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Environmental Policy for Waste Management in Taiwan: Regulatory Measures, Implementation Status, and Challenges

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Abstract: Municipal solid waste (MSW) management in Taiwan provides a valuable case study for Asian regions experiencing similar patterns of economic growth, urbanisation, and consumption. Over the past few decades, Taiwan has made substantial progress in addressing its waste management challenges. Through the implementation of comprehensive waste management policies and recycling programmes, the MSW recycling rate increased markedly from 12.7% in 2001 to 58.8% in 2020. Taiwan was also among the early adopters of policies aimed at reducing plastic consumption, including the introduction of charges on single-use plastic bags. Restrictions on plastic bag use at retail establishments contributed to an estimated reduction of approximately 200 million single-use plastic bags annually. Despite this progress, significant challenges remain. Taiwan continues to consume approximately 15 billion single-use plastic bags annually, equivalent to around 3.9 times the consumption in the European Union. Other emerging concerns include the increasing use of paper containers, declining recycling rates for food waste, and persistent difficulties in reducing plastic waste, particularly in traditional markets. These challenges highlight the importance of strengthening both public awareness and environmentally responsible behaviour. Environmental programmes, such as strategically located recycling bins and designated waste collection points, could help reduce the gap between environmental awareness and actual behaviour. In addition, eco-campaigns incorporating economic incentives, such as discounts or rewards for using reusable beverage cups, could encourage more sustainable consumption practices. Together, these measures could further strengthen Taiwan's transition towards a more circular and sustainable MSW management system.

Keyword: Waste Management; Legal Framework; Plastic Waste; Taiwan

1.0 Introduction

As a consequence of population growth and rapid urbanization, the generation of waste is increasing drastically and municipal solid waste (MSW) management has become a challenging task in many countries (Karim et al., 2020; Chen, 2018; Hannan et al., 2015). In Asia, the amount of generated MSW is estimated to reach 1.5 billion tons by 2030 and 1.9 billion tons by 2050 (Kaza et al., 2018). However, MSW management remains a low priority in many Asian cities compared with the investments into other sectors, such as infrastructure and transport (Hondo et al., 2020). As Hoornweg and Bhada (2012) indicate, “solid waste is usually one service that falls completely within the local government’s purview. A city that cannot effectively manage its waste is rarely able to manage more complex services such as health, education, or transportation.” Accurate and effective MSW management can improve public health, conserve natural resources, reduce environmental impacts, and contribute to reducing greenhouse gas (GHG) emissions. In addition, waste management is important for sustainable development in both developing and developed countries. Without effective MSW management, there is little possibility of achieving the related Sustainable Development Goals (SDGs) such as SDG 3 (good health and well-being), SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), SDG 13 (climate action), and SDG 14 (life below water) (Hondo et al., 2020).

In recent years, microplastic pollution or marine debris is also one of the most pressing global environmental issues and has attracted considerable attention and public concern worldwide (Barrett et al., 2020; Peixoto et al., 2019; Sharma and Chatterjee, 2017). Plastic waste has become one of the most prevalent ocean pollution problems, with plastic waste constituting over 60% of marine debris. Furthermore, the presence of microplastics within the food chain poses a serious threat to food safety and is a public health concern (Barboza et al., 2020). Several initiatives have been undertaken worldwide to prevent plastic pollution, and over 70 countries have a full or partial ban on single-use plastic bags (UNEP, 2018). However, the impact of the COVID-19 pandemic on plastic waste has been notable due to the increased use of plastic for packaging within e-commerce shopping and food take-outs (Parashar and Hait, 2021). In the United States, there was a 78% increase in online shopping and food services during the COVID-19 pandemic in 2020, while countries such as South Korea, China, and Singapore saw a similar trend, with an increase of more than 50% (Shams et al, 2021; Parashar and Hait, 2021). Furthermore, approximately 3.4 billion single-use face masks or face shields worldwide are discarded daily (Benson et al., 2021). Hence, developing and implementing relevant policies and measurements are vital to combat plastic pollution during and even after the COVID-19 pandemic (Costa, 2021).

