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Sustainable Waste Management in Urban Area

- A Case Study of the Waste Management of the Cities in China

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Abstract: As urbanisation continues to accelerate, the integration of regional waste treatment capacity is becoming increasingly important and challenging nowadays, as economic development imbalances and environmental problems are becoming more prominent. An important component of urban development is the generation and management of municipal solid waste , and due to differences in socio-economic status, China's world-class metropolises such as Shanghai and medium-sized cities such as Xiamen are facing the same problem. This study attempts to explore the possibilities and prospects for sustainable waste management in China's future by comparing Xiamen with Shanghai, using relevant structural models and relevant research data within the city and the region. The introduction of the concept of waste-free cities also provides a greater diversity of options for future programmes. Finding effective strategies based on China's socio-economic and cultural conditions has implications for developing countries such as China in promoting the shift from waste management to a circular economy.

Keywords: Municipal waste management, sustainable management, technological innovation, policy advice, social participation

1. Introduction

China, the world's largest developing country, has experienced dozens of years of rapid urban change and high-speed development, and urban waste has increased dramatically. Sanitation and management, the critical material supply system for cities, are becoming the focus of sustainable development [1]. The two main strategies for sanitation management are landfill and incineration, with a strong trend for the latter, which will account for 62.0 percent of the total in 2020 (Figure 1), while the proportion of landfill falls to 33.2 percent over the same period [2]. Landfill, composting, and incineration are the three standard waste disposal methods in domestic cities; improper treatment also accounts for a certain proportion.

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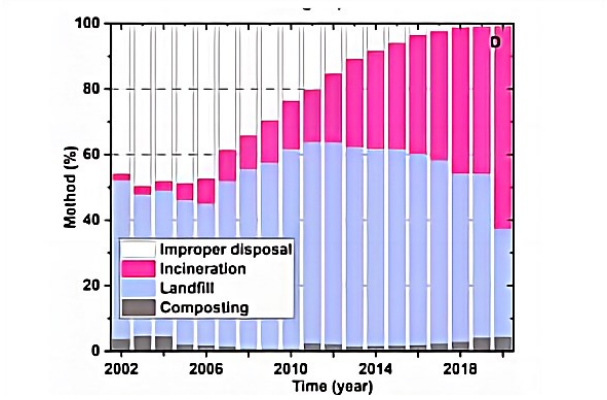

Figure 1: Proportion of MSW incinerated, landfilled, composted and improperly disposed of in China a from 2002 to 2020[2].

Landfill disposal is The primary solution to domestic waste discharge in most cities. Landfill disposal is a comprehensive solid waste management science and technology that moves away from the traditional simple stacking and filling. Landfill disposal has evolved from simple stacking, filling, and covering to engineered storage that encompasses, screens, and segregates[3].

Municipal waste is combustible and suitable for incineration. Harmful substances and pathogens are effectively eliminated during the high-temperature incineration process, while the heat generated can be used for power generation and heating. Waste incineration produces large quantities of acidic gases and incompletely burned organic components. Hence, the exhaust gas needs to be purified before discharge, and the waste residues must be disposed of safely.

Composting is an artificial fermentation process where microorganisms convert organic matter into fertilizer. It involves anaerobic (gas) and aerobic (gas) composting based on oxygen demand during fermentation. If waste is sorted, composting can be a key energy and resource utilization technique for municipal waste.

The circular economy is critical to sustainable urban development and waste management. Developing countries like ours need to look at socio-economic factors, study the spatial and temporal heterogeneity of waste generation and management, and share valuable insights. Local governments address the challenges of sustainable work management and develop comprehensive public participation strategies to address waste issues.

2. National solid waste generation and disposal status

2.1. Waste generation and classification

Municipal waste includes domestic waste, industrial solid waste, medical waste, drainage treatment sludge, construction waste, etc. 2018 data show that large and medium-sized cities in China produce a large amount of solid waste, such as 1.31 billion tonnes of industrial solid waste, 40.011 million tonnes of industrial hazardous waste, 781,000 tonnes of medical waste, and 201.944 million tonnes of domestic waste. The total volume and variety of these wastes are significant and increasing year by year. Although they are environmentally hazardous, they are also usable [4].

