Towards

Sustainable Municipal Solid Waste Management

in Malaysia

Synergors

UKRI Natural Environment Research Council

University of Oxford

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EXECUTIVE SUMMARY

The increasing amount of municipal solid waste (MSW) generation and the lack of strategic improvements on solid waste management in Malaysia require urgently the attention of the government and the public. It has been estimated that 1.17 kg/capita/day of MSW is generated in Malaysia, 65% of which is household solid waste that has doubled over the past 20 years due to population growth and urbanisation. Without a sufficient waste treatment and recycling infrastructure in place, most of the MSW is destined to continue to be landfilled. Not only it can cause pollution and health hazards, MSW is also one of the major sources of global methane emissions accounting for 11%. As methane is the second largest contributor of global greenhouse gas emissions after carbon dioxide, it is critical that Malaysia develops systemic sound solid waste management as part of its climate actions guided by the Paris agreement. Also, by treating waste as resource, the recent shift in the government strategy to move towards the circular economy should be aligned with SDG 12 targets (Responsible Consumption and Production). Although the quantity of recyclable waste collected tripled between 2018 and 2021, the officially reported recycling rate of 31.5% in 2021 remains questionable as the recycling infrastructure in Malaysia is not yet well established. This points to the significant efforts Malaysia needs to make to move towards a sustainable waste management regime, and to achieve its ambition for reaching a recycling target of 40% by 2025.

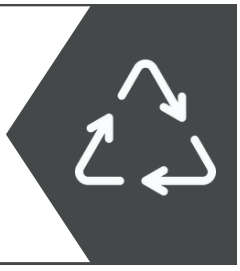
Malaysia started implementing a plan for moving towards sustainable waste management in the early 1990s. However, the recycling programmes were not well received by the public at that time, and it was only in 2001, that policy goals for sustainable waste management have been included in the regulatory landscape through the 8th Malaysia Plan (2001-2005). In 2005, the National Strategic Plan for Solid Waste Management was developed to guide solid waste policy planning and resource allocation. Two years after, the Solid Waste and Public Cleansing Management Act 2007 (Act 672) was created that came into enforcement in September 2011 in six out of the thirteen states (Perlis, Kedah, Pahang, Negeri Sembilan, Melaka, Johor) and two out of the three federal territories (i.e. Kuala Lumpur and Putrajaya).

This partial adoption of the Act has created inconsistency in waste management and planning as well as incomplete waste data gathering. This, has led to ineffective waste management practices, that, in turn, resulted in long-term environmental, economic and social consequences. Even though sustainable waste management goals continue to be included in the recent 12th Malaysia Plan (2021-2025), the lack of public awareness on the importance of source separation of waste and recycling prevents progress in this field. The infrastructure for waste collection and treatment is also insufficient to serve the needs. All these factors have created significant barriers for Malaysia to realise sustainable waste management.

Sustainable waste management requires a systemic approach in minimising waste through prevention, reuse, recycling, recovery and disposal. The proposed recommendations to overcome the barriers in waste management in Malaysia are:

Improve the way waste data is collected. The current data collection practice should be extended to cover every state in Malaysia. This will give a more comprehensive data set to reflect the actual situation which will enable appropriate measures to be undertaken.

Create a clear definition of recycling rate to reflect the actual amount of materials that have been recycled instead of considering the "potential" recyclable fraction, which may or may not be recycled.



Introduce an integrated action plan and streamlining policies and regulations for waste management for the whole Malaysia. Waste collection practices and regulations should be standardised across the country.

Increase investment and subsidies to upgrade waste infrastructure. This should involve converting all landfills into sanitary landfills; increasing waste-to-energy facilities for residual waste treatment; as well as anaerobic digestion and composting for organic waste treatment.

Enhance skills and expertise for human resources (e.g. engineers, waste collector) through training.

Promote public awareness of reduce, reuse and recycling through education and advocacy to foster behavioural changes.

This publication is an extension of "Malaysia versus Waste" authored by Dr Kok Siew Ng and Dr Eleni Iacovidou, featured in The Chemical Engineer (IChemE) in July 2020 (https://www.thechemicalengineer.com/features/malaysia-versus-waste/) to cover a wider aspect of municipal solid waste management in Malaysia. This work is mostly based on literature survey. This publication also serves as a supplementary material for the current 12th Malaysia Plan and future policy making to support the Malaysia's initiatives in transitioning towards sustainable waste management and circular economy.

ABOUT THE AUTHORS

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A Chemical Engineer by training with extensive research and consultancy experience in the fields of sustainable resources and waste management, sustainable industrial system design and circular economy. He is currently a Lecturer (Assistant Professor) in Chemical Engineering at Brunel University London, UK. Prior to joining Brunel, Kok Siew was a UKRI/NERC Industrial Innovation (Rutherford) Research Fellow and Lecturer in Chemical Engineering at the Department of Engineering Science, University of Oxford, from 2018 to 2022. During his time in Oxford, he was a Principal Investigator of the SYNERGORS project 'A systems approach to synergistic utilisation of secondary organic streams' (£0.5 million), funded by NERC. The project aimed to explore novel approaches to addressing challenges in organic waste management and achieving circular economy. He is also currently the Co-Investigator and Coordinator of the Oxford Agile project (Sprint 2) – a university-wide initiative focusing on tackling various environmental challenges using an interdisciplinary approach, funded through the £10 million NERC Changing the Environment programme. The sprint project aims to develop strategies for determining the best regional combination of nutrient recovery and utilisation options for both economic viability and environmental benefits. Kok Siew completed his MEng Chemical Engineering with Chemistry (First Class Honours) in 2008, and later gained his PhD in 2011 from the Centre for Process Integration (CPI), The University of Manchester. His research is significant in terms of addressing global challenges in the 21 st century, aligned with the UN SDG 7 and 12, the UK Industrial Strategy, and international ambitions to achieving circular economy and net-zero target.

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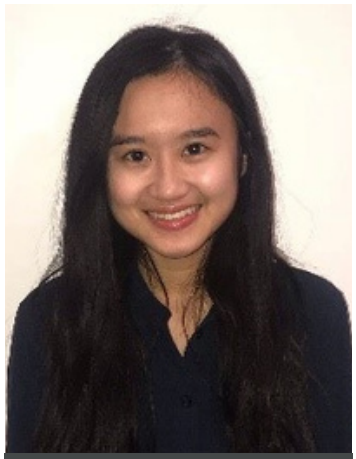
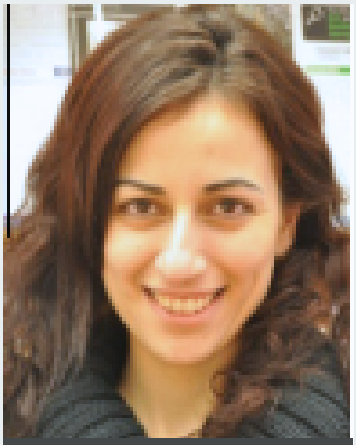


LYN YEOH



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A Chemist with expertise in environmental engineering and environmental management and policy research following studies at the University of Crete and Imperial College London. She is currently a Senior Lecturer in Environmental Management at Brunel University London, working on the lifecycle sustainability assessment of resources and waste management systems using a systems approach. She has been leading and delivering a broad spectrum of interdisciplinary and industrial projects (>£2 million) that involve the identification, mapping, analysis and assessment of the processes, stakeholders' structures and values (i.e., environmental, economic, social, technical) of resources and waste systems that inform policy development and champion resource efficiency and circularity of resources. Across the UK, Europe and the world, Eleni undertakes and leads research in multiple and interacting sectors of the circular economy. She supports strategic decision-making through the development of innovative frameworks that provide realistic insights into sustainability and resilience in the long term.