MSW management in Taiwan represents an important case study, especially for Asian regions with similar growth trajectories. Taiwan has overcome serious waste management problems over the past few decades. As with many developing countries, Taiwan had one of the world’s worst urban waste problems and some media reports referred to Taiwan as “Garbage Island” in the 1970s–1980s. Today, Taiwan has the second-highest effective waste recycling rate, following Germany (Eunomia, 2018). To ensure proper waste management, Taiwan has implemented a very specific waste collection system since 1998 and started to improve resource recycling, including plastic and food waste, in the 2000s. Furthermore, Taiwan is one of the first areas to initiate a plastic bag charge to restrict the use of plastic products. As a result of a series of waste measures, the recycling rate of MSW between 2001 and 2021 increased from 12.7 to 58.8 percent, and the number of single-use plastic bags consumed was reduced by 200 million annually after banning plastic bags at retail establishments (Taiwan Environmental Protection Administration (EPA), 2018). However, plastic bag consumption and the plastic composition of garbage are high. Taiwan consumes approximately 15 billion single-use plastic bags annually, which is 3.9 times higher than the number consumed by the EU. To further reduce plastic waste, the EPA has expanded restrictions on single-use plastic products since 2018, and Taiwan aims to reach a complete ban on all plastic bags, disposable cups, utensils, and straws by 2030.

In this study, we reviewed the strategies and regulatory measures for managing waste in Taiwan and discuss barriers to the elimination of single-use plastics in Taiwan. This study provides a comprehensive review of Taiwan’s current MSW management situation and the future perspectives related to the application of a “zero single-use plastics” frameworks by 2030. The discussion and results of this study

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are divided into four sections. Section 1 provides a comprehensive overview of Taiwan's MSW management, including a comparative status of MSW generation and composition among several selected countries, particularly Asian countries. Section 2 discusses regulatory measures and policies for MSW management in Taiwan. Section 3 focuses on policies aimed at reducing the use of plastic products in Taiwan. Finally, Section 4 presents our conclusions and recommendations.

2.0 Materials and Methodology

2.1 Descriptions of the Study Area

Taiwan is a small and densely populated island with a population of over 23 million and an average population density of 650.9 people/km2 in 2020 (MOI, 2021). Taiwan has experienced rapid industrialization and high economic growth since the 1980s (see Figure 1). From 1955 to 2000, Taiwan's GDP per capita growth rate was among the highest in the world, with an average growth rate of 6.82%. In contrast, the growth rates of the U.K. and U.S. were 2.49% and 2.45%, respectively (Wu, 2016). Underpinned by this rapid economic development, the quantity of MSW generated has climbed dramatically, and the average daily production of MSW per capita in Taiwan increased from 0.63 kg in 1981 to 1.14 kg in 1997. The average annual growth rate of MSW generation is over 4.78% (Lu, 2006). In the early 1970s, there was a complete lack of planning for the correct disposal of the large amounts of MSW produced by urban populations. Households disposed of their garbage through unsafe methods, such as open dumping and burning, and unsanitary landfilling. To properly manage MSW, the Taiwanese government began to improve waste management systems and enacted Taiwan's Waste Disposal Act in 1974. According to the Waste Disposal Act of Taiwan, general waste is defined as waste generated by non-industrial sectors that is collected and administered by local government agencies.

Figure 2 shows the total amount of MSW generated and the trend in disposal methods. Until the 1990s, landfills were the primary means to dispose of waste in Taiwan, with over 90% of the generated waste being disposed of in landfills. The proportion of MSW disposed by incineration accelerated after the 2000s. In 2020, there were 24 incineration plants and 11,776 garbage trucks in Taiwan (EPA, 2021).

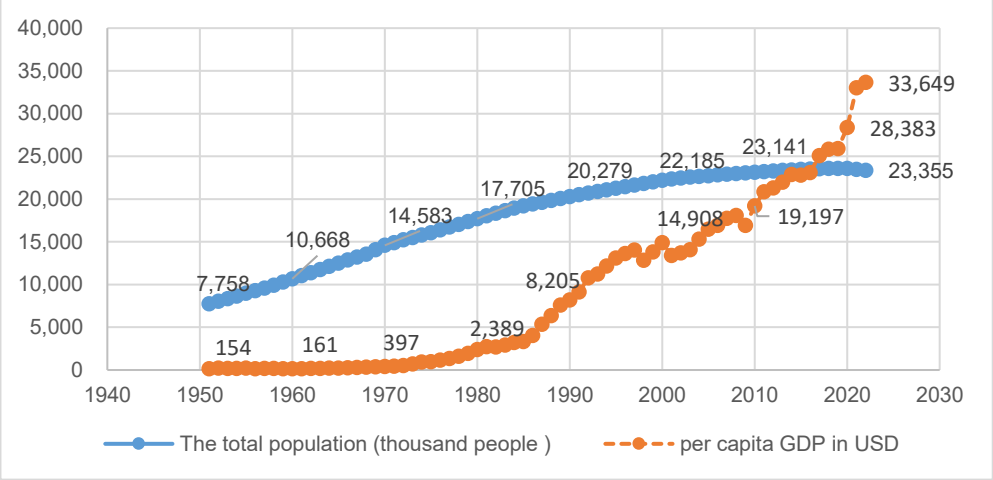


Figure 1: Taiwan's population and GDP/capita in USD. Source: MOI (2021)