Wastes can be categorised as general and hazardous, and sources are classified as industrial and agricultural solid wastes [5]. Hazardous wastes are dangerous, toxic, etc., and threaten human life. Municipal waste includes domestic, construction, and commercial waste. Industrial solid wastes are mainly metallurgical, mining, light industry, petrochemical, and other wastes; agricultural solid wastes are animal excreta, crop residues, etc. [5].

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2.2. Waste Management Infrastructure

Solid waste management in China is led by the environmental protection department and local environmental protection departments, with the construction and sanitation departments dealing with domestic and construction waste and the environmental protection department responsible for assessment and statistics. Industrial solid and hazardous waste is handled by the Environmental Protection Department, which sets lists and standards, and by local governments, which build treatment facilities. Hazardous waste treatment companies must apply for a business licence from the environmental protection department. Multiple departments work together to ensure that waste is handled correctly and effectively utilised to prevent pollution.

2.3. Waste management policies and regulations

China's current management of industrial hazardous waste includes regulations, online monitoring, public participation, and environmental protection supervision, and these measures have achieved significant results in management and disposal, curbing illegal transfers, emissions, and disposal. Enterprises are focusing on standardised storage and disposal, strengthening the concept of the rule of law and investing resources in treatment. Local governments use new media to educate on science and legal awareness, raise public awareness of the hazards of hazardous waste and compliant disposal, establish a sound incentive mechanism for public supervision and reporting, broaden the channels for detecting environmental violations, and increase social participation so that the public becomes the main force in environmental protection supervision[6].

National laws include the Environmental Protection Law of the People's Republic of China etc.; administrative regulations include the Regulations on the Management of Urban Environmental Sanitation, etc.; industry regulations include the Provisions on the Management of Municipal Construction Waste, etc.; and environmental protection standards related to municipal domestic waste include the Standards for Municipal Domestic Waste Landfills, etc[6].

Table 1: Summary of Hazardous Waste Management Policies and Regulations[6].

Release time	Policies and regulations	Outline
2012.12	Technical Specifications for the Collection Storage and Transport of Hazardous Wastes	Establishes technical requirements for the collection, storage and transport of hazardous wastes by hazardous waste generators and operators
2017.05	Thirteenth Five-Year Plan for the Prevention and Control of Hazardous Waste Polluton	Clarify the objectives and tasks of China’s hazardous waste polluton prevention and control work in the next five years
2017.09	Guidelines for Environmental Impact Assessment of Hazardous Wastes in Construction Project	To further regulate the evaluation of the environmental impact of construction projects generating hazardous wastes,and to provide guidance to the competent authorities for environmental protection at all levels in carrying out the relevant examination and approval work
2019.10	Hazardous Wastes Landfill Pollution Control Standards	Technical requirements for the selection of hazardous waste landfill sites have been standardised, admission standards

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Table 1: (continued).

		for hazardous waste landfills and requirements for the control of hazardous waste landfill wastewater discharges have been tightened.
2019.11	Criteria for the Identification of Hazardous Wastes	Clarification of hazardous waste identification procedures and refinement of the rules for determining hazardous waste after mixing and use for disposal
2020.04	Law onPrevention and Control of Environmental Pollution by Soild Waste	Provide for hazardous waste management, collection, storage, transport and disposal requirements
2020.11	National List of Hazardous Waste	Specification of hazardous waste categories, industrial sources, waste codes and hazard characteristics
2020.12	Pollution Control Standards for Hazardous Waste Incineration	Provides for the sitingoperation, monitoring and ecoenvironmental protection of hazardous waste incineration facilities in the process of waste storage, compounding and incineration and disposal, as well as for implementation and monitormg

2.4. Analysis of the current status of waste management

China has preliminarily established a regulatory and institutional framework for resource utilisation, and has carried out pilot projects on solid waste resource utilisation in various regions. Despite some progress, it still faces many challenges, such as problems in the institutional system, classification and recycling system, recycling efficiency, normality, and resource utilisation system [7]. There needs to be more top-level design for complete life-cycle analysis, government financial guidance, market incentives, and punitive financial and tax systems [7]. In order to promote solid waste classification and resourcing and its industrial development and to realise the great rejuvenation of the Chinese dream, China needs to solve the above problems as soon as possible.