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A Chemical Engineer with a first degree from Universiti Teknologi Malaysia (UTM) (2000) and PhD in Combustion Engineering from University of Sheffield, United Kingdom (UK) (2005). She joined Universiti Putra Malaysia (UPM) in 2000. Her research focuses on unlocking the potential of biomass and waste into production of renewable energy. She received research grants worth more than MYR 5 Million and won a prestigious international grant under Newton Fund and Malaysia's L'oreal Fellowship for Women in Science (FWIS). She has vast publications in reputable journals, conference papers, book chapters (>200 publications) with h-index of 27 as an outcome contributed by the 26 PhD and 29 master students. Her appointment as technical advisory panels by various governmental organisations namely Ministry of Housing and Local Government (MHLG), Department of Environment (DOE) and Department of Standards Malaysia (DSM) is a great recognition of her experiences and capability in the respective field.

AKI YAMAGUCHI

A Coordinator for the NERC-funded Sprint projects under the Agile Initiative at Oxford Martin School. Sprints are interdisciplinary science research projects responding to urgent and critical environmental policy needs in a timely manner. She manages the operation of Sprints currently focusing on nature-based solutions, circular economy for nutrient flows, decarbonisation of the shipping industry, and CO_2 storage in the sea, and monitors their progress based on the Theory of Change framework. Prior to this role, Aki focused on the nexus between environmental policy and development at national and international levels. She managed projects at UNESCO, OECD, and UNEP focusing on the areas of water resources management, financing urban water supply and sanitation, sustainable development, waste management, urban resilience, and the circular economy. Aki has an MA in Environment and Development from the School of Oriental and African Studies (SOAS), University of London.

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NOMENCLATURE

ABC	Action Plan for a Beautiful and Clean Malaysia
AD	Anaerobic digestion
CIDB	Construction Industry Development Board
JPSPN	Jabatan Pengurusan Sisa Pepejal Negara
MESTECC	Ministry of Energy, Science, Technology, Environment & Climate Change
MHLG	Ministry of Housing and Local Government
MIDA	Malaysia Investment Development Authority
MSW	Municipal solid waste
NGO	Non-governmental organisation
SWCorp	Solid Waste and Public Cleansing Management Corporation
SWM	Solid Waste Management
WtE	Waste-to-energy

1.0 INTRODUCTION

In Malaysia, municipal solid waste (MSW) comprises household waste and wastes generated from institutional, commercial and industrial activities. According to Solid Waste and Public Cleansing Management Act 2007 (Act 672) (see section 2 for more information), MSW includes the following:

- any scrap material or other unwanted surplus substance or rejected products arising from the application of any process;
- any substance required to be disposed of as being broken, worn out, contaminated or otherwise spoiled; or
- any other material that according to this Act or any other written law is required by the authority to be disposed of, but does not include scheduled wastes as prescribed under the Environmental Quality Act 1974 (Act 127), sewage as defined in the Water Services Industry Act 2006 (Act 655) or radioactive waste as defined in the Atomic Energy Licensing Act 1984 (Act 304).

Based on the latest population estimates in Malaysia, it was estimated that approximately 14 million tonnes of MSW were generated in 2021 (MHLG, 2021). Household solid waste (65%) is the dominant fraction of the total amount of MSW generated, followed by commercial and institutional waste (28%) and industrial waste (7%) (GSR Environmental Consultancy, 2012).

It should be noted that there are significant challenges in collecting comprehensive set of actual waste data for the whole Malaysia as certain states have not adopted Act 672. Therefore, the data presented herein will only represent 6 out of 13 states, and 2 out of 3 federal territories in Malaysia. This will be explained further in section 2.

Table 1 shows that the daily household MSW generation in Malaysia is more than doubled during the past 20 years. This high level of waste generation is primarily driven by growing population and increasing urbanisation (Ng and Iacovidou, 2020). The population in Malaysia has reached 32.8 million in 2021, with an estimated household MSW generation of 38,207 tonnes per day (1.17 kg/capita/day), of which 82.5% is disposed of in landfills (MIDA, 2021). The Solid Waste and Public Cleansing Management Corporation (SWCorp) reported that Malaysia achieved a recycling rate of 31.5% in 2021. However, this is still lower than the 2025 target of 40% (Bernama, 2021; MIDA, 2021). The composition of household MSW is illustrated in Figure 1.

Table 1: Daily household waste generation in Malaysia from 2001 to 2021.

Year	Household Waste Generation		Reference
	tonne/day	kg/capita/day	
2001	15000	0.81	Samsudin and Mat Don (2013)
2005	19000	0.90	Borongan and Okumura (2010); Mohamad Taha (2016)
2012	33151	1.17	MHLG (2018)
2018	36896	1.17	MHLG (2018)
2021	38207	1.17	MHLG (2021)

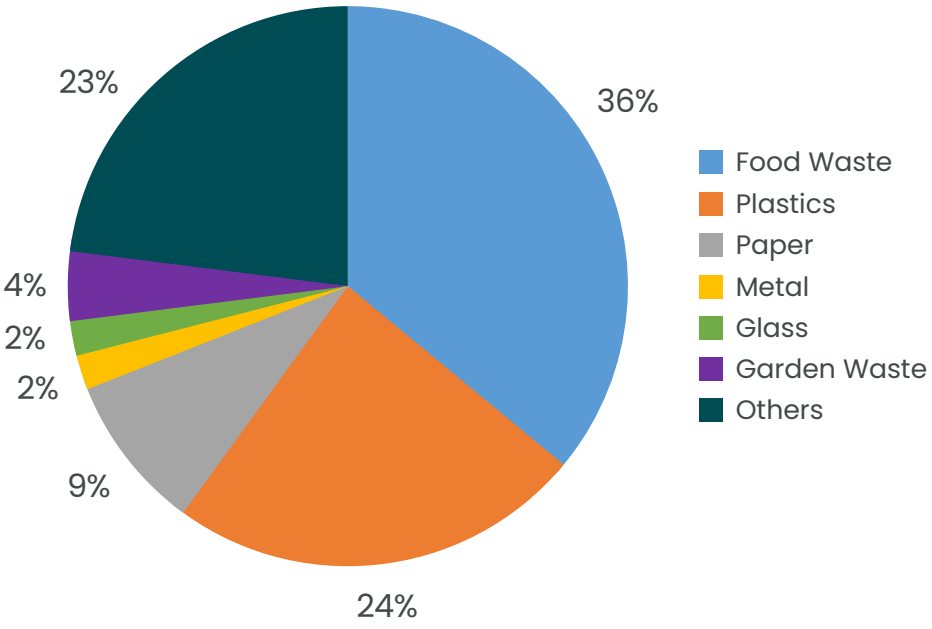

Figure 1: Composition of household MSW (MHLG, 2021)

"Others" refers to textiles, leather, rubber, hazardous waste, diapers and other wastes.

