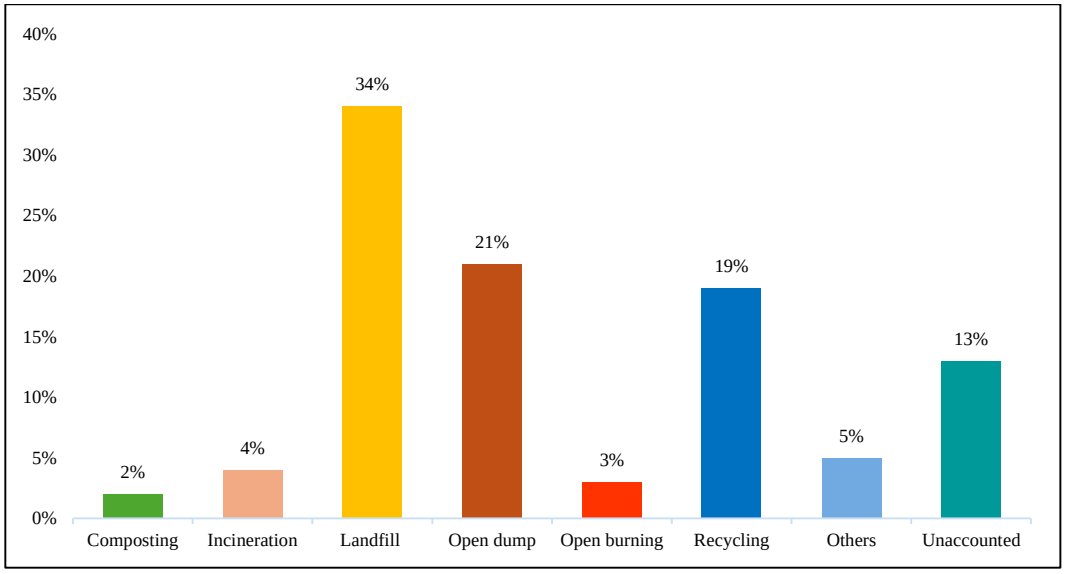
wood and rubber estimated for 1 percent each, and other waste accounted for 14 percent, as illustrated in Figure 5. The country's income level influences the waste composition of each country. In Southeast Asia, most countries are middle-income countries, and waste collection has become one of the challenges towards effective SWM.

As shown in Figure 6, landfills account for 34 percent of the region's SW disposal method. In comparison, open dumpsites account for 21 percent, recycling accounts for 19 percent, other waste disposal methods account for 5 percent, incineration accounts for 3 percent, open burning accounts for 2 percent, and composting accounts for 2 percent. The remaining 13 percent is unaccounted for disposal methods. In Southeast Asia, landfills and open dumps are the most common waste disposal methods. Apart from that, recycling rates are still low. Adapting sustainable SWM technologies such as Waste-to-Energy (WTE) is still uncommon in the region except for Singapore. Generally, this situation may result from financial constraints and operational difficulties due to the high cost of maintenance and operation of the plant, the high fraction of organic waste, and the lack of personnel with technical expertise in SWM technologies. Countries with financial constraints firmly focus on conventional methods rather than investing in technologies such as incineration.



Source: United Nations Environment Programme (2017b)

Figure 5 SW Composition in ASEAN



Source: United Nations Environment Programme (2017b)

Figure 6 SW Disposal and Treatment in ASEAN

Methodology

Theoretical framework on policy implementation

Implementing public policy has become a serious concern in developing countries, particularly ASEAN. Scholars have argued that achieving policy outcomes is always challenging. The policy implementation process is a crucial element in public policy, as Pressman and Wildavsky (1973) point out in their renowned literature, 'Implementation'. Thomas Dye offers the best-known short definition of public policy, describing public policy as 'whatever government choose to do or not to do' (Dye, 2012). William Jenkin, in 1978, developed a more complex definition of public policy as he described public policy as 'a set of interrelated decisions taken by a political actor or group of actors concerning the selection goals and the means of achieving them within a specified situation where those decisions should, in principle, be within the power of those actors' (Howlett et al., 2009).

Implementation can be defined as carrying out and completing the tasks to achieve the intended outcomes. In the field of public policy, Pressman and Wildavsky (1973) defined implementation as related to 'decisions' as outlined in official documents. They argued that implementing public policy could be seen as a process in which goals are defined and measures are performed to accomplish them. It was assumed that implementation would

proceed automatically once the right policies were developed in the policy implementation process. However, when the policy outcomes were different from what was intended, research was performed to explain the reasons for implementation failure, which might be attributed to a combination of weak execution, inadequate policy, or perhaps lousy luck (McLaughlin, 1987). Since then, researchers have continued to study the implementation of public policies around the globe to improve the process (O'Toole, 1995).

The emergence of different schools of thought in policy implementation as the implementation research gradually evolved has improved the understanding and implementation of public policy. The proponent of the top-down approach views the implementation process as derived from the policymakers and flowing downwards to the implementers at the ground level. In contrast, the bottom-up approach scholars believe that the implementer at the ground level is more significant and should be at the centre of the implementation process (Matland, 1995).

Research method and data collection

This study focused on the implementation of SWM policies in ASEAN countries. It explores top-down, and bottom-up approaches based on the abovementioned theoretical considerations. In the top-down approach, the study examines the current state of SWM, the policy implementation process and the extent to which the objectives are achieved at the national level. The bottom-up approach provides the study with the interactions and cooperation of implementers at the local level in the policy implementation process to achieve the intended outcomes. The study also identified the gaps and SWOT analysis through a critical review of existing policy frameworks developed by the countries in the region.

Since most countries in ASEAN are developing countries and classified as middle-income countries, their SWM needs to be well-developed. The availability of reliable waste statistics remains a significant challenge in the region (United Nation Environment Programme, 2017a). As a result, obtaining current data on SWM is challenging, and some of the data is only partially available. As a result, data for the study was gathered to the degree possible from prior research papers, review papers, World Bank policy reports, United Nations, United Nations Environment Programme, and other publicly available publications. The study then synthesised, analysed, and assessed data on SW, the SWM legislation, and policies in ASEAN to highlight the current state of SWM in the region. The study also examines the challenges in the

implementation process of SWM policies. In addition, several challenges identified may affect the implementation of SWM policies: technical, financial, environmental, and socio-political. Finally, the research recommends effectively implementing SWM policies in the region.

Findings

Several studies have been conducted to a reasonable extent on SWM in Southeast Asian countries. However, most of them have concentrated on waste classification, waste treatment, or recycling specific to the region. More literature is needed on implementing SWM policies in the region. The countries' data are shown in Table 5 in Appendix A.

Country's demographic and SWM status

Brunei Darussalam

Brunei Darussalam is classified as a High-Income Country (HIC) with the second-highest GDP per capita in the region, with 60,866 US dollars in 2016 (Kaza et al., 2018). The country's population in 2016 was 0.4 million people and is expected to reach 0.5 million in 2050 (United Nations, 2018b). In 2016, 0.3 million (77%) of the population living in the country's metropolitan area and the urban population were expected to increase to 0.4 million by 2050 (United Nations, 2018c). The nation generates 1.4 kilograms of SW per capita daily, with 0.2 million tons of SW generated in 2016 (Kaza et al., 2018). The waste collection efficiency was 90% (United Nations Environment Programme, 2017b). In addition, the country is anticipated to produce more SW in the future, generating an estimated 0.3 million tons of SW in 2050. Organic waste accounts for 36 percent of total SW created by Bruneians, followed by paper and cardboard (18%), plastic (16%), metal (4%), and glass (3%) (United Nations Environment Programme, 2017b). In 2016, Brunei Darussalam disposed of 70 percent of the total waste generated in landfills. Recycling accounted for 15 percent, and a small percentage (2%) of the waste was treated through composting (Kaza et al., 2018).

Cambodia

Cambodia is classified as a Lower-Middle-Income Country (LMIC), with

a GDP per capita of 3,364 US dollars in 2016 (Kaza et al., 2018). The country's total population in 2016 was 16 million people and is expected to reach 22 million in 2050 (United Nations, 2018b). The urban population accounted for 6 million people in 2016, and it is expected to increase to 9 million people (40%) of the total population living in urban areas by 2050 (United Nations, 2018c). The country generates 0.2 kilograms of SW per capita daily, with an annual 1.1 million tons of SW generated in 2016 (Kaza et al., 2018). The waste collection efficiency was 80% (United Nations Environment Programme, 2017b). Furthermore, the country is expected to receive a higher amount of SW In 2050, with an estimated 2.6 million tons generated by the population (Kaza et al., 2018). The country's primary waste composition was organic waste (60%), followed by plastic (15%), paper and cardboard (9%), glass (3%), rubber and leather and other waste accounted for 1 percent each (United Nations Environment Programme, 2017b). The country's recycling industry contributed 20 percent of the SW treatment and disposal methods. Open burning is still prevalent in Cambodia, with 15 percent of waste treated through this method, and other methods accounted for 2.5 percent (Kaza et al., 2018).