Table 2: Analysis of the benefits of solid waste resource utilisation in China [7].

Waste category	Name(of a thing)	2020	2030
Urban mine	Output/×108 t	50	80
	Recycling value of major renewable resources/trillion yuan	0.93	2.14
	Emission reduction of SO_2/×104 t	120	260
	Employed population/10,000 people	2 000	3 000
Rural waste	Output/×108 t	54	56
	Total amount of resource utilisation/×108 tce	8.43	9.93
	Investment stimulate/Trillion Yuan	3.37	3.97
	Emission reduction of SO_2/×108 t	22.51	26.51
	Emission reduction of SO_2/×104 t	170	200

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Table 2: (continued).

	Employed population/10,000 people	1 475	1 142
Industrial solid waste	Output/×108 t	35	30
	Comprehensive Utilisation Ratio	70%	80%
	Pulling investment/trillion yuan	1.08	1.35
	Employed population/10,000 people	200	150

3. Examples of sutainable waste management practices

3.1. Waste management cases in Shanghai and Xiamen

3.1.1. "Survey on the Current Status of Recyclables Recovery Patterns and Policies in the Context of "Double Carbon Suggestions: Taking Huangpu District of Shanghai as an Example

Under the background of "double carbon," the current recyclables recovery mode and policy suggestions in Huangpu District, Shanghai [8] are put forward. According to the Guiding Opinions on Accelerating the Establishment of a Green, Low-Carbon and Recycling-based Economic System issued by the State Council, it is required to strengthen the recycling of renewable resources and accelerate the construction of the recycling system of waste materials before the carbon dioxide emission peaks in 2030 and carbon neutrality is achieved in 2060 [8].

3.1.2. Xiamen Waste Management

Solid waste management in Xiamen covers industrial, medical, and domestic waste collection, treatment, and disposal. Socio-economic development has increased waste generation and discharge, and safe disposal is imminent.

3.2. Case Description

3.2.1. Waste Management Strategy for Huangpu District, Shanghai

Huangpu District has accelerated the construction of recyclables points and stations, expanded recycling channels throughout the district, and established four types of service points in residential districts and some commercial complexes. Huangpu District has formulated a policy to guarantee subsidy funds by the district finance, which is included in the annual special fund budget, regarding the standard of Shanghai's domestic waste disposal fee, mainly used to subsidise the market price of enterprises and the classification, recycling, transfer, disposal and other aspects of the reduction of domestic waste and resources to provide financial security [8].

3.2.2. Xiamen City Waste Management Strategy

Xiamen's waste management strategy includes building a waste-free city, upgrading treatment capacity, strengthening medical waste regulation, developing a waste-free Heron Island, and monitoring and evaluation. The strategic goal is to reduce, resource, and harmlessly manage waste and promote sustainable urban development.

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3.3. Case Description

3.3.1. Analysis and Discussion of the Shanghai Case

Ten streets in Huangpu District have recycling points and cooperate with enterprises to collect recyclables, including regular scheduling, telephone booking, and integrated mode. Most streets have one recycling transfer station; some have more than one. Five hundred fifty-six service points and 1 district transfer station were built in 2021, and professional companies were commissioned to operate them to improve efficiency [8].

Table 3: Basic situation of construction and recycling of recyclables transfer stations in Huangpu District[8].