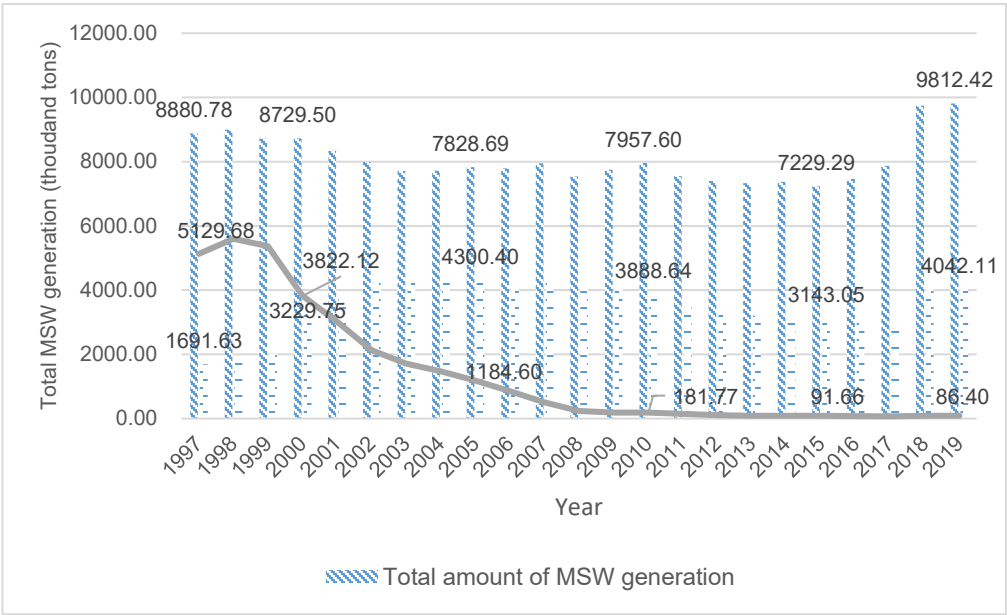


Figure 2: Amount of MSW generation and disposal methods. Source: EPA (2021)

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2.2 Data mining

In this study, updated data on the statistics and status of MSW management in Taiwan were obtained from the official yearbook, the Solid Waste Statistics (EPA), and a literature review, which was utilized to systematize the fragmentary knowledge and provide the latest information about regulatory measures on MSW and the results of its implementation in Taiwan. A comparative status of MSW generation and composition among several selected countries is also discussed based on a literature review and important reports of international organizations. In addition, an analysis of the implementation of plastic and food waste management in Taiwan is provided.

3.0 Results and Discussion

3.1 The current MSW situation in Taiwan

As described above, Taiwan had serious urban waste problems, as some media reports referred to Taiwan as "Garbage Island" in the 1970s–1980s. During this period, Taiwan lacked safe and proper MSW management systems to correctly dispose of the large amounts of MSW generated. Today, Taiwan has the second-highest effective waste recycling rate, following Germany (Eunomia, 2018). Figure 3 shows the trends of the MSW disposal and recycling rates in Taiwan. Taiwan's MSW recycling rate has exceeded 50% since 2010. A review of the relationship between GDP per capita and MSW generation rate in several selected countries reveals that Japan, Korea, and Taiwan have a similar tendency, while Malaysia, Indonesia, and Thailand may be classified into the same group (see Figure 4). In addition, evidence from Taiwan has shown that aggressive waste management can disrupt the correlation that exists between GDP and waste generation. Taiwan's per capita waste generation dropped from 1.09 to 0.94 kg between 2000 and 2017, despite an 83 percent increase in real GDP in the same period (EPA, 2021; Federal Reserve Economic Data (FRED), 2021). The composition of the MSW in Taiwan is presented in Table 1; paper, food, and garden waste comprised the highest proportion. A comparison of the composition of MSW in Taiwan with MSW compositions in other countries is also shown in Table 1. The results indicate that the contribution of plastics in Taiwan was higher than that in other countries. To reduce these wastes, Taiwan has implemented a series of waste polices since 2002, as described in the next section.