Indonesia

Indonesia is classified as a Lower-Middle-Income Country (LMIC), with a GDP per capita of 10,531 US dollars in 2016 (Kaza et al., 2018). The country has the highest total population in the region, with 261 million people in 2016 and is expected to reach 322 million people in 2050 (United Nations, 2018b). In 2016, 141 million (54%) of the total population lived in the country's metropolitan area, and the urban population were expected to increase to 234 million people by 2050 (United Nations, 2018c). The nation generates 0.68 kilograms of SW per capita daily, with 65 million tons of SW generated in 2016 (Kaza et al., 2018). The waste collection efficiency ranged from 56 to 75 percent (United Nations Environment Programme, 2017b). In addition, the country is anticipated to produce more SW in the future, generating an estimated 119 million tons of SW in 2050. The Major waste composition was organic waste accounted for 60% of total SW created by the population, followed by plastic (14%), paper and cardboard (9%), rubber and leather (6%), metal (4.3%), glass (3%), and other (5.9%) (United Nations Environment Programme, 2017b). In 2016, Indonesia disposed of 69 percent of the total waste generated in landfills, followed by open dumps at 10 percent, recycling at 7 percent, open burning at 5 percent, and other methods accounted for 9 percent (Kaza et al., 2018).

Lao PDR

Lao PDR is classified as a Lower-Middle-Income Country (LMIC), with a GDP per capita of 6,544 US dollars in 2016 (Kaza et al., 2018). The country's total population in 2016 was 6.8 million people and is expected to reach 9.2 million in 2050 (United Nations, 2018b). The urban population accounted for 2.3 million people in 2016, and it is expected to increase to 5.1 million people (56%) from the total population living in urban areas by 2050 (United Nations, 2018c). The country generates 0.15 kilograms of SW per capita daily, with an annual SW generation of 0.4 million tons in 2016 (Kaza et al., 2018). The waste collection efficiency ranged from 40 to 70 percent(United Nations Environment Programme, 2017b). The country is expected to generate a higher amount of SW in 2050, with an estimation of 0.7 million tons will be generated by the population (Kaza et al., 2018). Organic waste is the largest share of the country's SW generated, which is 64 percent, followed by plastic (12%), paper and cardboard (7%), glass (7%), rubber and leather (3%), metal (1%), and other waste accounted for 5 percent (United Nation Environment Programme, 2017b). The open dump is the primary waste disposal method in the country, with 60 percent of the total SW disposed of via open dumping, followed by landfill (30%), and recycling at 10 percent (Kaza et al., 2018).

Malaysia

Malaysia is classified as an Upper-Middle-Income Country (UMIC), with a GDP per capita of 23,906 US dollars in 2016 (Kaza et al., 2018). The country's population was 31.2 million in 2016 and is expected to reach 41.8 million in 2050 (United Nations, 2018b). In 2016, 23.3 million (75%) of the total population lived in the country's metropolitan area and the urban population was expected to increase to 36.4 million people by 2050 (United Nations, 2018c). The country generates 1.21 kilograms of SW per capita daily, with 13 million tons of SW generated in 2016 (Kaza et al., 2018). The waste collection efficiency was above 70 percent (United Nations Environment Programme, 2017b). In addition, the country is projected to produce more SW in the future, generating an estimated 23.8 million tons of SW in 2050. The highest percentage of waste composition is organic waste, 60 percent of total SW created by the population, followed by other waste (27.3%), plastic (13.2%), paper and cardboard (8.2%), and glass (3.3%) (United Nations Environment

Programme, 2017b). In 2016, Malaysia disposed of the majority of SW generated in landfills (81.5%), followed by recycling (17.5%), and a small percentage through composting, which accounted for 1 percent (Kaza et al., 2018).

Myanmar

Myanmar is classified as a Lower-Middle-Income Country (LMIC), with a GDP per capita of 1,094 US dollars in 2016 (Kaza et al., 2018). The country's total population 2016 was 52.9 million people and is expected to reach 62.4 million in 2050 (United Nations, 2018b). The urban population accounted for 16 million people in 2016, and it is expected to increase to 29.4 million people (47%) from the total population living in urban areas by 2050 (United Nations, 2018c). The country generates 0.39 kilograms of SW per capita daily, with an annual SW generation of 4.7 million tons in 2016 (Kaza et al., 2018). The country is expected to produce a higher amount of SW in 2050, with an estimation that 11.2 million tons will be generated by the population (Kaza et al., 2018). Organic waste is the largest share of the country's SW generated (73%), followed by plastic (17.8%), other (6.3%), paper and cardboard (2.2%), and glass at 0.5 percent (United Nations Environment Programme, 2017b). The country benefited a small percentage from the recycling industry, as 5 percent of the total SW generated is recycled (Kaza et al., 2018).

Philippines

The Philippines is classified as a Lower-Middle-Income Country (LMIC), with a GDP per capita of 7,705 US dollars in 2016 (Kaza et al., 2018). The country's total population in 2016 was 103.3 million people and is expected to reach 151.3 million in 2050 (United Nations, 2018b). The urban population accounted for 48 million people in 2016, and it is expected to increase to 93.5 million people (62%) from the total population living in urban areas by 2050 (United Nations, 2018c). The country generates 0.39 kilograms of SW per capita daily, with an annual SW generation of 14.6 million tons in 2016 (Kaza et al., 2018). The waste collection efficiency ranged from 40 to 90 percent (United Nations Environment Programme, 2017b). The country is expected to produce a higher amount of SW in 2050, with an estimation that 29.4 million tons will be generated by the population (Kaza et al., 2018). The country's largest share of waste composition is organic waste (52%), followed by metal (14.6%), plastic (10.6%), paper and cardboard (8.7%), glass (2.4%), and other waste accounting for 1.6 percent (United Nations Environment Programme, 2017b).

The open dump is the primary waste disposal method in the country, with 60 percent of the total SW disposed of via open dumping, followed by landfill (30%), and recycling at 10 percent (Kaza et al., 2018).

Singapore

Singapore has the highest GDP per capita in the region, with 97,341 US dollars in 2016 and is classified as a High-Income Country (HIC). The country's total population 2016 was 5.6 million people and is expected to reach 6.6 million in 2050 (United Nations, 2018b). Singapore is the most urbanised country in Southeast Asia, with a 100 percent urbanisation rate (United Nations, 2018a). The country generates 3.72 kilograms of SW per capita daily, with an annual SW generation of 1.9 million tonnes in 2016 (Kaza et al., 2018). The waste collection efficiency is above 90 percent (United Nations Environment Programme, 2017b). The country is expected to produce a higher amount of SW in 2050, with an estimation that 10 million tonnes will be generated by the population (Kaza et al., 2018). The country's waste comprises organic waste (10.5%), glass (1.1%), metal (20.8%), paper and cardboard (16.5%), plastic (11.6%), wood (1%) and other types of waste at 31 percent (United Nations Environment Programme, 2017b). Singapore has benefited from the recycling activity in which 61 percent of waste generated is recycled, followed by incineration (37%) and a small percentage of 2 percent of waste disposed at landfills (Kaza et al., 2018).

Thailand

Thailand is classified as an Upper-Middle-Income Country (UMIC), with a GDP per capita of 16,302 US dollars in 2016 (Kaza et al., 2018). The country's total population in 2016 was 68.9 million, and the projected population in 2050 will be 65.4 million (United Nations, 2018b). The urban population accounted for 33.4 million people in 2016, and it is expected to increase to 45.4 million people (69%) from the total population living in urban areas by 2050 (United Nations, 2018c). The country generates 1.08 kilograms of SW per capita daily, with an annual SW generation of 26.9 million tons in 2016 (Kaza et al., 2018). The waste collection efficiency was above 80 percent (United Nations Environment Programme, 2017b). The country is expected to produce a higher amount of SW in 2050, with an estimation that 37.3 million tons will be generated by the population (Kaza et al., 2018). The country's largest share of

waste composition is organic waste, which is 64 percent, followed by plastic (17.6%), paper and cardboard (8%), glass (3%), metal (2%), other waste (1.4%), wood (1%), and leather and rubber at 1 percent (United Nations Environment Programme, 2017b). The open dump is prevalent in the country as 54 percent of the total SW is disposed of through open dumping, followed by landfill (27%), recycling (10%), and a small percentage (0.4%) of waste generated is disposed of through incineration (Kaza et al., 2018).

Viet Nam

Viet Nam is classified as a Lower-Middle-Income Country (LMIC), with a GDP per capita of 5,089 US dollars in 2016 (Kaza et al., 2018). The country's total population in 2016 was 94.6 million people and is expected to reach 114.6 million in 2050 (United Nations, 2018b). The urban population accounted for 32.6 million people in 2016, and it is expected to increase to 65.7 million people (57%) from the total population living in urban areas by 2050 (United Nations, 2018c). The country generates 0.33 kilograms of SW per capita daily, with an annual SW generation of 9.6 million tons in 2016 (Kaza et al., 2018). The waste collection efficiency ranged from 80 to 82 percent (United Nations Environment Programme, 2017b). The country is expected to produce a higher amount of SW in 2050, with an estimation that 22 million tons will be generated by the population (Kaza et al., 2018). The country's largest share of waste composition is organic waste (55%), followed by plastic (10%), paper and cardboard (5%), metal (5%), rubber and leather (4%), and glass at 3 percent (United Nations Environment Programme, 2017b). Composting accounted for 15 percent of the country's waste disposal method, and recycling accounted for 23 percent (Kaza et al., 2018).

Legal framework for SWM in ASEAN countries

ASEAN countries are now dealing with several waste management challenges, including rising yearly SW generation, which necessitates new disposal sites, the scarcity of spaces, and environmental pollution. Open dumping and open burning are prevalent in most regional countries (Tun et al., 2020). According to the United Nations Environment Programme (2017b), most countries in ASEAN have developed effective strategies to address SWM issues, such as rules and regulations and policy frameworks. Table 6 (see Appendix B) presents the selected regulatory framework for SWM in ASEAN countries.