The recycling rate in Malaysia has generally improved over the years from 10.5% in 2013 to 31.5% in 2021 as illustrated in Figure 2. However, the recycling rate data should be interpreted with caution, as they may not align with the definition of recycling rate in other countries and hence they should not be directly compared. The current calculation of recycling rate considers all the "potential" recyclable materials at source which may or may not be sent for recycling.

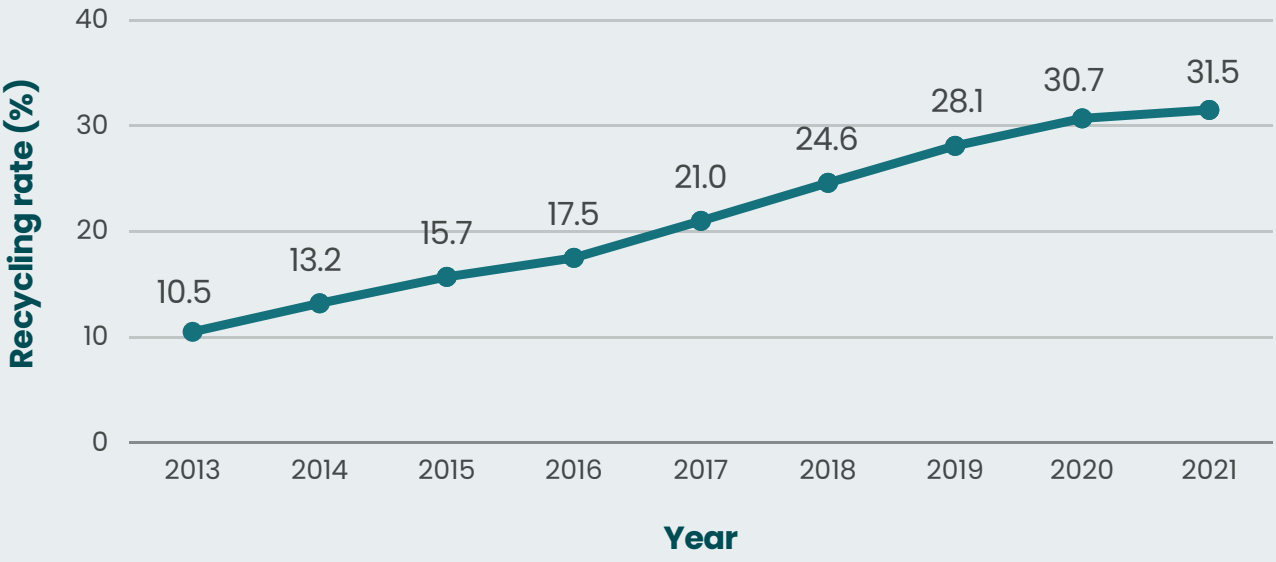

Figure 2: Recycling rate in Malaysia.

The aim of this report is to review the status quo in waste management practices in Malaysia and identify the gaps in terms of its strategies for moving towards sustainable waste management goal. The report is structured as follows. Section 2 provides a detailed discussion on policies and initiatives in Malaysia that promote sustainable waste management. Section 3 discusses the government investment that has been made to improve waste management. Section 4 indicates the key stakeholders in waste management sector. Current waste management practices such as landfilling, incineration and recycling are covered in Section 5. Some examples of waste management campaigns are discussed in Section 6. Section 7 discusses the various challenges faced by the waste management sector in Malaysia. Some recommendations for improving waste management in Malaysia are summarised in Section 8.

2.0 SOLID WASTE MANAGEMENT POLICIES & TARGETS

2.1 Legislation and Policies

In the Local Government Act of 1976 (Act 171), it is stated that local authorities and the state government are responsible for solid waste management (SWM) services and public cleansing (Alias et al., 2018). Under this act, the federal government only creates policies and finances facilities, equipment and waste collection vehicles based on applications from local authorities (Yahaya and Larsen, 2010). However, in the regions where financial resources and human capital are insufficient, deterioration of the environment surrounding landfill sites as well as poor SWM service quality led to rising public criticism (Yahaya and Larsen, 2010).

In response, the federal government began the process of improving the coordination and efficiency of SWM in 1995. This involved two main actions: (1) federalising SWM through the enactment of Act 672; and (2) privatising household waste collection and transport to reduce financial pressure on the local authorities. The goal of privatising SWM was to standardise and integrate SWM practices, thereby improving the quality and efficiency of waste management services provision (Yahaya and Larsen, 2010).

In 1997, solid waste collection and transportation services in 44 of the 144 local authorities in Peninsular Malaysia were replaced by two government appointed waste management corporations, also referred to as concessionaires, namely the Alam Flora Sdn. Bhd. in the central region (Pahang, Kuala Lumpur, Putrajaya), and Southern Waste Management Sdn. Bhd. in the southern region (Negeri Sembilan, Melaka, Johor). Local authorities in the northern region, Sabah and Sarawak continued to claim responsibility for SWM services.

Unfortunately, the federal government did not have the executive authority over SWM in Malaysia back in 1998. Thus, the concessionaires could not enter a long-term agreement with the federal government. The government then established an interim period whereby concessionaires and local authorities had to enter agreements on a yearly basis. During this interim period, the local authorities paid concessionaires the same amount as they had previously spent on SWM services. Additionally, each consortium was required to develop their own technologies and methods to account for rising levels of MSW (Sakawi, 2011).

The draft bill to transfer the executive authority from local authorities to the federal government was prepared in 1998. Unfortunately, the bill was not tabled to Parliament, resulting in the continuation of the interim period for 9 years. The prolonged interim period caused high uncertainty among the concessionaires, affecting their ability to secure funding from financial institutions and make long-term plans. This ultimately had a negative impact on the quality of the concessionaires' services. Moreover, the situation was further exacerbated by some local authorities defaulting in their payments to the concessionaires due to insufficient funds. Inadequate payments from local authorities and the lack of access to funding resulted in the concessionaires claiming losses. In their efforts to limit negative impacts on SWM services, the Federal Government agreed to grant 3 to 6 months of payment in default to local authorities with an annual income of less than RM 5 million (Yahaya and Larsen, 2010).

When the bill was finalised in 2006, it was no longer solely about enabling privatisation. Pressure on the government to monitor waste disposal and the services provided by concessionaires had grown during the interim period due to poor SWM services and illegal dumping. Thus, a new dedicated department for SWM was established and the National Committee on Solid Waste Management and Environment was formed (Yahaya and Larsen, 2010).