Subdistrict	Situation at transit centres			Recyclables recovery
	Quantities	Area/m^2	Design ability/(t/d)	
R	1	150	20.00	Glass, clothing mainly, wood, foam generally not recycled
L	1	150	15.00	Glass mainly, foam, clothing in small quantites
H	1	150	25.00	Paper, glass, plastic mainly, foam secondly, clothing, wood to a lesser extent
W	1	15	0.50	Foam-based, small amounts of glass
N	2	230	9.00	Glass, foam mainly, clothing in small quantities
T	1	200	20.00	About 50 percent glass and the remaing 50 percent
Y	1	100	15.00	Paper, plastic, glass primarily, foam secondarily
D	2	212	4.42	Paper, foam mainly, plastic secondarily, clothing in small quantities
X	1	200	10.00	Glass, paper,plastic mainly, foam, clothing to a lesser extent
B	2	350	8.00	Glass, clothing, foam-based

Residents can send their recyclables to recyclers, smart cabinets, or service points, where they will be collected and transported by two-networked vehicles, sorted, baled, weighed, and then transported to collection and distribution yards, where they will then be statistically counted, managed and monitored, before finally arriving at the recycling centre for processing [8]. A community survey in Huangpu District showed that 64.54% of respondents had a strong awareness of waste classification and could classify it in detail; 28.29% of respondents were aware but did not classify it comprehensively, and a small number did not classify it [8].

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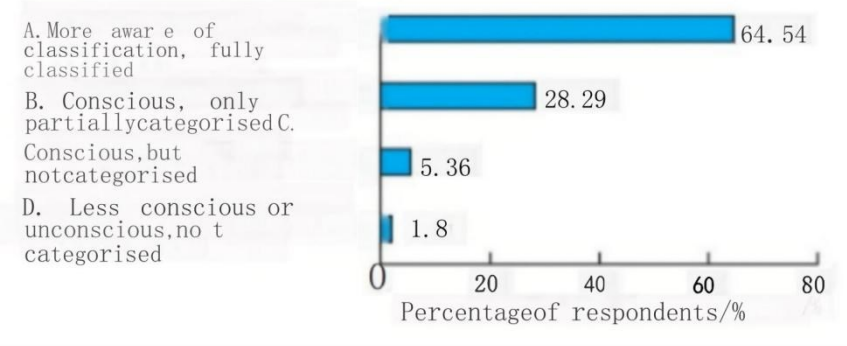

Figure 2: Awareness of Waste Separation among Community Residents in Huangpu District[8].

Figure 3 shows that the main way residents in Huangpu District dispose of recyclables is by separating them and putting them into recycling bins, followed by selling them to individual recyclers and giving them to cleaning and recycling personnel without compensation [8]. However, two years after implementing the Shanghai Municipal Domestic Waste Management Regulations, 35.35% of residents still neededneeded to separate and put out their recyclables according to the regulations. Figure 4 reveals the main reasons for the barriers to sorting, including unclear sorting standards, unreasonable drop-off times, time-consuming and laborious sorting, and inadequate facilities. 57.43% of the respondents needed clarification about the sorting standards, and 48.62% thought the drop-off times were unreasonable, e.g., they missed them because of work [8].

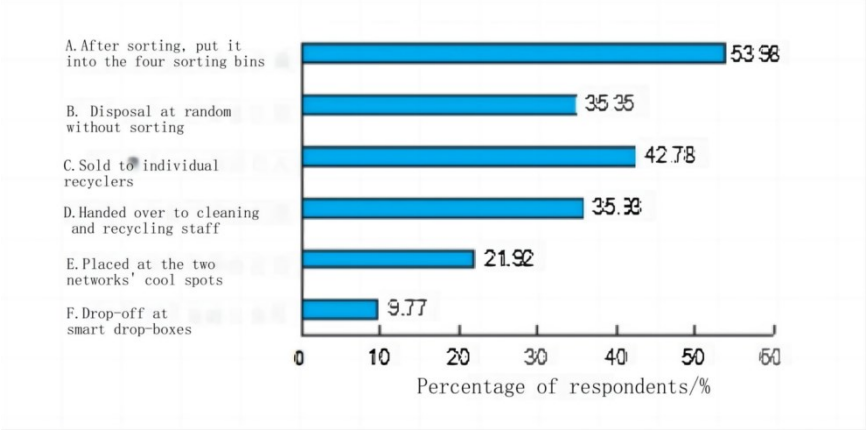

Figure 3: Disposal of recyclables by residents in Huangpu District[8].