According to the findings, most ASEAN members have enacted legislation to enhance SWM. Despite this, many governments need help with adequate SWM systems (Yukalang et al., 2018). Effective policy frameworks are essential to address SWM issues with clearly defined objectives (Abas, 2019). However, the current state of the enforcement of these policies and the extent to which the objectives of the laws have been achieved remained vague. Many incidents of inefficient SWM have occurred in the region due to the government's failure to implement and enforce these policies effectively. According to Ancog et al. (2012), a solid political will may lead to the effective implementation of designated policies. The lack of political will among Philippines' lawmakers has been highlighted as the major challenge in implementing SW-related legislation (Guisansana et al., 2020). Furthermore, a strong leader must address weak coordination among stakeholders to properly perform their duties (Abas, 2019).

Government stability significantly influences the effectiveness of the policy implementation process in protecting the environment and public health from the adverse impacts of development. Most environmental policies in industrialised countries have evolved over the past decades with successful implementation (Das et al., 2019). In developing economies, particularly in Southeast Asia, government policies must be adequately enforced and implemented, resulting in inefficient SWM (Agamuthu et al., 2020). In contrast, developed countries such as Singapore emphasise sustainability in the circular economy by adopting the Extended Producer Responsibility (EPR) scheme in Zero Waste Masterplan 2019 (Bea & Low, 2019). In addition, most ASEAN countries, except for Singapore, still use conventional SW disposal and treatment methods. Developed economies have emphasised waste-to-energy in SWM policies (Yan et al., 2020). The inability of governments to implement the policy framework effectively results in poor procedures and low-quality SW services (Agamuthu et al., 2020).

Institutional framework

The roles and responsibilities of stakeholders in implementing SWM policies significantly affect the process. In addition, ambiguity in stakeholders' roles and responsibilities may cause loose administration and lax enforcement and implementation of policy framework. For instance, some ASEAN members

have difficulties such as a lack of clearly defined ground rules for resource allocation and monitoring processes, insufficient and ineffective national coordinating bodies, cooperation among stakeholders, and the absence of public-private partnerships that may significantly affect the effectiveness of the policy implementation process. These difficulties predominantly originated from the weak organisational structures within governments both at national and local levels. Policy experts clarified that this situation might affect the implementation process and jeopardise the progress of the policy outcomes. The weak structures also resulted from political unrest in the region. These challenges also highlight the fact that ASEAN lacks SWM capacity and planning. Apart from that, the region also lacks compliance measures. For example, in Malaysia, institutional weaknesses and poor cooperation among stakeholders may affect the effectiveness of the policy implementation process (Abas, 2019). According to Fernando (2019), this situation is due to a limited budget and insufficient technical knowledge and expertise that may affect the institutional capacity to implement the policy effectively.

Technical and infrastructure

Regarding the technologies and infrastructure of SWM in ASEAN countries, Singapore can be considered the most advanced country in adopting the latest technologies and infrastructures, leaving the remaining countries with some limitations. Currently, the disposal and treatment of SW have remained with limited resources due to a lack of advanced technology. Landfills and open dumping are preferred waste disposal methods in the region due to the low operating cost and unlimited space for landfill locations. On the other hand, Singapore opted for greener technologies, such as waste-to-energy plants, due to the country's limited space, as the country has only one landfill site (National Environment Agency of Singapore, 2010). The high organic waste percentage in the SW composition in most countries creates problems for waste separation and adapting incineration technology as it would require more energy for the waste disposal process. The recycling rate is still low in most countries as the sector is not well developed and are small businesses. Thus, investment in recycling technologies is relatively low as these businesses may need more resources, leading to low-quality recyclable items.

Conventional SW disposal methods such as landfills, open dumping and open burning have caused damage to the environment. These poor disposal methods may lead to various land, air, and water pollution (Hoang &

Fogarassy, 2020). Landfill sites may release dangerous gases such as methane that have many environmental implications (Khan et al., 2022). The Payatas incident in Quezon City was a significant example of the negative impact of landfills on the environment, as many lives have succumbed to the tragedy (Guisansana et al., 2020). Open burning, for instance, has developed continuous environmental pressure in Cambodia as part of a contributing factor, which has already seen a 50 percent increase in carbon dioxide emissions for the past decades (Ozturk & Al-Mulali, 2015).

Increasing SW amounts is straining the government's and municipalities' capacity to deliver adequate SW service coverage. Lack of infrastructure has affected the waste collection system in Hoi An City, Viet Nam, due to the increased tourism industry in the city (Pham Phu et al., 2019). Inconsistent SW collection schedules and poor infrastructures in Bandung City, Indonesia, have increased public dissatisfaction and reduced their participation in SWM programmes (Rachmawati et al., 2019). Initiatives such as the waste separation programme require sufficient facilities to be effectively implemented. Cities in Indonesia, such as Surabaya and Makasar, need help implementing waste separation programmes due to the authorities' lack of waste sorting facilities (Permana et al., 2015; Setiawan, 2020).

Capacity building

Capacity building is a significant concern in SWM (Abas, 2019; de Oliveira, 2019). Human resources are one of the critical elements in policy implementation. Adequate human resources may lead to the successful implementation of policy (Abas, 2019). One of the significant concerns in SWM in developing countries is the need for more technical expertise and opportunities to improve their knowledge of SWM. More personnel may lead to limited capacity and affect SWM operation and implementation efficiently and effectively as governments and municipalities grapple to control large service areas. Many ASEAN cities need help managing the SW operation and implementation effectively.

Implementing a public-private initiative in SWM in Cambodia is criticised due to local government authorities' limited skills and capacity (Spoann et al., 2019). Similarly, authorities in Makasar City, Indonesia, have difficulties implementing SWM programmes due to insufficient quantity and

technical personnel, leading to unsatisfactory SWM (Permana et al., 2015). Limited personnel capacities and numbers have hindered the effectiveness of the waste management system in Lao PDR (Japan International Cooperation Agency, 2021). Differently in Singapore, the National Environment Agency is actively building capacity in 3R areas through various programmes for the private sector to increase energy and resource efficiency (National Environment Agency of Singapore, 2019).

The progress of the waste separation programme initiated in most ASEAN countries is average. It is only effective with full cooperation and participation of the public. Thus, more educational programmes and campaigns are required to stimulate public awareness of SWM as a long-term solution.

Financial mechanism

In managing SW, the authorities have to consider the financial factors. Investment in new technologies and infrastructures while maintaining the existing ones has contributed to more constraints for governments and municipalities. Most of the SWM in ASEAN countries are under the responsibility of the local government, except for Malaysia, where SWM is under the central government's authority. Financial constraints and other existing limitations of the local governments, such as inefficient and ineffective institutions, lead to lower practices of SWM. Apart from that, intergovernmental structures, and various numbers of agencies from the central and local governments involved in SWM practised by most countries may lead to complications and redundancy of tasks in the operation and implementation of SWM. When various relevant authorities are involved in SWM, it may delay decision-making and necessary funding allocated to the cities for financing SW administration and operation. Thus, alternative funding from the private sector is in the best interest of cities in ASEAN to ensure the effectiveness of the implementation and operation of SWM.

SWOT analysis of waste management

The SWOT analysis is an effective tool to analyse the strengths, weaknesses, opportunities, and threats of any process, organisation, or project that helps address the effectiveness of the planning and implementation activities undertaken. Divided into two internal and external factors, it will provide the relevant stakeholders with an analytical framework for better

understanding the current operation and implementation of SWM in ASEAN. Thus, it will provide valuable insights for the future development of policies, strategies, and programmes by utilising strengths and opportunities while minimising the impact of weaknesses and threats in the future. Table 4 illustrates the SWOT analysis for the ASEAN SWM.

Strengths

The strength of ASEAN countries in managing SW is the existence of policies, legislation, and programmes related to environmental conservation and SWM, which enable the governments to plan and implement an effective SWM system through the guidance established by the policies framework. Most of the ASEAN countries have developed and implemented policies, legislation, and programmes addressing challenges in SWM (see Table 6, Appendix B). Some countries, such as Indonesia, Malaysia, the Philippines, and Thailand, have specific laws about the management of SW.

Managing SW requires organisation structures with defined roles and responsibilities. The structure may span from the top (central government) to the bottom (state and local government). The function of policymaking is at the central government, under the jurisdiction of the relevant ministry, for example, the Ministry of Environment. At the same time, other ministries, such as the Ministry of Health, are also granted roles in the policymaking process regarding environmental conservation and public health.

Apart from that, ASEAN countries also granted states and local governments the right to formulate state or local legislation to be implemented at the state or local level. In the Philippines, the Republic Act 9003 enables the Cebu City Government to develop, implement, and enforce several ordinances related to SWM (Ancog et al., 2012). Similarly, in Indonesia, the central government established Act No. 18/2008, while the regional government determines waste policies at the local government as predetermined by the central government to strengthen the operation and implementation of SWM (Meidiana & Gamse, 2011). Under the jurisdiction of the Public Health Act B.E. 2535 (1992), the local governments in Thailand were granted the legal role to formulate and enforce ordinances or regulations for SWM, which covers the collection, transportation, and disposal of waste within their administrative areas (Siriratpiriya, 2014).