In 2007, Act 672 (The Solid Waste and Public Cleansing Management Act) was finally passed by the Parliament. It was decided that the interim period must end, and full privatisation in the central and southern region was to occur as soon as Act 672 was enforced. The interim period was extended for a year in the northern region to give the concessionaires time for necessary preparations. Act 672 came into enforcement in September 2011 in 6 states (Perlis, Kedah, Pahang, Negeri Sembilan, Melaka, Johor) and 2 federal territories (i.e. Kuala Lumpur and Putrajaya), while the others remain under Act 171 (Ng and Iacovidou, 2020). It is implemented by 2 federal institutes: The National Solid Waste Management Department and the Solid Waste and Public Cleansing Management Corporation (SWCorp).

Policies, strategies and action plans are developed by the National Solid Waste Management Department. Standards, specifications and codes of practices are also set by this department, as well as plans for SWM facilities (Sreenivasan et al., 2012; Mohamad Taha, 2016). In 2008, there were 23 staff employed, with a plan to increase the number to 71 when the department is fully established. On the other hand, SWCorp is a body corporate established by Act 673, also known as the Solid Waste and Public Cleansing Management Corporation Act 2007. It is responsible for implementing the solid waste and public cleansing laws, regulations, policies and strategies. Furthermore,

it also aims to improve SWM services as well as public awareness and participation in SWM (Mohamad Taha, 2016). This was to be achieved by establishing recycling banks in schools, drive-through programmes and public awareness exhibitions.

Act 672 transferred the executive authority on solid waste management and public cleansing within Peninsular Malaysia and Labuan from the local authorities to the federal government (Yahaya and Larsen, 2010). This allowed the federal government to issue licenses that authorise persons or corporations (also referred to as concessionaires) to manage and operate SWM or public cleansing services. Thus, the full privatisation of SWM was enabled and the interim period ended. This was done with 3 corporations for states where the act was implemented: E-Idaman Sdn. Bhd. in the northern region (Kedah, Perlis); Alam Flora Sdn. Bhd. in the central region (Pahang, Kuala Lumpur, Putrajaya); and Southern Waste Management Sdn. Bhd. in the southern region (Negeri Sembilan, Melaka, Johor). The quality of service in these states have notably improved compared to states where the Act 672 is not enforced (Tan, 2018). These SWM services include separation, storage, collection, transportation, transfer, processing, recycling, treatment and disposal of controlled solid waste (Sreenivasan et al., 2012). The roles of local authorities are limited to powers delegated by the Federal Government, and staff from local authorities were given the option to join the concessionaires (Sreenivasan et al., 2012; Zainu and Songip, 2017).

The act aims to regulate SWM and public cleansing (Yahaya and Larsen, 2010). Under the act, solid waste separation at source was made mandatory in September 2015. As a result of this, around 4740 tonnes of recyclables were collected from the 6 states and 2 federal territories in 2015-2017 (Alias et al., 2018). In order to ensure the quality of services, the payments to service providers for the collection, transportation, transfer, recovery, treatment, or disposal were based on key performance indicators. New waste bins and collection vehicles were also provided (Mohamad Taha, 2016).

Under Act 672, Jabatan Pengurusan Sisa Pepejal Negara (JPSPN) is able to perform the following (MHLG, 2015):

Develop a plan for waste recovery	Construct SWM facilities that focus on waste pre-treatment before disposal and extraction of recyclable matter
Set guidelines for licensing extraction, recycling and pre-treatment services	Provide licenses for operators to extract and pre-treat wastes

However, there are claims that Act 672 has not been enforced by SWCorp effectively, particularly with regards to littering and household waste segregation (Tan, 2018). Additionally, SWCorp has failed to boost public awareness of SWM and public cleansing services. Its duties also overlap with that of JPSPN.

2.2 National SWM Initiatives

Figure 3 shows a timeline of the SWM initiatives from the early 1990s to 2015.

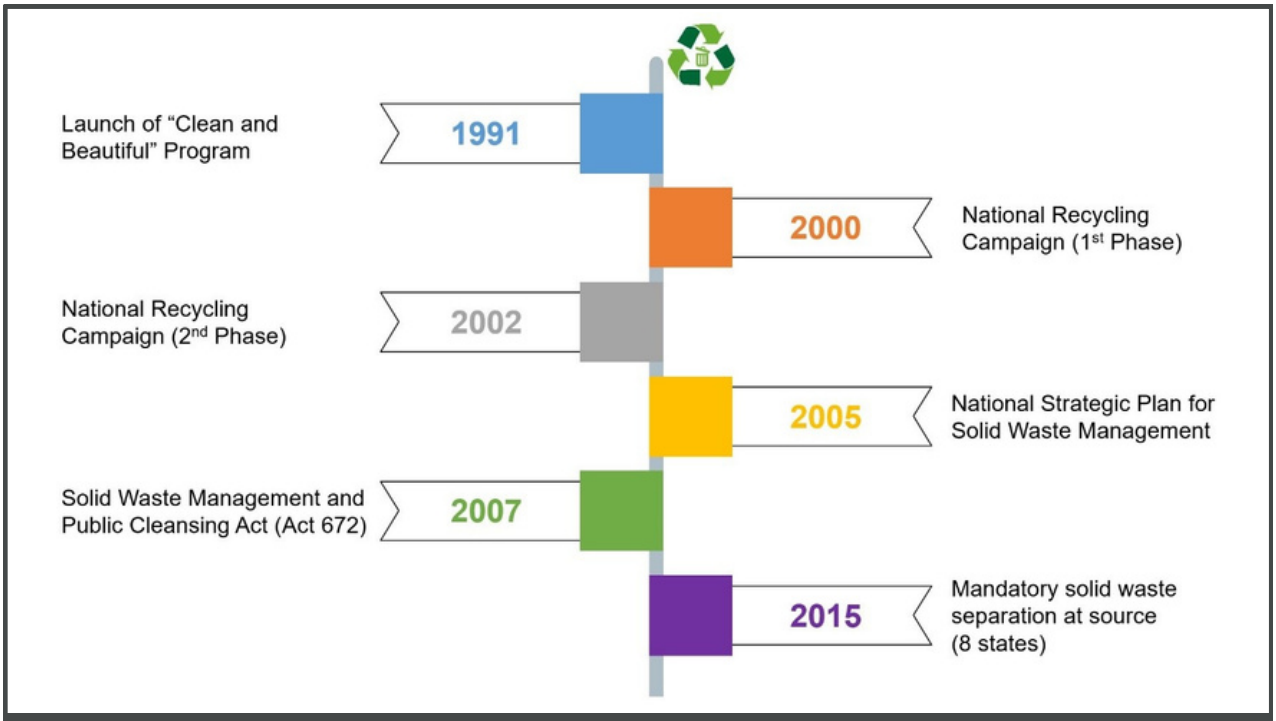

Figure 3: Timeline of national solid waste management policy and campaign.