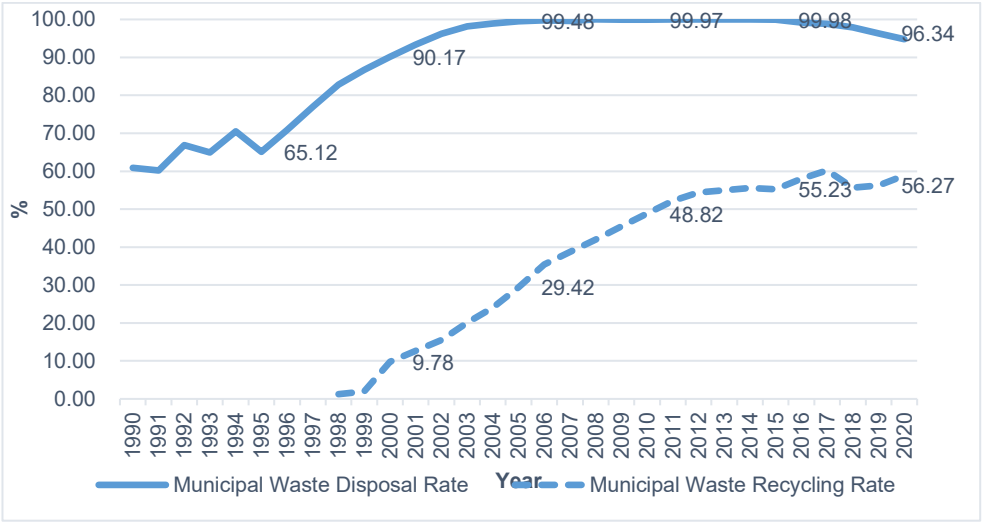


Figure 3: MSW disposal rate and MSW recycling rate of Taiwan. Source: EPA (2021)

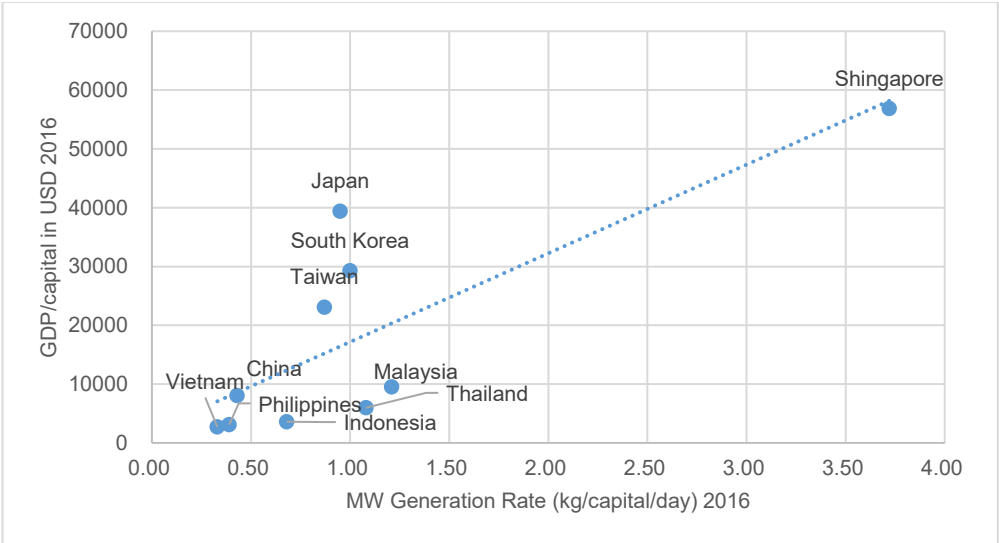


Figure 4: Relationship between GDP per capita and MSW generation rate, 2016.

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Source: MOI (2021); EPA (2021); Kaza et al. (2018)