Table 4 SWOT Analysis of SWM in ASEAN

	Strengths	Weaknesses
Internal factors	▪ Existence of policies, legislations, and programmes related to environmental conservation and SWM are in place. ▪ Institutional arrangements are in place. ▪ Additional state/local legislation on SWM exists.	▪ Weak and insufficient policies, legislations, and programmes. ▪ Lax of enforcement in policies implementation (e.g., 3R policy) ▪ Weak institutional arrangements (e.g., various relevant authorities) ▪ Insufficient human resources with technical and knowledge to meet demand of SWM. ▪ Financial constraints. ▪ Inadequate technologies and infrastructures. ▪ Ineffective waste disposal and treatment management facilities. ▪ Unutilised private sectors capacity in SWM.
	Opportunities	**Threats**
External factors	▪ Public-private cooperation in developing and implementing an effective SWM system. ▪ Linkages with higher learning institutions, environmental centres, and research institutes in SWM. ▪ Engagement and empowerment of community-based organisation (CBOs) in SWM programmes. ▪ High percentage of organic waste (>50%). ▪ Engagement with informal sector in recycling industries.	▪ Lack of political will in environment protection. ▪ Increasing waste generation due to rapid economic expansion and changing lifestyle. ▪ Increasing population may cause high consumption of new products and services. ▪ Increasing rate of urbanisation may lead to expansion of new urban areas and migration from rural areas to cities. ▪ Low public awareness and participation in SWM. ▪ Geographical and climate condition as constraints for disposal and waste treatment. ▪ Low value (price) of recyclable materials.

Weaknesses

The ASEAN members have various weaknesses that need to be addressed. The prominent obstacles to the successful implementation and operation of SWM in ASEAN hinge upon a need for more political will. Environmental issues such as SWM are a massive collective action problem (Kaza et al., 2018). Apart from changes in individual behaviour, changes in

system-level government policies from the local to the international level still need improvement. Governments need to have more political will to implement and enforce SWM policy.

The effectiveness of the region's SWM is affected by the weak and insufficient policies, legislation, and programs governing solid generation, collection, transportation, treatment, and disposal. Most emerging economies, particularly in Asia, face implications due to inadequate policies, enabling legislation to stimulate environmental programs and public awareness (Rachmawati et al., 2019). Insufficient policies and regulations on different kinds of SW are increasing stress to significant ASEAN cities such as Phnom Penh and Cambodia (Singh et al., 2018).

In Myanmar, the insufficient policies and regulations to address waste management issues have increased the amount of generation and hazardous waste in the country (Premakumara et al., 2017). Several other cities in ASEAN, such as Phnom Penh, Cambodia (Singh et al., 2018), and Banjarbaru, Indonesia (Nuzuli et al., 2015), share a similar situation as the absence of specific policies governing SWM in the cities. Policies such as environmental laws and regulations about waste separation, treatment, and disposal are crucial for an effective SWM system (Trinh et al., 2021).

Although some of the ASEAN governments have established SWM policies, the situation has mostly stayed the same. Only some studies in Malaysia found that the ineffectiveness of implementing a SWM policy is due to the gap in policy enforcement (Abas & Wee, 2020; Sa'adi et al., 2016). A similar problem also occurs in the Philippines and other countries in the region with lax enforcement in policy implementation, thereby leading to increased pollution (Wynne et al., 2018; Yukalang et al., 2018). Focusing on policy implementation may lead to effective, sustainable SWM (Mani & Singh, 2016).

Establishing well-structured institutions can support the conservation of environmental quality and maintain public health through effective SWM. In most ASEAN countries, the institutional structures for SWM remain unclear as specific government agencies were assigned to manage the sector without clear duties and responsibilities. de Oliveira (2019) suggested that for effective SWM in Malaysia, building robust institutions for institutional relations can support better environmental governance. In some cases, different institutional approaches are employed to support the process of SWM. Some countries

have established institutional arrangements in local government through decentralisation, as established in their policies.

For instance, enacting the Ecological SWM Act (RA 90003), with the primary objective of achieving waste reduction, has left the local government units with uncertainties concerning the enforcement and financial support of SWM programmes (Guisansana et al., 2020). Strengthening cooperation between federal and state may improve the implementation of SWM policy. The lack of understanding and integration of roles among state and federal governments has resulted in a low recycling rate in the City of Padang, Indonesia (5.5%) compared to the national target of 20% (Oh & Hettiarachchi, 2020).

The limited capacity of human resources with technical expertise is a disadvantage for the region. More personnel or experts may help with SWM planning and operation (Das et al., 2019). A few studies in Thailand found that implementing SWM in Thailand would be more effective if more personnel equipped with the necessary training were employed (Wannawilai et al., 2017; Yukalang et al., 2018). In Cambodia, the need for more personnel has increased the workload among the existing officers at the provincial and municipal levels (Mun, 2016).

Limited financial support from the government is among the challenges in implementing SWM activities. According to Agamuthu et al. (2020), less attention is given to SWM in developing countries. Thus, municipalities need more capacity to provide SWM services to protect public health and the environment. The limited budget also stresses that most governments at national and local levels invest in new technologies and infrastructures to support an effective SWM system. As a result, landfills, open dumping, and open burning activities are still prevalent in the region as the primary method of waste disposal. This situation leads to weak environmental protection due to poor landfill management, and unregulated landfills may produce leachate and hazardous gases.

Technologies such as waste-to-energy plants can reduce waste volume and the demand for new land for landfills (Tun & Juchelková, 2018). However, technologies like incinerators are uncommon in developing countries (Tun et al., 2020). In different scenarios of developed countries such as Singapore, SWM is well established due to the investment and development of technologies in SW treatment and disposal.

On the other hand, it is a significant concern for the remainder of the

low-income and middle-income ASEAN members. Inadequate technologies and infrastructures in SWM are turning landfills into the primary disposal method in Southeast Asia. For instance, 80% of SW collected in Malaysia is disposed of at landfills. Apart from that, Southeast Asian municipalities are still struggling to provide adequate SWM services. Due to inadequate waste collection, SW generated in major Philippines cities is thrown directly into the river, burned, or left uncollected. In Lao PDR, it is estimated that only 40-70% of waste is collected in urban areas, while in Indonesia, about 56-75% SW is collected (United Nations Environment Programme, 2017b). The low waste collection and conventional method in SW treatment and disposal may negatively impact public health and the environment.

Opportunities

The private sector plays an essential role in SWM. ASEAN members have considerable opportunities to harness the benefits of the private sector to improve SWM. Private sector participation can be seen as an alternative to improve SWM efficiency when governments are incapacitated. The involvement of the private sector can lower the cost and mobilise private investment in infrastructure and technology in SWM. Municipalities have outsourced the SWM service to private operators. In Malaysia, under the Solid Waste and Public Cleansing Management Act 2007, the federal government appointed the private sector to collect, transport, treat, and dispose of SW (de Oliveira, 2019). In a similar situation, the Government of Cambodia has proposed partnerships with the private sector to improve SWM in the country (Spoann et al., 2019). Engagement with the private sector can support sustainable SWM as the public-private-community partnership initiated by the Bangkok Metropolitan Authority (BMA) can increase the cooperation and participation of relevant stakeholders in SWM (Sukholthaman et al., 2017).

Furthermore, higher learning institutions, environmental centres, and research institutes should be utilised to provide a frame of reference for potential external support, especially in developing SWM policies and strategies. These organisations may assist the government with technical assistance and collaborative projects to develop expertise in enhancing SWM implementation and operation.

Apart from the involvement of the public and private sectors in SWM,

empowering the community can be a crucial factor in effective SWM. Ideally, the community is the closest group at the local level in dealing with SW. Community-based organisations (CBOs) complement the gap left by the municipalities and private sector in extending individuals' participation in SWM activities such as waste separation, recycling, and composting. In many developing countries, this has helped reduce the rate of indiscriminate SW disposal (Sinthumule & Mkumbuzi, 2019). In Thailand, community involvement has increased organic waste separation efficiency (Boonrod et al., 2015). Similarly, neighbourhood associations are essential in increasing public participation in recycling activities in Makassar, Indonesia, through community-based waste banks (Kubota et al., 2020). However, the community's role is yet to be given more attention by the region's governments, which disadvantages SWM.

As for the specific opportunity of the SWM issue, with a high percentage of organic waste in the region (average of more than 50%), there is potential to convert waste to energy and waste to compost. For example, Shams et al. (2014) found that Brunei Darussalam organic waste comprises 36% of the waste composition. They also argued that composting is a crucial element in zero waste management. It can produce valuable fertilisers for agricultural usage, benefiting the community. However, composting is yet to be fully utilised in the region. For instance, composting needs to be better practised in Thailand due to the lack of knowledge and the high cost of maintenance (Kaosol, 2009). Engagement with the informal sector in recycling activities is another potential opportunity that can be further developed. Typically, informal waste recycling is undertaken on a limited scale by private recyclers such as scavengers and waste pickers. Informal recycling can significantly affect social, economic, and environmental (Ezeah et al., 2013). Typically, most ASEAN countries need help providing better coverage in waste collection and improper waste disposal methods, which allows providing opportunities for informal waste recycling.

Threats

Lastly, the threats of the region are also defined. Environmental issues, particularly SWM, are massive collective action problems. Apart from changes in individual behaviour, changes at the system level through government policies from the local to the international level still need to be made. There needs to be more political will in the governments' implementation and enforcement of SWM policy.