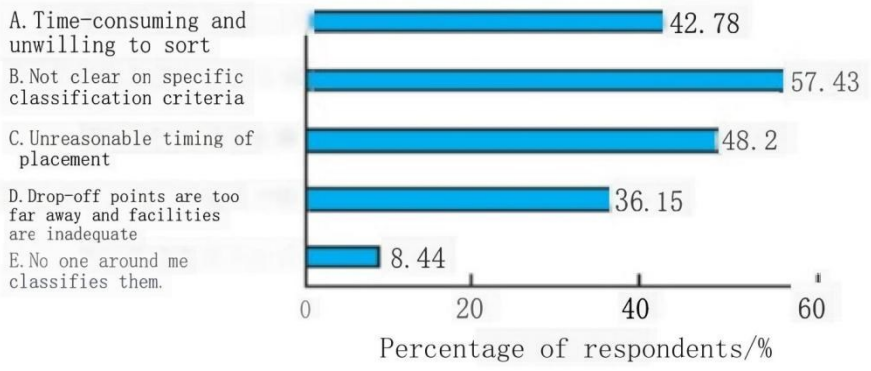

Figure 4: Main reasons cited by community residents in Huangpu District as barriers to sorting recyclables[8].

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3.3.2. Analysis and Discussion of the case of Xiamen

Hazardous wastes in Xiamen mainly come from industrial and medical sources, with industrial wastes dominated by waste-to-energy incineration, metal surface treatment, and the manufacture of electrical and electronic equipment [9]. Haicang District is the largest generator of industrial waste, followed by Xiang'an District and Huli District [9]. The amount of medical waste generated in the city is 3,395 tonnes, all handled by Xiamen Oasis Environmental Protection, with a treatment rate of 100%.

However, in Xiamen City, the treatment of solid waste facilities is insufficient, the amount of generation over the years, the existing facilities can not meet the demand, the lack of dedicated disposal landfill, industrial waste accumulation is severe, and even mixed with domestic rubbish, the formation of environmental safety hazards [9]. Solid waste management is weak, compared to water and air pollution, and needs to be paid more attention to; insufficient capacity of the management department, the regulatory system, and the market economy does not adapt. With increased domestic waste, harmless treatment occupies land resources and threatens the ecological environment. Existing technologies have environmental hazards, such as landfill leachate, gas (biogas) generated by the treatment of secondary pollutants [9], waste incineration, hazardous waste, medical waste incineration, secondary pollutants generated by the comprehensive utilisation of waste, the lack of effective countermeasures [9].

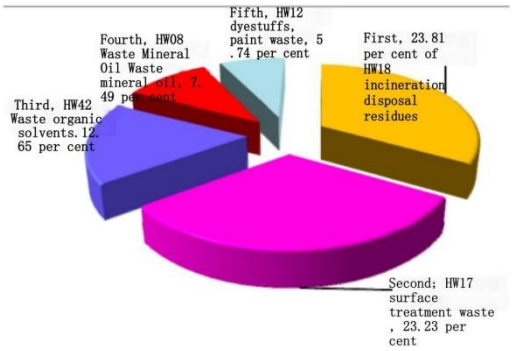

Figure 5: Composition of major industrial hazardous wastes in Xiamen[9].

3.4. Case Comparison

Shanghai's waste management attaches importance to source separation and reduction, with sound policies and regulations and effective treatment and utilisation. However, selecting sites for transfer facilities is challenging, and the facilities could be better. The atmosphere of public participation is intense, but the awareness of waste classification needs to be stronger, and the methods need to be standardised. The utilisation rate of intelligent recycling facilities is low, the management mechanism needs to be more sound, recycling points are few, the time is unreasonable, and the market is chaotic, affecting residents' participation. Low-value recyclables are challenging, market enthusiasm is low, and the recycling network system needs to be fixed.