Table 1: Comparison of the MSW composition in Taiwan and other countries

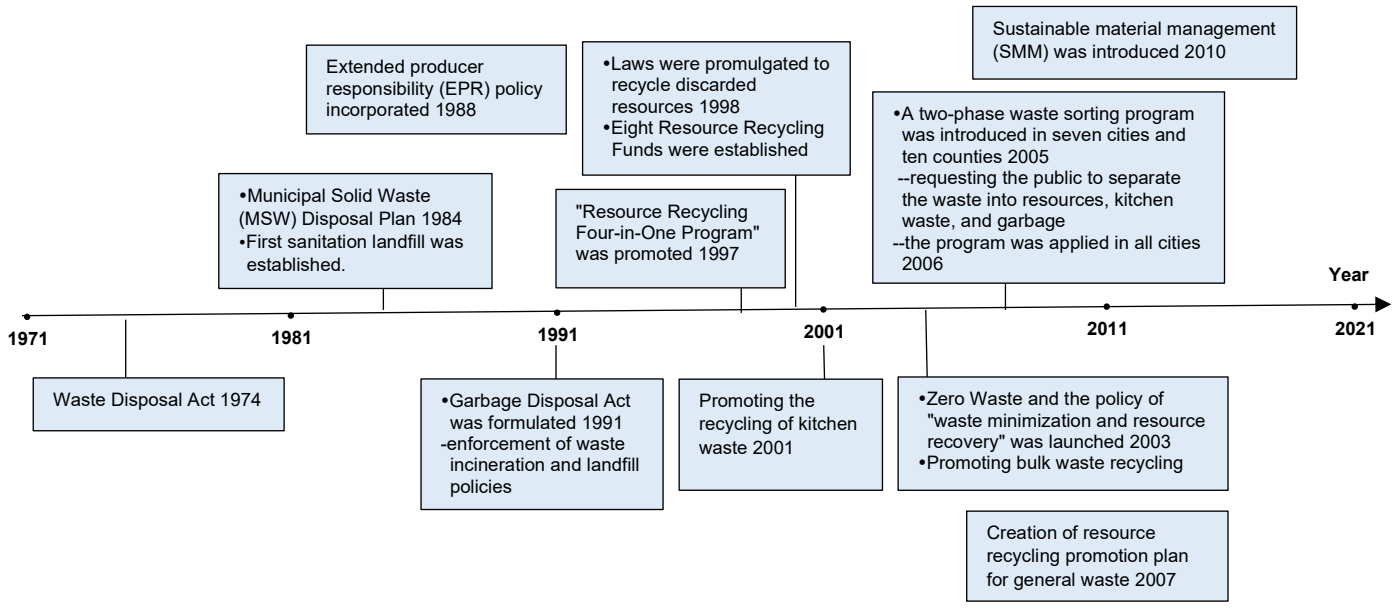
	Year	Paper	Organic matter	Plastic	Glass	Metals	Wood	Textiles and others	References
USA	2015	25.9	28.3	13.1	4.4	9.1	6.2	12.8	USEPA (2018)
Japan	2015	32.8	36.1	10.5	4.8	3.8	4.4	7.6	MOEJ (2015)
Korean	2000	26.0	25.0	7.0	4.0	9.0	N.A	29.0	Shekdar (2009)
Malaysia	2005	16.0	44.8	15.0	3.0	3.3	N.A	17.9	Periathamby et al. (2009)
Taiwan	2018-2019	37.6	33.0	18.3	0.9	0.7	N.A	7.8	EPA (2020)

3.2 MSW management in Taiwan

Figure 5 shows the MSW management strategy in Taiwan. Taiwan's Waste Disposal Act was enacted in 1974, and the Municipal Waste Disposal Plan was formulated in 1984 to manage waste disposal effectively. Source minimization and resource recovery are two major concepts for waste disposal. Since 1990, the MSW policy has been transformed from landfill disposal to incineration with proper garbage sorting. Simultaneously, the initial MSW recycling program "Resource Recycling 4-in-1 Program" was promoted in 1997, which includes the public community, local government agencies, recycling enterprises, and recycling funds. The budget costs of recycling, clearance, and disposal fees were collected from manufacturers and importers to establish a recycling fund. This recycling fund is used to support the recycling disposal system and extend the producer responsibility (EPR). This recycling system also provides economic incentives to encourage the development of recycling and reuse industries. These regulations and implementations comprise the recycling system in Taiwan (EPA, 2021). In 2020, 96.9% of the waste was properly disposed, and the resource recovery rate (including resources, kitchen waste, and bulk waste) reached 58.8% (EPA, 2021). In addition, the amount of waste generated per capita per day was less than 1 kg in 2000, while the amount in other OECD countries exceeded 1 kg (Lu, 2006).

Owing to effective waste management, Taiwan's achievements in reducing and recycling MSW have been remarkable. Simultaneously, Taiwan can report accurate waste generation data, indicating a well-managed waste collection, transportation, and storage system. However, a review of the composition of MSW in Taiwan shows that the contribution of plastics was higher than that in other countries (Table 1). In addition, organic matter (food and garden waste) comprised the largest portion. To promote recycling and reduction of plastic and food waste, Taiwan has implemented a series of policies to reduce single-use plastic products since the 2000s. Although the number of single-use plastic bags consumed was reduced by 200 million annually after banning plastic bags at retail establishments, the plastic composition of the garbage slightly increased in recent years, and plastic bag consumption remained high. Taiwan consumes approximately 15 billion single-use plastic bags annually. To keep pace with the global trends of reduction in plastic waste, the Taiwanese government has expanded restrictions on single-use plastic products since 2018. Taiwan aims to achieve a complete ban on all plastic bags, disposable cups, utensils, and straws by 2030. To achieve this goal, measures and support for the traditional market, food, and beverage businesses will be key factors, as described in Section 3.3.