Due to the regional strategic location and large population, Southeast Asia has a vast potential for economic growth and a market for products and services. However, as the ASEAN members increase their efforts in developing the economy, the SW generation may increase, resulting from the economic activities and changing the public's lifestyle from having relatively no power to purchase. Furthermore, population growth in situations may benefit the economy through the labour market, but at one point, it may increase demand for new products and services. Consequently, there is an increasing demand for raw materials, such as unnecessary packaging.

Apart from that, urbanisation may lead to the expansion of new urban areas and higher mobilisation of immigrants from the rural areas to the urban areas. The increasing number of populations residing in urban areas will create more challenges for governments both at national and local levels in ensuring their participation in SWM activities. Nevertheless, many SWM programmes and activities implemented by municipalities in ASEAN were ineffective due to the gap in public participation. The increasing SW generation may add more constraints to the existing landfills, which are already bloated with the current amount of SW generated. Improper landfill management may cause environmental problems such as flooding, which affect public health and security (Nguyen & Le, 2011). In Southeast Asia, climate, and seasonal variations, especially during the rainy season, could affect the quality and quantity of waste. In such a case, the waste-to-energy plant's operation would be affected as the waste input quality is not suitable for the process.

Discussion

The SWM status review in Southeast Asia has revealed that the region's SWM remained a severe problem. In order to implement SWM policies effectively, ASEAN members need to address several challenges in strengthening the strategies framework to ensure effective policy implementation. A coordinated effort by relevant stakeholders, such as governments at national and local levels, the private sector, communities, NGOs, and the public, is urgently needed in the policy implementation process.

Inadequate institutional structure capacity is one of the shortcomings of ASEAN's SWM. It has been reported that ASEAN's governments face difficulties administering SWM due to insufficient coverage of waste services

and technical and environmental standards. This situation may relate to weak enforcement and implementation of SWM policies or programmes. There is also a situation whereby the policies or programmes are not adequately developed to address the communities' local issues and needs.

Furthermore, governments face difficulties involving relevant stakeholders during implementation and lack human resources with technical expertise in SWM. Based on observation, weak institutional capacity also leads ASEAN towards an inability to develop comprehensive policies, interdisciplinary decisions, and long-term strategies in addressing SWM issues at national and local levels. Thus, there is an urgent need for ASEAN to strengthen its institutional capacity at national and local levels, including adequate human capital with expertise in SWM and ensuring the participation of all relevant stakeholders in implementing SWM policies.

Studies have shown that the effective implementation of SWM policies is supported by establishing an adequate legislation framework and environmental awareness. The majority of ASEAN's governments have developed policies for SWM. However, the review found that these policies are not comprehensive. For instance, each composition of SW is different in material flows and requires a different method for material recovery. Although few countries have embarked on different alternative solutions for SW processing, treatment, and disposal, they are still in their infancy and poorly established.

Consequently, this situation cannot promote waste prevention and minimisation, has a low recycling rate, has a low rate of waste collection coverage, and needs to establish reliable data on SWM. An integrated approach to SWM and investing in sustainable waste technologies can support effective SWM. Like other developing countries, most countries in the region pay less attention to material recovery and recycling in the legislative framework. Abas and Wee (2020) argue that an adequate legislative framework requires a stricter and more systematic structure to support sustainable SWM. They added that developed countries have significantly enhanced the effectiveness of SWM implementation and operation and maintained environmental sustainability through their systematic and stricter legislation framework. Thus, these are the critical factors for engaging the relevant stakeholders in ensuring SWM policy implementation.

The development of technologies is an alternative solution to address SWM issues. Based on the reviews, the adaptation of technologies in SWM

varies across Southeast Asian countries. Technologies in SWM are essential to developing a more sustainable environment and maintaining public health. Typically, advanced economies such as Singapore have invested in and employed state-of-the-art technologies to manage SW effectively. The country also has the highest percentage of waste being treated through the incineration process in the region. Technologies require a considerable investment, and employing new technologies demands technical skills and knowledge.

Thus, many developing economies in ASEAN are choosing less costly technologies in waste management due to tight budgeting, which are less sustainable and negatively impact the environment. The presence of the informal recycling sector is significant in the region. The lack of infrastructure and equipment for SWM has provided more significant opportunities for the informal recycling sector to function in the waste collection system. This may lead to other operational challenges, such as waste material flow recovery.

On the other hand, the availability of data related to SWM is another challenge for the region in developing an effective SWM system. Effective policy implementation requires reliable data regarding SWM processes such as waste generation, composition, recycling rate, treatment, and disposal. Many countries need reliable data sources to support policymakers and implementers in developing practical plans for both the short- and long-run that hinder improvement in SWM.

Environmental awareness plays a crucial factor in supporting effective policy implementation. However, environmental awareness in ASEAN is another primary concern for governments at national and local levels. Developed societies are more concerned about environmental issues. The government plans and implements various programmes and strategies to increase awareness among the societies.

In contrast, much more needs to be done in ASEAN to enhance environmental awareness. Effective programmes should be planned and implemented effectively. The implementation process requires concerted efforts from the public and private sectors and NGOs that may lead to better programme outcomes. For instance, environmental awareness-building strategies may be incorporated into the school syllabus as part of education campaigns to expose society early on to SWM issues.

Financial, environmental, social, governance and political factors all have a role in ensuring the effective implementation of SWM policies. In these areas, the Southeast Asia region tends to have certain disadvantages. Furthermore, political leadership has a significant influence on the policy implementation process. There needs to be more leadership in environmental issues in the region, particularly SWM, due to weak governance and lack of institutional capacity.

Typically, most of the policies adopted in ASEAN target waste minimisation. Senpong and Wiwattanadate (2022) suggested that waste minimisation and a sustainable environment can be achieved through incorporating sustainable SWM technologies such as waste-to-energy (WTE). In order to enhance the implementation process of SWM policies in ASEAN, difficulties such as administrative issues in SWM must be addressed. Furthermore, apart from constant monitoring activities on SWM programmes, governments at national and local levels should emphasise the role of public-private partnerships. As a result, a holistic approach that integrates all aspects of policy implementation in SWM, including environmental, legislation, technologies, technical, financial, and all relevant stakeholders' participation, is required.

In order to improve the effectiveness of the policy implementation process, the best practices from developed economies could be integrated with the region's socio-economic context. ASEAN developing economies might learn from developed economies with successful experiences with SWM. For instance, as presented in this review, Singapore could be the best example of managing SW to improve the implementation and operation of SWM. Consistent with the arguments of Agamuthu et al. (2020), the integration of low-cost technologies and cost-effective approaches in SWM by most developing economies can develop the capacity of both national and local governments in SWM. Apart from that, the composition of organic waste is significant in SW generated in the region. Thus, programmes such as waste separation at the source should be implemented systematically to ensure positive outcomes and minimise the quantity of organic waste disposed in landfills.

Although ASEAN members can adopt successful approaches implemented by other countries, the local socio-economic context must be observed and integrated for effective implementation and operation of SWM. The involvement of relevant stakeholders is not just during the implementation

process but would entail developing strategies and alternative solutions for preserving the environment and safeguarding public health. This would result in greater cooperation and synergies in implementing and operating SWM. The community and individuals should be empowered, which will yield greater participation in SWM activities. Indeed, substantial improvements in waste management can be achieved in the region.

Conclusion

Increasing purchasing power, improving individual economic status, rapid economic development, population growth, and higher urbanisation rates have significantly affected SWM worldwide. In Southeast Asia, SWM has become one of the significant environmental concerns. This situation urges the government at national and local levels to develop and implement a practical policy framework, establishing a well-structured institutional capacity with the support of human resources equipped with expertise and knowledge in SWM and investment in sustainable SWM technologies and infrastructures.

Conventional waste treatment and disposal methods, such as open burning and landfilling, are still prevalent in Southeast Asia. These methods remain dominant in most countries due to low operational costs. They do not require intense technical or technological skills to maintain, which may negatively affect the sustainability of the environment. ASEAN members must address several issues to ensure effective policies and achieve a sustainable SWM system. Among the issues are needing comprehensive policies and programmes supporting effective SWM, practical assessment and continuity of policies and programmes, financial resources, and public-private partnerships. Lack of political will from the political leaders consequently leads to adequate institutional capacity, resulting in solid implementation and enforcement of policies and programmes. ASEAN members must observe that successful SWM policies in developed economies might not be effective if they are not integrating with the aspect of local context, such as the socio-economic, environmental, and political conditions to design and implement ‘home-made’ solutions with ‘home-based’ strategies.

The presence of all stakeholders is essential in the design and implementation process. Programmes and strategies for waste minimisation, recycling, and separation at the source should be revamped, systematically

implemented, and closely monitored for assessment. The role of the informal recycling sector should be addressed together with that of the formal recycling sector. Participation from the public would determine the outcomes of the SWM policies. Thus, increased public participation may lead to effective policy implementation to develop an environmentally conservative society supporting sustainable SWM.

References

Abas, M. A. (2019). Public policy and governance: Theory and practice. *Global Encyclopaedia of Public Administration, Public Policy, and Governance*, 1-7.

Abas, M. A., & Wee, S. T. (2020). Exploring policy governance factors using stepwise multiple regression analysis: A case study of solid waste management policy in Malaysia. *International Journal of Public Sector Performance Management, 6*(6), 876-892. https://doi.org/810.1504/IJPSPM.2020.110990.

Abdel-Shafy, H. I., & Mansour, M. S. (2018). Solid waste issue: Sources, composition, disposal, recycling, and valorization. *Egyptian journal of petroleum, 27*(4), 1275-1290. https://doi.org/1210.1016/j.ejpe.2018.1207.1003.