2.2.1 National Strategic Plan and Master Plans

In addition to Act 672, Malaysia has also implemented numerous other plans and strategies for tackling SWM challenges. For instance, the National Strategic Plan for SWM (2005) was created to serve as a guide for solid waste policy planning and resource allocation depending on national priorities. It provided a framework for the SWM legislation master plan, National Waste Minimisation master plan, and the SWM facilities master plan (Abas and Wee, 2016). Its key strategy involves employing the appropriate technologies and facilities to achieve sustainable SWM through reduction, re-use and recycling. Under this plan, a target recycling rate of 22% by 2020 was set (Alias et al., 2018). To achieve this, 6 steps were proposed (Abas and Wee, 2016):

i. Determine and set SWM priorities (reduce, reuse, recover, disposal);
ii. Develop the waste reduction, reuse and recovery aspects of SWM, ensuring full participation from all main stakeholders;
iii. Develop the required legal and institutional framework through adoption of the SWM services privatisation policy;
iv. Improve public participation in SWM;
v. Implement the necessary technologies for SWM;
vi. Develop a socially accepted SWM system that meets current requirements, minimises social inequality and allows for full cost recovery by the year 2020.

Although Malaysia has policies for construction waste management, construction practitioners rarely adhere to them (Tey et al., 2013). As a result, the government agency, Construction Industry Development Board (CIDB), was established to monitor and improve the construction industry's environmental performance. A Construction Industry Master Plan was created to increase awareness of sustainability in the construction sector. The CIDB also governs the Pembinaan Malaysia Act of 1994, which aims for the reduction of pollution generated by construction and demolition waste. Furthermore, the government has established standard specifications for Building Works. These are governed by the Ministry of Works and aim to ensure that garbage and construction clearance is performed twice a week and is sent to a landfill.

2.2.2 Malaysia Plans

As of 2023, Malaysia has developed 12 four-year-long national plans known collectively as the "Malaysia Plan". These plans present steps that the country must take to become a fully developed nation. Policy goals for sustainable waste management have first been introduced in the 8th Malaysia Plan (2001-2005) to promote 'waste minimisation', 'promotion of reuse', and 'implementation of pilot recycling projects' (Zainu and Songip, 2017). In 2001, the 3Rs (reduce, reuse and recycling) were relaunched by the Ministry of Housing and Local Government (MHLG). The 8th Malaysia Plan also saw local authorities introducing several initiatives and charges to incentivise the reduction of household waste generated (Sreenivasan et al., 2012).

The 9th Malaysia Plan (2006-2010) aimed to establish sustainable and integrated SWM based on waste management hierarchy. It highlighted the importance of reducing, reusing, recovering and recycling waste along with increased usage of environmentally friendly products (Zainu and Songip, 2017). Through this plan, the National Solid Waste Management Department was set up under the MHLG. All matters related to MSW management were placed under the jurisdiction of this department. Several types of waste treatment facilities (i.e. thermal treatment plants, waste transfer stations and waste-to-energy (WtE) facilities) were identified as potential methods of MSW management to be adopted in the future (Zainu and Songip, 2017). The National Strategic Plan for SWM (from 2005) was implemented under the 9th Malaysia Plan. Furthermore, unsanitary landfills were upgraded and new sanitary landfills were built, along with transfer stations with integrated material recovery facilities.

The 10th Malaysia Plan (2011-2015) involved the adoption of waste recycling as a long-term strategy for municipal waste management. In collaboration with Universiti Teknologi Malaysia, the Ministry of Natural Resources and Environment developed an Environmental Performance Index in order to track environmental performance of each state (Sreenivasan et al., 2012). This plan also included the construction of a WtE plant in Negeri Sembilan that had completion plans for 2018 (Zainu and Songip, 2017). built alongside their transfer station networks.

The 11th Malaysia Plan (2016-2020) established further SWM targets and action plans (MHLG, 2015). The plan mentioned goals of 40% waste diversion from landfills and a 22% recycling rate. To support these goals, 17 open dumpsites were to be safely closed by 2020 and sufficient facilities built to accommodate for the waste diverted. Furthermore, 23 integrated sanitary landfills were to be

The 12th Malaysia Plan (2021-2025) emphasises the need of transitioning from a linear to a circular economy. The plan includes aspirations for introducing integrated waste management facilities, controlling waste imports and exports, minimising single-use plastics and packaging materials. A 40% recycling rate target by 2025 has been set (Ministry of Economy, 2021).

2.2.3 Action Plan for a Beautiful and Clean Malaysia

In 1988, the Action Plan for a Beautiful and Clean Malaysia (also known as the ABC Plan) was prepared by MHLG, serving as the national plan for MSW. This included a roadmap for SWM development under local authorities. Although MHLG had launched recycling programmes, the plan was never fully authorised or implemented. Despite the ABC plan was not officially endorsed by the national council of local government, many points considered within the plan were adopted in the National Strategic Plan on Solid Waste Management (Abas and Wee, 2016).

The ABC plan emphasises the importance of regional SWM and that MSW should be regarded as a resource and that recycling efforts and material recovery should be prioritised over landfilling and incineration (Sreenivasan et al., 2012). Furthermore, the plan states that producers, distributors and consumers of consumer goods should all actively reduce the generation of solid waste. Additionally, SWM services should involve user charges or other methods to achieve self-financing.

Although the ABC plan required all city and municipal councils to launch recycling programmes, few recycling activities were organised. The first launch of the recycling campaign was the "Clean and Beautiful Programme" in Shah Alam in 1991. The relaunch (1st phase) in 2000, known as the National Recycling Campaign, involved 29 local authorities but still resulted in poor recycling rates. This was due to poor management and planning of the programme, lack of policy, public awareness and participation from relevant stakeholders. The second relaunch in 2002 saw the involvement of 95 local authorities.

3.0 GOVERNMENT EXPENDITURE & BUDGET

The government spent on average RM 0.06 to deal with per kg of waste generated (Samsudin and Mat Don, 2013). As of 2018, SWM costs RM 148/t/d. Around 40-80% of local authority expenditure stemmed from SWM and public cleansing costs (Alias et al., 2018), whilst around two-thirds of total assessment fees collected by local councils was spent on the collection and disposal of solid waste. On average, the capital expenditure of a new landfill is more than RM 30 million, and its operating expenditure around RM 35/t (Zainu and Songip, 2017). The privatisation of waste management services has costed the government upwards of RM300 million and is projected to continue to rise (Zainu and Songip, 2017). This is due to the increased adoption of Act 672 by a larger number of areas requiring SWM and public cleansing services. Thus, SWM costs borne by the federal government have risen. According to MHLG (2015), 61% of the total SWM and public cleansing costs are paid by the federal government, with the remainder paid by local authorities (Alias et al., 2018). This is because many local authorities cannot afford the high costs of implementing SWM systems (Zainu and Songip, 2017). Alias et al. (2018) pointed out that the discrepancies of actual costs of SWM can be as high as 2.5 times compared to the allocated budget (e.g. RM 3018 million compared to RM1241 million in 2017). The three main sources of funding for MSW are municipal taxation, service fees and government subsidies. Municipal taxation is essential for funding MSW services as service fees do not cover the costs of the collection and transfer operations.