For food waste management, the central government has developed recycling systems for food waste from general and industrial waste and provided subsidies for local governments to establish their food waste collection programs (Tsai, 2020). Taiwan has a specific waste collection system for general waste. Yellow garbage trucks visit garbage pickup spots and take garbage directly from citizens. Every garbage truck has a set of bins used to collect recyclable materials, such as raw and cooked food waste. This waste collection system allows the food waste generated by households to be collected and recycled. According to official statistics, the amount of food waste was 168,601 tons in 2003 compared to 834,541 tons in 2012. The raw food waste was utilized as fertilizer for farmers, and cooked food waste was used as food for farm animals, such as pig feed (EPA, 2021). However, the amount of collected food waste has indicated that a decreasing trend exists due to the limitation of the composting treatment capacity and collection systems in some cities and the lack of economic incentives for recycling enterprises (Figure 6).



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Figure 5: Taiwan roadmap towards sustainable MSW management
Source: EPA (2022), Lai and Lee (2021), Wu et al. (2021), Tsai (2021)

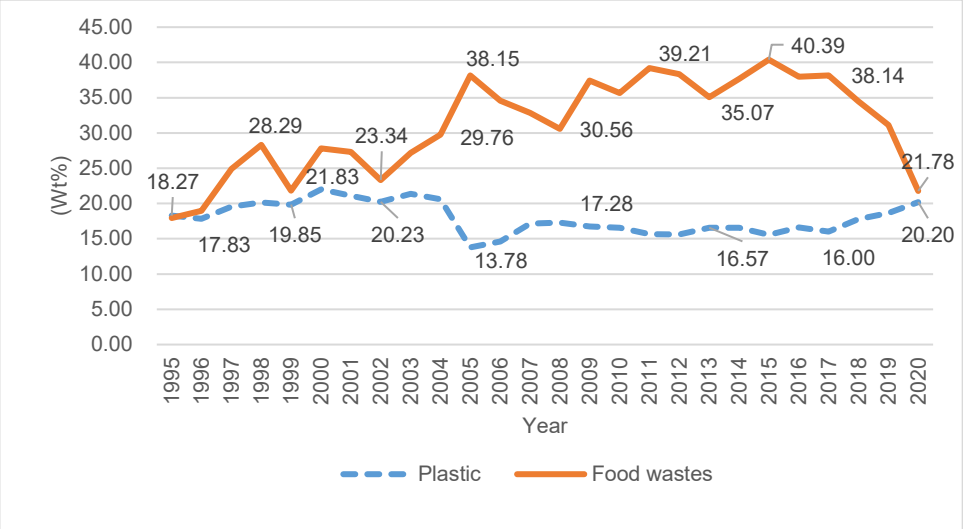


Figure 6: Plastic and food waste composition in the garbage
Source: EPA (2021)

In summary, MSW management in Taiwan can be divided into three phases. Before 1990, over 90% of garbage was disposed of in landfills and there were no specific measures or policies on MSW reduction or recycling (the first phase of MSW management). From 1991 to 1998, the MSW method was transformed from landfill disposal to incineration, and an initial waste recycling policy was implemented (second phase, the first step of MSW recycling). The daily per capita amount of MSW generated increased dramatically during this period in accordance with rapid economic growth. After 1998, MSW generation began to decrease and regulatory measures for plastic waste and food waste were implemented. In addition, modification of the EPR is involved in the MSW recycling system (Lu, 2006). This provides economic incentives to encourage the development of recycling and reuse industries.

3.3 Regulatory Measures and Plans for Restriction on the Uses of Plastic Products

As described above, the Taiwanese government has implemented several regulatory measures and plans to reduce and recycle plastic waste since 1998. The following measures have been implemented to support these efforts:

(1) Resource recycling system: As described in Section 3.2, the Resource Recycling 4-in-1 Program is one of the most important waste policies for implementing Taiwan's recycling system. The roles of residents, local governments, recycling companies, and recycling funds were clearly defined. Citizens should take the responsibility of garbage separations, while local governments should properly manage waste collection and disposal systems. Recycling enterprises should encourage development of private recycling industry and purchase recyclable waste from communities and governments; responsible producers should pay the fees for recycling as a Recycling Fund. Additionally, since 2005, the EPA has promoted a two-phase waste sorting program that requests citizens to separate waste into resources, kitchen waste, and garbage. In the first phase, the program was conducted in seven cities and ten counties, and in the second phase, the program was applied to all cities in 2006 (EPA, 2021). Taiwan's specific waste collection system for general waste also facilitates the collection of resource waste, including regulated recyclable plastic containers. Figure 7 summarizes the quantities of recycled paper and plastic containers between 1998 and 2020. The number of recycled plastic containers has increased steadily in recent years, and the number of recycled paper containers in 2020 was over 400% that in 2018. The increasing number of online shopping and food deliveries during the COVID-19 pandemic was the main reason for the large numbers of recycled paper containers and cutlery.