Agamuthu, P., Fauziah, S. H., & Bhatti, M. S. (2020). *Sustainable waste management challenges in Developing Countries*. IGI Global. https://doi.org/10.4018/978-1-7998-0198-6.

Ancog, R. C., Archival, N. D., & Rebancos, C. M. (2012). Institutional arrangements for solid waste management in Cebu City, Philippines. *Journal of Environmental Science and Management, 15*(2), 74-82. https://www.ukdr.uplb.edu.ph/journal-articles/2211.

Association of Southeast Asian Nations. (2008). *The ASEAN Charter*. Retrieved from ASEAN Secretariat. Jakarta, Indonesia. Available at: https://asean.org/wp-content/uploads/images/archive/publications/ASEAN-Charter.pdf

Bea, E., & Low, M. (2019). *Extended producer responsibility in Singapore's Resource Sustainability Act*. NUS Law Working Paper 2019/024. National University of Singapore. Available at: https://law.nus.edu.sg/apcel/wp-content/uploads/sites/3/2020/04/024_2019_Eric-Bea.pdf.

Boonrod, K., Towprayoon, S., Bonnet, S., & Tripetchkul, S. (2015). Enhancing organic waste separation at the source behavior: A case study of the application of motivation mechanisms in communities in Thailand. *Resources, Conservation and Recycling, 95*, 77-90.

https://doi.org/10.1016/j.resconrec.2014.1012.1002.

Chen, T. C. (2018). Effects of urbanization on municipal solid waste composition. *Waste Manag, 79*, 828-836. https://doi.org/810.1016/j.wasman.2018.1004.1017.

Das, S., Lee, S. H., Kumar, P., Kim, K.-H., Lee, S. S., & Bhattacharya, S. S. (2019). Solid waste management: Scope and the challenge of sustainability. *Journal of Cleaner Production, 228*, 658-678. https://doi.org/610.1016/j.jclepro.2019.1004.1323.

de Oliveira, J. A. P. (2019). Intergovernmental relations for environmental governance: Cases of solid waste management and climate change in two Malaysian States. *Journal of Environmental Management, 233*, 481-488. https://doi.org/410.1016/j.jenvman.2018.1011.1097.

Dye, T. R. (2012). *Understanding public policy* (14th ed.). Pearson Education, Inc.

Erdiwansyah, Mamat, R., Sani, M. S. M., & Sudhakar, K. (2019). Renewable energy in Southeast Asia: Policies and recommendations. *Science of the Total Environment, 670*, 1095-1102. https://doi.org/1010.1016/j.scitotenv.2019.1003.1273.

Fernando, R. L. S. (2019). Solid waste management of local governments in the Western Province of Sri Lanka: An implementation analysis. *Waste Management, 84*, 194-203. https://doi.org/110.1016/j.wasman.2018.1011.1030.

Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health, 16*(6), 1060. https://doi.org/1010.3390/ijerph16061060.

Guisansana, L. G. G., Mag, J. D. R., Nabing, C. B. P., & Festijo, F. (2020). Solid waste management: The enactment of ecological solid waste management act of 2000 (R.A 9003) in addressing the waste crisis. *European Journal of Molecular and Clinical Medicine, 7*(2), 4186-4196.

Hoang, N. H., & Fogarassy, C. (2020). Sustainability evaluation of municipal solid waste management system for Hanoi (Vietnam)—Why to choose the 'Waste-to-Energy' concept. *Sustainability, 12*(3), 1085. https://doi.org/1010.3390/su12031085.

Howlett, M., Ramesh, M., & Perl, A. (2009). *Studying Public Policy: Policy Cycles and Policy Subsystems* (3rd ed.). Oxford University Press.

Iyamu, H. O., Anda, M., & Ho, G. (2020). A review of municipal solid waste management in the BRIC and high-income countries: A thematic framework for low-income countries. *Habitat International, 95*, https://doi.org/10.1016/j.habitatint.2019.102097.

Japan International Cooperation Agency. (2021). *Data Collection Survey On Waste Management Sector In The Lao People's Democratic Republic: Final Report*. Retrieved from Tokyo, Japan: https://openjicareport.jica.go.jp/618/618/618_112_1000044478.html

Jenkins, W. I. (1978). *Policy analysis: A political and organizational perspective*. London: M. Robertson.

Kaosol, T. (2009). Sustainable solutions for municipal solid waste management in Thailand. *World Academy of Science, Engineering and Technology, 60*(5), 665-670.

Kaza, S., Yao, L., Woerden, F. v., & Bhada-Tata, P. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050* (9781464813290). Retrieved from World Bank, Washington, DC: https://openknowledge.worldbank.org/handle/10986/30317

Khan, S., Anjum, R., Raza, S. T., Ahmed Bazai, N., & Ihtisham, M. (2022). Technologies for municipal solid waste management: Current status, challenges, and future perspectives. *Chemosphere, 288*, 132403. https://doi.org/132410.131016/j.chemosphere.132021.132403.

Kubota, R., Horita, M., & Tasaki, T. (2020). Integration of community-based waste bank programs with the municipal solid-waste-management policy in Makassar, Indonesia. *Journal of Material Cycles and Waste Management, 22*(3), 928-937. https://doi.org/910.1007/s10163-10020-00969-10169.

Mani, S., & Singh, S. (2016). Sustainable Municipal Solid Waste Management in India: A Policy Agenda. *Procedia Environmental Sciences, 35*, 150-157. doi:10.1016/j.proenv.2016.07.064

Manowong, E. (2012). Investigating factors influencing construction waste management efforts in developing countries: An experience from Thailand. *Waste Management and Research, 30*(1), 56-71. doi:10.1177/0734242X10387012

Matland, R. E. (1995). Synthesizing the implementation literature: The ambiguity-conflict model of policy implementation. *Journal of public administration research and theory, 5*(2), 145-174. https://doi.org/110.1093/oxfordjournals.jpart.a037242.

McLaughlin, M. W. (1987). Learning from experience: Lessons from policy implementation. *Educational Evaluation and Policy Analysis, 9*(2), 171-178. doi:10.3102/01623737009002171

Meidiana, C., & Gamse, T. (2011). The new Waste Law: Challenging opportunity for future landfill operation in Indonesia. *Waste Manag Res, 29*(1), 20-29. doi:10.1177/0734242x10384013

Mun, V. (2016). *Progress and challenges of deconcentration in Cambodia: The case of urban solid waste management*. CDRI Working Paper Series No. 110. Phnom Penh: Cambodia Development Resource Institute (CDRI). Available at: https://cdri.org.kh/publication/progress-and-challenges-

of-deconcentration-in-cambodia-the-case-of-urban-solid-waste-management/.

National Environment Agency of Singapore. (2010). *Solid Waste Management in Singapore*. Paper presented at the 2nd Regional 3R Forum in Asia, Kuala Lumpur, Malaysia. Available at: https://www.uncrd.or.jp/content/documents/RT3_06_Singapore.pdf.

National Environment Agency of Singapore. (2019). *Country 3R Progress Report - Singapore*. Paper presented at the Ninth Regional 3R Forum in Asia and the Pacific - "3R as a way for moving towards sufficiency economy – Implications for SDGs", Bangkok, Thailand. Available at: https://www.uncrd.or.jp/content/documents/7536Combined-front%20page+report-Singapore.pdf. https://www.uncrd.or.jp/content/documents/7536Combined-front%20page+report-Singapore.pdf

Nguyen, X. H., & Le, H. V. (2011). Solid waste management in Mekong Delta. *Journal of Vietnamese Environment, 1*(1), 27-33. https://doi.org/10.13141/jve.vol13141.no13141.pp13127-13133.

Nuzuli, O. F., Gani, Y. A., Pratiwi, R. N., Hanafi, I., & Fitrianto, A. (2015). Policy implementation of local communities development-based waste management in Banjarbaru, South Kalimantan, Indonesia. *Asian Social Science, 11*(18), 279-287. https://doi.org/210.5539/ass.v5511n5518p5279.

O'Toole, L. J. (1995). Rational choice and policy implementation: Implications for interorganizational network management. *The American Review of Public Administration, 25*(1), 43-57. doi:10.1177/027507409502500103

Oh, J., & Hettiarachchi, H. (2020). Collective action in waste management: A comparative study of recycling and recovery initiatives from Brazil, Indonesia, and Nigeria using the institutional analysis and development framework. *Recycling, 5*(1), 4. https://doi.org/10.3390/recycling5010004.

Ozturk, I., & Al-Mulali, U. (2015). Investigating the validity of the environmental Kuznets curve hypothesis in Cambodia. *Ecological Indicators, 57*, 324-330. https://doi.org/310.1016/j.ecolind.2015.1005.1018.

Permana, A. S., Towolioe, S., Aziz, N. A., & Ho, C. S. (2015). Sustainable solid waste management practices and perceived cleanliness in a low income city. *Habitat International, 49*, 197-205. https://doi.org/110.1016/j.habitatint.2015.1005.1028. doi:10.1016/j.habitatint.2015.05.028

Pham Phu, S. T., Fujiwara, T., Hoang Minh, G., & Pham Van, D. (2019). Solid

waste management practice in a tourism destination – The status and challenges: A case study in Hoi An City, Vietnam. *Waste Management & Research, 37*(11), 1077-1088. https://doi.org/1010.1177/0734242X19862042.