4.0 MAJOR STAKEHOLDERS IN SOLID WASTE MANAGEMENT

Stakeholders in the SWM sector include the Department of National Solid Waste Management, SWCorp, the Prime Minister Department (for the privatisation of SWM facilities and services) and the Ministry of Finance (for budget allocation). Other ministries indirectly involved include the Ministry of Health and the Ministry of Sciences, Technology and Environment. Furthermore, state governments are responsible for guiding local authorities in improving their MSW management, both institutionally and financially.

Some projects involving both authorities and other stakeholders have been listed below (Borongan and Okumura, 2010):

Bukit Tagar Sanitary Landfill, Selangor	Pulau Burong Sanitary Landfill and Ampang Jajar Transfer Station
Partnership between the Federal Government and a private operator.	Partnerships between local authorities and a private operator.
Seelong Sanitary Landfill and Taruka Transfer Station, Johor	Resource Recovery Centre/Refuse Derived Fuel - Waste to Energy (RRC/RDF-WtE) Plant, Selangor
Partnership between the Federal Government and an interim company.	Partnership between a local authority and a private operator.

5.0 CURRENT PRACTICES

5.1 Landfill

Landfilling is the most common method of MSW disposal in Malaysia. Due to its low cost, landfills take up around 89% of total solid waste produced (MHLG, 2015). In particular, open-dumping has the lowest costs and can handle waste consisting of high proportions of organic components. It is estimated that around 65% of waste disposed in landfills are recyclable waste materials (Samsudin and Mat Don, 2013).

In 1988, there were 230 official dumping sites in Malaysia, with 49 being landfills (Sakawi, 2011). There are currently 141 operational landfills and 182 closed landfills in Malaysia (MHLG, 2021). Of the 141 operational landfills, only 21 (15%) are sanitary landfills whilst the remaining are open dumpsites. Table 2 presents the distribution of these landfills across the states of Malaysia.

Table 2: Distribution of operating and closed landfills across states in Malaysia (MHLG, 2021).

State	Operating	Closed
Johor	8	29
Kedah	4	11
Kelantan	10	10
Melaka	1	7
Negeri Sembilan	3	16
Pahang	10	22
Perak	16	15
Perlis	1	2
Pulau Pinang	2	4
Sabah	22	20
Sarawak	46	15
Selangor	8	12
Terengganu	9	9
Wilayah Persekutuan	1	10
Total	***141***	***182***

5.2 Incineration

Incineration is the second most widely used method of waste management in Malaysia (Zainu and Songip, 2017). As national policy dictates that all clinical waste must be incinerated, incineration is widely used to manage all clinical and hazardous waste (Samsudin and Mat Don, 2013). Currently, there are 5 regional medical waste incinerators with capacities from 200 to 500 kg/h and 7 smaller incinerators with capacities of 20 to 50 kg/h. These incinerators are all built on the site of waste generation to minimise handling processes and human exposure.

Malaysia's first WtE plant – Kajang Municipal Council WtE facility converts MSW into refuse-derived fuel and subsequently used for electricity generation via an integrated steam power plant. The plant has a capacity of 1000 tonne/day of MSW and generates 8 MW of electricity per day, managed by Core Competencies Sdn. Bhd. and Recycle Energy Sdn. Bhd. (Neville, 2010). There are 4 small scale incinerators located in Langkawi (at a capacity of 100 tonne/day operated by Drizzle Engineering Sdn. Bhd.), Tioman (at a capacity of 15 tonne/day operated by Drizzle Engineering Sdn. Bhd.), Pangkor (at a capacity of 20 tonne/day operated by DRB-Hicom Environmental Services) and Cameron Highlands (at a capacity of 40 tonne/day operated by DRB-Hicom Environmental Services) (MHLG, 2021).

MSW is challenging to dispose of via incineration due to its high moisture content. Accurate projections of future waste volumes and characteristics are essential to the success of incineration plants.

5.3 Integrated Waste Management Facility

Material recovery facilities for separating MSW into individual components such as papers, metals and glass are uncommon in Malaysia. The Kota Kinabalu City Hall material recovery facility in Sabah is the only facility that exists. It processes around 800 tonne/day of waste and is managed by Borneo Waste Industries Sdn. Bhd. (http://www.borneowasteindustries.com/iwmpp-project.html). Nevertheless, there are a number of plastics recycling facilities established in Malaysia. An exhaustive list can be found here https://www.enfrecycling.com/directory/plastic-mrf/Malaysia.

The only integrated hazardous waste management facility in Malaysia is located in Negeri Sembilan. Owned and operated by Kualiti Alam Sdn. Bhd., the facilities include incineration, solidification, physical and chemical treatment, clinical waste treatment and a secured landfill. The facility is capable of processing >100,000 tonne/year of all classes of hazardous wastes (Cenviro, 2023). There are plans for increasing the number of integrated waste treatment facilities in Malaysia in view of meeting the target of 40% recycling rate in 2025 under the 12th Malaysia Plan (Ministry of Economy, 2021). The Government has thus extended the Green Technology incentives to 31st December 2023 as set out in the Budget 2020 (Thadani

and Singh, 2023). It must be emphasised, that this target seems ambitions considering the global average waste recycling rate is 13.5% and 9% for East Asia and Pacific. By income, the average recycling rates are: 29% for high-income countries, 4% for upper-middle income countries, 6% for lower-middle income countries, and 3.7% for low-income countries (World Bank, 2018).

5.4 Recycling Practices

There are two main types of collection centres for recycling: buy-back centres and kerbside collection centres. At buy-back centres, people sell their separated recyclables and are either paid directly or indirectly (through a reduction in waste collection). There are 599 buy-back centres in Malaysia, and they are typically found in convenient locations like supermarkets or shopping centres. On the other hand, kerbside collection centres are set up and operated by local authorities, non-governmental organisations (NGOs), concessionaires or other private organisations. The recyclables that have been separated at source need only be transported to the kerb, leading to much higher participation rates than buy-back centres (Alias et al., 2018). Kerbside collection is recognised as an effective way to minimise recycling costs and time. Collected recyclables are then sold to recycling factories or to companies that export the recyclables overseas.

Figure 4 presents the recyclable waste that is collected at source from households and through 3R programmes. The recyclable waste collected via the 3R programmes are from kindergartens, schools, government offices, communities, industries and higher education institutions. It should be noted that the quantity of recyclable waste collected only represents the data from the states where Act 672 is implemented. The figure shows that the recycling practices in these states improved over the years 2018-2021 and the recyclable waste collected tripled during that period. This increase emerges from the recycling programmes.