(2) Restriction on the use of single-use plastic products: Since 2002, a two-phase approach that restricted the use of plastic shopping bags and plastic products was promoted (Figure 8). In the first phase, the EPA requested governmental agencies, public and private schools, government-run enterprises, and public hospitals to stop providing plastic shopping bags and disposable plastic tableware. The targets in the second phase were department stores, shopping malls, supermarkets, convenience stores, restaurants, and food and beverage stores with a shop front. The main enforcement method was to restrict targets from offering free plastic bags, and consumers must pay 1–3 Taiwan dollars (US$ 0.034–0.1) for each plastic bag. Furthermore, the thickness of the charged plastic shopping bags was restricted to less than 0.06 mm to encourage consumers to reuse plastic bags for future shopping trips (Tsai, 2021). However, according to an official survey, the reduction rate of the number of plastic shopping bags in restaurants and food and beverage stores with a shop front was 33%, and the reduction rate of the quantities of plastic bags was -74% (EPA, 2005). To solve this unexpected issue, the Taiwanese government revised the regulations to cancel the restrictions on the thickness of the charged plastic bags in 2017.

As described earlier, as a result of this measure, the consumption of single-use plastic bags was reduced by 200 million annually after plastic bags were banned at retail establishments. However, plastic bag consumption is still higher than that in other countries, such as the EU. The main reason is that the restricted targets do not include fresh markets and diners such as traditional markets, night markets, and food stands. In 2022, Taiwan had 1,195 markets (including traditional and night markets), and many plastic bags were consumed in these markets every day. Moreover, the plastic bags used for raw or cooked food are usually difficult to reuse owing to hygiene issues. The Taiwanese government implemented several measures to address this issue, such as the promotion of "green night markets" that use reusable tableware or set an eco-box for used plastic on of plastic and food waste, Taiwan has implemented a series of policies to reduce single-use plastic products since the 2000s. Although the number of single-use plastic bags consumed was reduced by 200 million annually after banning plastic bags at retail establishments, the plastic composition of the garbage slightly increased in recent years, and plastic bag consumption bags, which can be provided to the next consumer for free in traditional markets. To address the issue of increased online shopping packages or food delivery

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services (e.g., containers or plates), the EPA proposed a new approach designed to set pickup sites for consumers to return their used cutlery. This type of approach can encourage reuse or make recycling easier and overcome the awareness-behavior gap. The other programs/regulatory programs are shown in Figure 8.

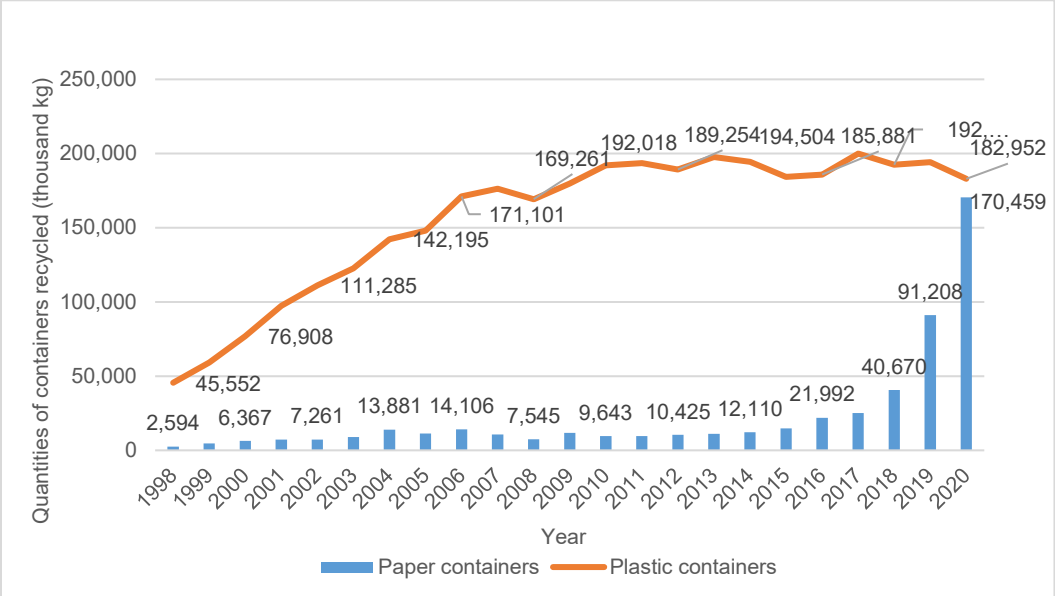


Figure 7: Quantities of paper and plastic containers recycled in Taiwan
Source: EPA (2021)