Premakumara, D. G. J., Hengesbaugh, M., Onogawa, K., & Hlaing, O. M. T. (2017). *Waste management in Myanmar: Current status, key challenges and recommendations for national and city waste management strategies*. Japan: UN Environment International Environmental Technology Centre (UN Environment-IETC), Institute for Global Environmental Strategies (IGES) Centre Collaborating with UNEP on Environmental Technologies (CCET). Available at: https://stg-wedocs.unep.org/bitstream/handle/20.500.11822/30985/WMM.pdf?sequence=1&isAllowed=y.

Pressman, J. L., & Wildavsky, A. (1973). *Implementation: How great expectations in Washington are dashed in Oakland; or, why it's amazing that federal programs work at all, this being a saga of the economic development administration as told by two sympathetic observers who seek to build morals on a foundation* (1st ed.). University of California Press.

Rachmawati, E., Alamianti, D., Kamil, R. I., Suhara, E., & Yani, W. O. N. (2019). The implementation of local government's policy using the waste management program based on household needs in Bandung City. *International Journal of Engineering and Advanced Technology, 8*(5), 521-528. https://doi.org/510.35940/ijeat.E31075.30585C35919.

Rupani, P. F., Delarestaghi, R. M., Abbaspour, M., Rupani, M. M., El-Mesery, H. S., & Shao, W. (2019). Current status and future perspectives of solid waste management in Iran: a critical overview of Iranian metropolitan cities. *Environmental Science and Pollution Research, 26*(32), 32777-32789. https://doi.org/32710.31007/s11356-32019-06456-32775.

Sa'adi, N., Ismail, Z., Makmor, M., & Zawawi, E. M. A. (2016). Implementation of Malaysian goverment initiatives in managing construction waste. *Jurnal Teknologi, 78*(5-2), 55-60. doi:10.11113/jt.v78.8490

Senpong, C., & Wiwattanadate, D. (2022). Sustainable Energy Transition in Thailand: Drivers, Barriers and Challenges of Waste-to-Energy at Krabi Province. *Applied Environmental Research, 44*(2), 32-43. doi:10.35762/AER.2022.44.2.3

Serge Kubanza, N., & Simatele, M. D. (2020). Sustainable solid waste management in developing countries: A study of institutional strengthening for solid waste management in Johannesburg, South Africa. *Journal of Environmental Planning and Management, 63*(2), 175-188. https://doi.org/110.1080/09640568.09642019.01576510.

Setiawan, R. P. (2020). Factors determining the public receptivity regarding waste sorting: a case study in Surabaya city, Indonesia. *Sustainable*

Environment Research, 30(1), https://doi.org/10.1186/s42834-42019-40042-42833.

Shams, S., Juani, R. H. M., & Guo, Z. (2014, 1-3 Nov. 2014). *Integrated and sustainable solid waste management for Brunei Darussalam.* Paper presented at the 5th Brunei International Conference on Engineering and Technology (BICET 2014).

Shumon, M. R. H., Ahmed, S., & Islam, M. T. (2014). Electronic waste: present status and future perspectives of sustainable management practices in Malaysia. *Environmental Earth Sciences, 72*(7), 2239-2249. doi:10.1007/s12665-014-3129-5

Singh, R. K., Premakumara, D. G. J., Yagasa, R., & Onogawa, K. (2018). *State of waste management in Phnom Penh, Cambodia*. Retrieved from IGES Centre Collaborating with UNEP on Environmental Technologies (CCET) of Institute for Global Environmental Strategies (IGES), Tokyo, Japan. Available at: https://www.ccet.jp/sites/default/files/2018-07/State%20of%20Waste%20Management%20in%20Phnom%20Penh%2C%20Cambodia%20_web.pdf

Sinthumule, N., & Mkumbuzi, S. (2019). Participation in community-based solid waste management in Nkulumane Suburb, Bulawayo, Zimbabwe. *Resources, 8*(1), 30. doi:10.3390/resources8010030

Siriratpiriya, O. (2014). Municipal solid waste management in Thailand: Challenges and strategic solution. In A. Pariatamby & M. Tanaka (Eds.), *Municipal solid waste management in Asia and the Pacific Islands: Challenges and strategic solutions* (pp. 337-354). Springer Singapore.

Spoann, V., Fujiwara, T., Seng, B., Lay, C., & Yim, M. (2019). Assessment of public–private partnership in municipal solid waste management in Phnom Penh, Cambodia. *Sustainability, 11*(5), 1228. https://doi.org/1210.3390/su11051228.

Sukholthaman, P., Shirahada, K., & Sharp, A. (2017). Toward effective multi-sector partnership: A case of municipal solid waste management service provision in Bangkok, Thailand. *Kasetsart Journal of Social Sciences, 38*(3), 324-330. doi:10.1016/j.kjss.2017.05.004

Trinh, L. T. K., Hu, A. H., & Pham Phu, S. T. (2021). Situation, challenges, and solutions of policy implementation on municipal waste management in Vietnam toward sustainability. *Sustainability, 13*(6), 3517. https://doi.org/3510.3390/su13063517.

Tun, M. M., & Juchelková, D. (2018, 1-2 October). *Problems with Biodegradable Wastes—Potential in Myanmar and Other Asian Countries for Combination of Drying and Waste Incineration.* Paper presented at the IRRC Waste to Energy Conference, Vienna, Austria.

Tun, M. M., Palacky, P., Juchelkova, D., & Síťař, V. (2020). Renewable Waste-to-Energy in Southeast Asia: Status, Challenges, Opportunities, and Selection of Waste-to-Energy Technologies. *Applied Sciences, 10*(20), 7312. https://doi.org/7310.3390/app10207312.

United Nations. (2017). *World Population Prospects: The 2017 Revision, DVD Edition [File POP/1-1: Total population (both sexes combined) by region, subregion and country, annually for 1950-2100 (thousands) Medium fertility variant, 2015 - 2100]*. Retrieved from United Nations Department of Economic and Social Affairs, Population Division (UN DESA), New York: https://population.un.org/wpp/Download/Standard/Population/

United Nations. (2018a). *World Urbanization Prospects: The 2018 Revision, Online Edition [File 9: Average Annual Rate of Change of the Percentage Urban by Region, Subregion, Country and Area, 1950-2050 (per cent) Estimates, 1950 - 2015]*. Retrieved from United Nations Department of Economic and Social Affairs, Population Division, New York: https://population.un.org/wup/Download/

United Nations. (2018b). *World Urbanization Prospects: The 2018 Revision, Online Edition [File 18: Annual Total Population at Mid-Year by Region, Subregion, Country, and Area, 1950-2050 (thousands)]*. Retrieved from United Nations Department of Economic and Social Affairs, Population Division, New York: https://population.un.org/wup/Download/

United Nations. (2018c). *World Urbanization Prospects: The 2018 Revision, Online Edition [File 19: Annual Urban Population at Mid-Year by Region, Subregion, Country and Area, 1950-2050 (thousands)]*. Retrieved from United Nations Department of Economic and Social Affairs, Population Division, New York: https://population.un.org/wup/Download/

United Nations Environment Programme. (2015). *Global Waste Management Outlook*. Nairobi, Kenya: United Nations Environment Programme (UNEP).

United Nations Environment Programme. (2017a). *Asia Waste Management Outlook*. Retrieved from United Nations Environment Programme (UNEP), New York: http://wedocs.unep.org/handle/20.500.11822/27289

United Nations Environment Programme. (2017b). *Waste Management in ASEAN Countries*. Retrieved from United Nations Environment Programme (UNEP), Thailand: https://wedocs.unep.org/bitstream/handle/20.500.11822/21134/waste_mgt_asean_summary.pdf?sequence=1&amp%3BisAllowed=

United States EPA. (2022). Facts and Figures about Materials, Waste and Recycling. Retrieved from https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/guide-facts-and-figures-report-

about#Materials

Vergara, S. E., & Tchobanoglous, G. (2012). Municipal Solid Waste and the Environment: A Global Perspective. *Annual Review of Environment and Resources, 37*(1), 277-309. doi:10.1146/annurev-environ-050511-122532

Wannawilai, P., Poboon, C., & Maneein, J. (2017). Analysis of solid waste management and strategies for Bangkok metropolitan. *Environment and Natural Resources Journal, 15*(2), 1-12. https://doi.org/10.14456/ennrj.12017.14457.

World Bank. (2018). *World Bank Annual Report 2018* (9780821359716). Retrieved from Washington, DC: http://www.worldbank.org/en/about/annual-report

World Bank. (2020). *What A Waste Global Database*. Retrieved from The World Bank Group. Washington, DC. Available at: https://datacatalog.worldbank.org/search/dataset/0039597/What-a-Waste-Global-Database

Wynne, A. L., Nieves, P. M., Vulava, V. M., Qirko, H. N., & Callahan, T. J. (2018). A community-based approach to solid waste management for riverine and coastal resource sustainability in the Philippines. *Ocean and Coastal Management, 151*, 36-44. https://doi.org/10.1016/j.ocecoaman.2017.1010.1028.

Yan, M., Agamuthu, P., & Waluyo, J. (2020). Challenges for Sustainable Development of Waste to Energy in Developing Countries. *Waste Management & Research, 38*(3), 229-231. https://doi.org/210.1177/0734242X20903564.

Yukalang, N., Clarke, B. D., & Ross, K. E. (2018). Solid waste management solutions for a rapidly urbanizing area in Thailand: Recommendations based on stakeholder input. *International Journal of Environmental Research and Public Health, 15*(7), 1302. https://doi.org/1310.3390/ijerph15071302.