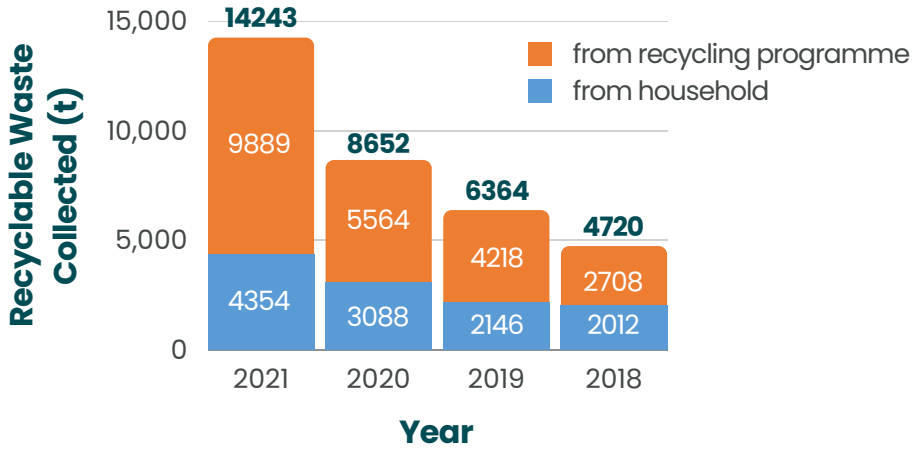

Figure 4: Recyclable waste collected from household and through recycling programme (MHLG, 2018; 2019; 2020, 2021).

5.5 Public Attitudes

Malaysian public are generally not aware of the importance of the 3R concept. This was clearly demonstrated during a Penang recycling campaign in 2001, where 40-60% of recycling bins were filled with non-recyclables (Samsudin and Mat Don, 2013). The low awareness of SWM stems from the fact that households do not pay separate charges for the collection and disposal of waste generated but the payment is made thorugh joint billing with property tax (Tan, 2018). Without adequate appreciation of the consequences of their consumption patterns and the cost of the SWM services, the mindset of the public is that SWM is completely under the responsibility of local authorities.

Although the general public often do not see the linkages, waste management directly impacts a broad range of environmental, social and economic issues including climate change, health, environment, economy, resource efficiency and food security. Addressing waste management, therefore, helps to promote a number of SDGs including: SDG 2 (End hunger and achieve food security), SDG 3 (Good health), SDG 8 (Decent work and economic growth), SDG 11 (Sustainable cities and communities), SDG 12 (Responsible consumption and production), SDG 13 (Climate action), and SDG 15 (Life on land) (UNEP, 2015).

In fact, MSW is one of the major sources of methane emissions accounting for 11% of the global emissions (Global Methane Initiative, 2012). Also, CO_2 emissions from waste treatment and disposal is estimated to account for 5% of the global emissions in 2016 (World Bank, 2018). Food loss and waste alone is estimated to account for 8-10% of greenhouse gas emissions (UNEP, 2021). Furthermore, public health and the environment are directly impacted by the pollution from waste that are not properly collected or treated, which can cost to society through lost productivity, health care, and negative impact to business and tourism (UNEP, 2015). The recovery from such negative impacts can take a long time and the costs to society and economy can be 5-10 times of what sound waste management would cost per capita (UNEP, 2015).

Therefore, it is vital to promote public awareness of the interlinkages between waste management and environmental issues so that the public are aware of the long-term consequences of their decisions and behaviours. Engaging the public through advocacy and educational programmes should be an on-going effort for Malaysia to successfully implement sustainable waste management and promote resource efficiency towards the circular economy.

6.0 SUSTAINABLE WASTE MANAGEMENT CAMPAIGNS

6.1 Roadmap Towards Zero Single-Use Plastics

Malaysia is a sizable player in the global plastic industry. With around 1300 plastic manufacturers, environmental issues stemming from plastic waste have worsened to the point where the country now ranks 8th in the mismanagement of plastic waste. One study estimates that up to 0.37 million tonnes of mismanaged plastic waste in Malaysia may have entered the ocean (United Nations ESCAP, 2020). The Ministry of Energy, Science, Technology, Environment & Climate Change (MESTECC) in Malaysia has thus prepared a roadmap for addressing single-use plastic pollution. This 3-phase plan is being implemented during 2018-2030 and includes specific action points as well as the stakeholders responsible (e.g. MHLG, federal government, state governments, NGOs, business operators, manufacturers, suppliers and the general public) (MESTECC, 2018). With the UN Environment Assembly resolution adopted in February 2022 to develop an internationally binding instrument to end plastic pollution, there is greater urgency for Malaysia to further implement comprehensive plastic waste management through life-cycle approach.

6.2 Universiti Malaya Zero Waste Campaign

The Zero Waste Campaign of Universiti Malaya was initiated to establish sustainable waste management practices within the university campus. Its outlined objectives included increasing the rates and efficiencies of recycling activities, developing policy and systems for energy recovery, anaerobic digestion (AD) and composting of organic waste, and improving awareness and practices of waste separation at source. The campaign also developed a roadmap with goals for diversion of waste from landfills: 15% by 2020, 30% by 2030 and 60% by 2040. So far, first target in 2020 has been achieved (Yusoff, 2018).

This campaign involved various initiatives. For example, food waste (constituting 40% of Universiti Malaya's total waste) was collected with cooperation from Universiti Malaya café operators. 4-5 tonnes of degradable organic waste was processed monthly via the Takakura composting method. Of this, 90% was food waste and 10% green waste. Furthermore, an AD facility was installed in 2013, converting 1 tonne/month of food waste into biogas and bio-fertiliser.

A used clothes collection programme (in collaboration with Life Line Clothing) in 2014 resulted in the collection of more than 20 tonnes of waste clothes and textiles. Additionally, an automated recycling centre, known as the Intelligent Recycle Centre, was established in 2017 to promote the practice of source separated waste recycling through small financial and material incentives. In partnership with TSP Waste Management Sdn. Bhd., the campaign also successfully implemented a wood waste collection system for energy recovery. This system had around 5 tonne/month of capacity in its first month. In total, 700 tonnes of waste was diverted towards recycling and treatment between the years 2013-2017 (Yusoff, 2018).

6.3 Penang Sustainable Waste Efforts

In Penang, food waste processors producing agricultural fertilisers can be found in markets, schools, the Bukit Jawi Golf Resort and the Penang Girl Guides Association (Khor, 2015). Penang Methodist Girls' School has been running an environmental programme since 2002. This involves recycling, electrical and electronic equipment waste collection, energy saving practices, as well as campaigns to reduce the use of plastic bags (Borongan and Okumura, 2010).

7.0 CHALLENGES

Malaysia's waste management system is hurdled by a broad range of challenges. Firstly, there is a severe lack of environmental awareness in both the general public as well as within the industrial sector. A survey by SWCorp in 2012 indicated that 68% of respondents participated in household waste separation (GSR Environmental Consultancy, 2012). The survey also showed that financial incentive is the main motivation of practicing household recycling. Within the industrial sectors, many industry players are still unaware of the importance of SWM and how to use the waste management 3R hierarchy (prioritising in the order of waste reduction, treatment and final disposal). This situation has not changed despite the introduction of waste management policies (Tey et al., 2013). This low level of awareness is coupled with increasing rates of waste generation (Borongan and Okumura, 2010).

Secondly, there is lack of funds and market competition that could attract waste management companies. Sustainable waste management tends to incur high costs for the government and industry with no sufficient economic returns to effectively implement it. This is further exacerbated by the lack of funds allocated by the government towards solid waste management which has to compete for funding with other priorities such as education, healthcare, and other utilities. Few of the planned recycling facilities were approved by the government due to insufficient funds and manpower (Alias et al., 2018). Easy collection and high value have been the two main drivers of Malaysia's recycling industry. As a result, only waste such as transparent polyethylene terephthalate (PET) plastic bottles are recycled in large volumes, while other waste materials like food packaging are rarely recycled due to their low value nature, contamination and the lack of viable business options with economies of scale (MESTECC, 2018). It is worth highlighting that biodegradable alternatives to petrochemical-based plastics are of higher cost, hence they have not yet become the mainstream option for packaging applications.