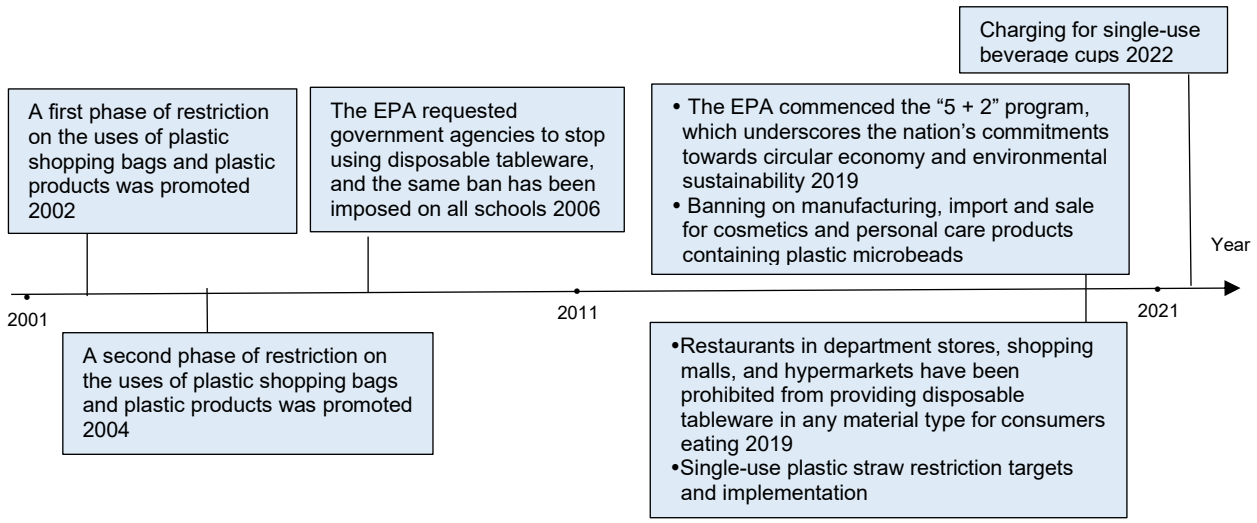


Figure 8: Taiwan roadmap towards reduction on the uses of single-use plastic products
Source: EPA (2022), Lai and Lee (2021), Wu et al. (2021), Tsai (2022)

4.0 Conclusion

Waste management in Taiwan has developed since the 1990s, and Taiwan's achievements in reducing and recycling MSW are remarkable. In addition, Taiwan can report accurate waste generation data, indicating a well-managed waste collection, transportation, and storage system. The reasons for this success can be considered as follows: (1) Taiwan has implemented appropriate and effective MSW systems in consideration of geographic conditions and cultural background; for example, the MSW method has been transformed from landfill disposal to incineration because of limited landfill space, and a specific waste collection system has been designed to fit citizens' lifestyles. The waste collection system also makes food waste recycling easier and encourages citizens to segregate their waste properly. (2) Taiwan has established a MSW management system with a clearly defined role among the central and local governments, recyclers and collectors, and community residents. Each stakeholder is involved or engaged in the management of MSW and understands their individual responsibilities. (3) With growing environmental awareness, an increasing number of companies and citizens are willing to cooperate with governments to deal with the challenges and issues surrounding waste management. For instance, the government has implemented strategies for phasing out single-use cups since July 2022. This includes supermarkets, convenience stores, restaurants, and food and beverage stores offering reusable

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cups for free and providing a five Taiwan-dollar (USD $0.164) discount to customers who bring their own cups. Based on the results of several online surveys conducted by food companies and Yahoo online surveys, more than 70 percent of the respondents were willing to support this policy. This policy aims to enhance public awareness and behavior changes to reduce the use of single-use plastic or paper products, and thus contribute to accomplishing the relevant SDGs. Changing the awareness of each individual will become the driving force behind changes in the world. However, there are still some issues in waste management that remain to be resolved. The increasing number of paper containers, declining recycling rate of food waste, and issues related to the reduction of plastic waste, especially in traditional markets, remain important challenges. Conducting environmental programs such as the setting of recycling boxes or pick-up sites could help overcome the awareness-behavior gap. In addition, the promotion of eco-campaigns that incorporate economic incentives, such as reusable beverage cups, could be adopted.

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Conflicts of Interest The authors declare no conflict of interest.

Ethics Statement: Ethical approval was not required as the study involved no human participants or identifiable personal data.

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