Appendix A

Table 5 Population, Solid Waste Generation, Collection, Treatment, and Disposal in ASEAN Countries

Region of countries		Brunei	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam
GDP[a]	(USD/ capita/year)	60,866	3,364	10,531	6,544	23,906	1,094	7,705	97,341	16,302	5,089
Country income classification[b]		HIC	LMIC	LMIC	LMIC	UMIC	LMIC	LMIC	HIC	UMIC	LMIC
Total population, 2016[c]	million	0.4	15.8	261.1	6.8	31.2	52.9	103.3	5.6	68.9	94.6
Urbanisation rate, 2016[d]	(%)	41%	176%	121%	184%	78%	80%	50%	0%	150%	200%
Urban population, 2016[e]	million	0.3	3.6	141.0	2.3	23.3	15.9	48.0	5.6	33.4	32.6
Projected total population, 2030[c]	million	0.5	18.8	295.6	8.1	36.8	58.9	125.4	6.3	69.6	106.3
Projected urbanisation rate, 2030[d]	(%)	0.34	1.82	0.98	1.61	0.52	1.26	0.79	0.00	1.20	1.66
Projected urban population, 2030[e]	million	0.4	5.5	185.8	3.5	30.1	20.6	63.8	6.3	40.7	47.3
Projected total population, 2050[c]	million	0.5	22.0	321.6	9.2	41.7	62.4	151.3	6.6	65.4	114.6
Projected urbanisation rate, 2050[d]	(%)	25%	164%	63%	115%	26%	145%	95%	0%	72%	109%
Projected urban population, 2050[e]	million	0.5	9.1	234.1	5.1	36.4	29.4	93.5	6.6	45.4	65.7
SW generation, 2016[a]	million tonnes/year	0.22	1.09	65.20	0.35	12.98	4.68	14.63	1.87	26.85	9.57
	kg/capita/day	1.40	0.20	0.68	0.15	1.21	0.39	0.39	3.72	1.08	0.33
Projected SW generation, 2030[a]	million tonnes/year	0.26	1.70	87.96	0.52	18.24	9.32	20.04	9.29	32.49	15.92
Projected SW generation, 2050[a]	Million tonnes/year	0.31	2.64	118.55	0.75	23.73	11.21	29.38	9.99	37.34	21.96
Estimation SW generation growth rate (2016 - 2050)	(%)	41%	142%	82%	113%	83%	140%	101%	434%	39%	129%
Average SW collection rate[a]	(%)	50-70%	80%	56% - 75%	40% - 70%	>70%	NA	40% - 90%	>90%	>80%	80% - 82%
SW composition[f]	Organic (%)	36%	72.4%	65%	46%	46%	77%	52.3%	15%	64%	42%
	Glass (%)	3%	1.9%	1%	8%	3%	1%	2.3%	1%	3%	7%
	Metal (%)	4%	0.4%	1%	12%	3%	1%	4.2%	20%	2%	6%
	Paper (%)	18%	3.5%	13%	6%	14%	3%	8.7%	16%	8%	2%
	Plastic (%)	16%	16.4%	11%	10%	15%	8%	10.6%	11%	18%	16%
	Rubber (%)	1%	0.1%	0%	0%	3%	0%	0.4%	0%	1%	0%
	Textile (%)	2%	3.6%	1%	0%	3%	2%	1.6%	2%	0%	0%
	Wood (%)	1%	0.0%	0%	0%	7%	0%	0.0%	5%	1%	0%
	Other (%)	19%	1.8%	8%	18%	6%	8%	19.9%	30%	3%	27%
SW treatment and disposal methods (%), 2016[a,f,g,h]	Composting	2%	na	na	na	1%	na	na	na	na	15%
	Incineration	na	na	na	na	na	1%	na	37%	0.4%	na
	Landfill	70%	64%	69%	30%	82%	na	na	2%	27.0%	na
	Open dump	na	na	10%	60%	na	83%	na	na	53.5%	na
	Open burning	na	22%	5%	na	na	na	na	na	na	na
	Recycling	15%	5%	7%	10%	18%	2%	28%	61%	19.1%	23%
	Others	13%	10%	9%	na	na	14%	na	na	na	na
	Unaccounted	na	na	na	na	na	na	72%	na	na	62%

Source: [a]Kaza et al. (2018), [b]World Bank (2020), [c]United Nations (2018b), [d]United Nations (2018a), [e]United Nations (2018c), [f]United Nations Environment Programme (2017b).

Appendix B

Table 6 Selected Regulatory Framework on SWM in ASEAN Countries

Country	Year	Policy/Regulation/Strategy	Definition	Key Authority
Brunei Darussalam	2016	Environmental Protection and Management Order, 2016	The regulation defines administration, powers, offences, and penalties regarding environmental management, monitoring, protection, control, and rehabilitation.	Ministry of Development
	2015	Brunei National Vision 2035	Visions that are established to promote sustainability in the country's development by 2035.	Government of Brunei Darussalam
	2013	Hazardous Waste (Control of Export, Import and Transit) Order (HWO) 2013	The law is to regulate the management of hazardous waste in the country.	Ministry of Development
Cambodia	2016	Cambodia's National Environment Strategy and Action Plan, 2016–2023 (ESAP)	The plan is part of the country's strategies to ensure environmental protection and sustainable natural resource management in the country's economic development.	National Council for Sustainable Development
	1999	Sub Decree on Solid Waste Management 1999 (2015 Amendment)	The legal basis of environmental protection in the country focuses on the activities related to the management of municipal solid waste (MSW) and hazardous waste.	Ministry of Environment, Ministry of Interior
	1996	Law on Environmental Protection and Natural Resource Management, 1996	The law on the general to promote environmental quality and public health through the prevention, reduction, and control the pollution.	Ministry of Environment, Royal Government of Cambodia.
Indonesia	2017	Presidential Regulation No. 97 of 2017 regarding Indonesian National Strategy Policy on Managing	The regulation aims to improve the management and reduce the amount of domestic waste and domestic waste equivalents generation in the	Ministry of Environment and Forestry

		Domestic Waste and Domestic Waste Equivalents	country.	
	2012	Government Regulation No. 81/2012 on Municipal Solid Waste	This regulation aims to safeguard public health and environmental quality by managing household waste and other similar waste management and promoting long-term economic growth.	Ministry of Environment and Forestry
	2008	Act No. 18/2008 concerning Solid Waste Management	The law focuses on municipal SW to increase public health and environmental quality and utilise waste as resources through recycling activities.	Ministry of Environment and Forestry
	2009	Act No. 32/2009 concerning Environmental Protection and Management	The law focuses on industrial and hazardous waste in optimising the quality of the environment through proper management of the related waste.	Ministry of Environment and Forestry
Lao PDR	2013	Environmental Protection Law (revised 2013)	The law is vital legislation in Cambodia to preserve and protect the environment covers resource management, waste management, and pollution control.	Minister of Natural Resources and Environment
Malaysia	2019	National Cleanliness Policy	The policy promotes a clean environment and develops a society that adopts cleanliness values to safeguard the environment's public health and sustainability.	Ministry of Housing and Local Government
	2007	Solid Waste and Public Cleansing Management Act 2007	The act aims to regulate the SWM public cleansing in a sustainable manner.	Ministry of Housing and Local Government
	1974	Environment Quality Act 1974	The act aims to preventing, abating, controlling pollution, and improving environmental quality.	Ministry of Water and Environment
Myanmar	2015	Procedures for Environmental Impact Assessment and the Environmental Quality (Emission) Guidelines 2015	The guidelines aim for environmental protection resulting from air, noise, water, and SW pollution projects.	Ministry of Environmental Conservation and Forestry
	2012	Environmental Conservation Law 2012	The law objective is to promote environmental conservation and improving the quality standard of	Ministry of Environmental Conservation and Forestry

			the environment.	
	1994	National Environmental Policy 1994	The policy provides a framework and guidelines for environmental and sustainable development.	Ministry of Environmental Conservation and Forestry
Philippines	2000	Ecological Solid Waste Management Act 2000	This act provides a regulatory framework for managing SW more systematically, comprehensively, and sustainably.	National Solid Waste Management Commission National Ecology Centre
Singapore	2002	Environmental Protection and Management Act 2002	The act provides the legal basis for environmental management and protection from pollution, including water, noise, and air pollution.	Ministry of Environment
	2002	Environmental Public Health Act 2002	It is the primary law to manage waste, including refuse from residences, businesses, and industries.	Ministry of Environment
Thailand	1992	Public Health Act B.E. 2535 (A.D. 1992)	The act is the basis for waste management in the country. It provides the regulatory framework for the central and local authorities in managing waste.	Ministry of Natural Resources and Environment
	1992	Enhancement and Conservation of National Environmental Quality Act B. E. 2535 (A.D. 1992)	The law provides authority to the administrators to set up necessary waste management facilities in the respective areas.	Ministry of Natural Resources and Environment
	1992	Public Cleansing Act B.E. 2535 (A.D. 1992)	The law aims to provide sanitation and public cleansing services concerning waste management activities.	Ministry of Natural Resources and Environment
Viet Nam	2020	Law on Environmental Protection 2020	The law is the primary regulatory framework for environmental protection and conservation to support sustainable development, including waste management regulation. The new and partially accepted law is expected to be fully enforced in 2022	Ministry of Natural Resources and Environment