Many of these issues can be traced back to the lack of systemic and effective waste management legislation and regulations (Ng and Iacovidou, 2020). For instance, the recycling market is highly unregulated, operating as a grey market. Most recycled waste is collected informally, i.e. by scavengers in landfills (Alias et al., 2018). Although the informal sector provides useful function that is often not performed by the formal waste management sector, informal recycling practice is inefficient and can negatively interfere with the waste management systems (OECD, 2016). The low level

of formal recycling collection, in turn, results in the poor quality of recycling data as informal recycling centres are not registered with local authorities. Furthermore, waste management practices and policies across states are inconsistent. Only 6 states and 2 federal territories have implemented Act 672 whilst the states of Selangor, Penang and Perak have decided against privatising their solid waste collection and public cleansing services. Meanwhile, Sabah and Sarawak have implemented their own SWM and public cleansing regulations. Ineffective legislation and the lack of technical expertise needed for SWM planning and operation within government institutions have led to poorly defined functions of agencies and their poor coordination.

Despite its lack of treatment infrastructure, Malaysia increased its imports of plastic waste following China's ban in 2018 (Lee, 2019). Consequently, illegal dumping and open-air burning of these plastic wastes have intensified to a degree that is now damaging the country's ecosystems. A temporary import ban on plastic waste in October of 2018 was imposed due to new political reform, which evolved into a permanent ban on plastic scrap. However, there is uncertainty regarding the official definition of plastic scrap. Malaysia has declared its intention to stop plastic waste imports completely over the next three years and shut down 114 illegal plastic waste recycling facilities in 2019. Figure 5 illustrates the trend of plastic waste imported into the country that has been approved from 2015 to 2019 (MHLG, 2018; 2019).

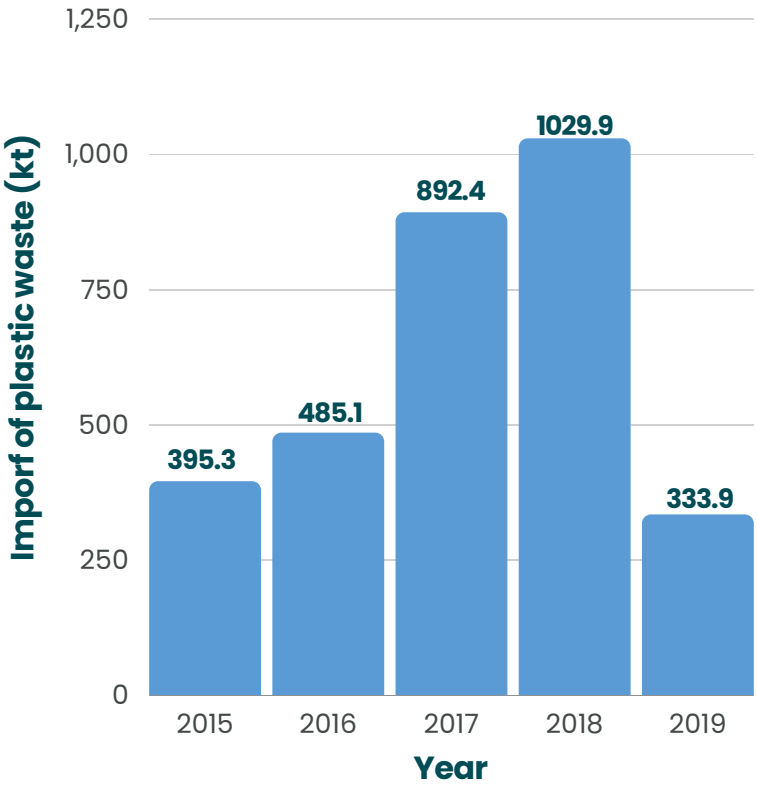

Figure 5: Approved plastic waste imports from 2015 to 2019, Tariff code 3915 (MHLG, 2018; 2019).

8.0 CONCLUSIONS & RECOMMENDATIONS

This report provides a comprehensive review of the status quo in waste management practices in Malaysia, including: policies, initiatives and investment that promote sustainable waste management; major stakeholders; current waste management practices such as landfilling, incineration and recycling; waste management campaigns and challenges faced by the waste management sector in Malaysia.

Sustainable waste management requires a systemic approach in minimising waste through prevention, reuse, recycling, recovery and disposal. Increasing public awareness on the importance of sustainable waste management and its linkages to environmental, social, and economic impacts should be of the highest priority so that the informed decision can be made at the governmental and industrial level. Waste minimisation should be prioritised and engrained in the actions and attitudes of the government, industry, as well as society.

Governmental bodies must ensure that SWM services (either provided directly or via contractors) must include the separation of wastes. Manufacturers are responsible for minimising product packaging, producing and promoting recyclable and environmentally sustainable products, and making recycling systems accessible to consumers. Additionally, they should take responsibility for the entire product life cycle and implement the 'cradle-to-cradle' concept in their manufacturing processes through extended producer responsibility (EPR) systems. When introducing EPR system, effective integration of the informal sector is a key component to avoid the leakage of recyclable resources that could undermine the system. The integration, however, needs to be through a gradual, inclusive approach providing the people in the sector with a constructive role supported by safeguards within the appropriate legal and regulatory frameworks. Finally, the public should apply the 3Rs rule (Reduce, Reuse, Recycle) and be conscious of the environmental impact of the products they use.

Furthermore, investment in the MSW management infrastructure must be increased to upgrade the service. For instance, increasing accessibility and convenience of recycling and waste management facilities could improve the recycling rates of household waste. Introducing waste-to-energy facilities will enable the treatment of residual waste stream. Source-segregated organic waste such as food waste and garden waste needs to be treated by anaerobic digestion and composting. Additionally, alternative waste management technologies such as advanced thermal technologies (e.g. pyrolysis and gasification) can be considered.

Regulations and incentives for sustainable waste management must be improved through appropriate regulatory and economic policy instruments. For example, a revision of landfill tipping fees may be necessary to generate sufficient resources for sustainable landfill practices. Furthermore, incentives can be used to compensate for the higher costs of waste minimisation through economic instruments such as landfill tax or volume-based pricing models that encourage waste reduction. Additionally, comprehensive nationwide MSW data collection and analysis are vital for future planning of infrastructure and policy and thus must be improved. Furthermore, the official recycling rate must reflect the actual amount of recycled materials without including the amount of potentially recyclable waste.

Finally, federalisation of SWM should be implemented nationwide. This would involve transferring the MSW management responsibilities of all local authorities to an integrated MSW management system managed by the federal government. Alongside this, human capital (expertise, skills and knowledge) within the solid waste management industry must be improved by relevant capacity building and training programmes.

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