Xiamen has achieved remarkable results in reducing domestic waste at source, resource utilization, and harmless treatment, with the city's domestic waste resource utilization rate rising from 43.2 percent to 82.27 percent and the harmless treatment rate reaching 100 percent. However, problems such as inadequate infrastructure, limited hazardous waste disposal capacity, and weak enforcement of laws and regulations still require attention and improvement.

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4. Sustainable waste management recommend ations

"Waste-free city" is an urban development concept that pursues the efficient use of resources and the reduction of waste generation, involving urban planning, infrastructure, production methods, and other aspects to achieve synergistic development of the economy, society, and the environment [10]. This concept originated from the early research and advocacy of environmentally sustainable development and circular economy and is the result of the joint efforts of experts, urban planners, and environmentalists. Globally, including China, more and more cities, organizations, and individuals are promoting the development of "waste-free cities" to achieve a sustainable urban future [10]. The concept is committed to environmental protection, promotes economic development and social progress, lays the foundation for building harmonious and livable cities, and advocates a beautiful vision of harmonious coexistence between human beings and nature.

4.1. Technological innovation

Science, technology, innovation, and development can make waste management and resource use more efficient, environmentally friendly, and sustainable by contributing to the achievement of "waste-free cities"[10]. Innovative science and technology solutions can help transform cities and promote sustainable economic development and environmental protection[10]. Below are the directions for science, technology, and innovation for waste-free cities.

4.1.1. Technological innovation in waste treatment

The realisation of a "waste-free city" requires continuous development and innovation of waste treatment technologies. Scientific and technological progress promotes the development of waste treatment technologies, such as waste classification and recycling, waste treatment and conversion, and waste resourcing [10]. The development of new technologies improves waste treatment efficiency, reduces waste generation, and lowers the environmental impact [10].

4.1.2. Innovation in circular economy models

New technological inventions help the circular economy. Information technology, the Internet of Things, and artificial intelligence enable waste tracking, monitoring, and management, promote waste recycling, and improve resource use efficiency [10]. At the same time, science, technology, and innovation promote sustainable product design and the development of circular economy.

4.2. Policy recommendations

4.2.1. Research and analysis

By collecting and analysing these data, precise analyses can be produced, leading to the formulation of targeted policies and regulations for better waste management and resource use[10].

4.2.2. Setting goals and targets

Setting clear goals and targets is critical to achieving a "waste-free city ."Governments should set specific waste reduction and recycling targets and renewable energy and energy transition targets[10]. These targets and indicators should be quantifiable and measurable to monitor progress and assess effectiveness.

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4.3. Social participation

Increase community participation and public awareness of environmental protection, motivate citizens to actively participate and take responsibility, and form a common motivation to achieve a "waste-free city ."Through publicity and education, to enhance public understanding and awareness of a "waste-free city" and to build a sustainable lifestyle and environmental culture [10]. The following are the directions for developing a "waste-free city" regarding community participation and awareness-raising.

4.3.1. Community education and awareness

Implementing community education and publicity programmes to raise residents' awareness and understanding of a "waste-free city"[10]. To educate and motivate residents to raise their awareness of environmental protection and participate in environmental protection actions by organising training courses on waste separation and resource utilization, organising environmental protection seminars, and showcasing examples of sustainable living.

4.3.2. Community participation mechanisms

Promote community participation in zero-waste urban practices by setting up waste management groups or environmental volunteer organisations to participate in waste separation, recycling and sustainable living. Community meetings are held to collect residents' opinions and suggestions and involve them in waste management decisions [10].

4.4. Directions for the development of "waste-free cities" in terms of economic incentives and market mechanisms

"Waste-free cities" achieve efficient and sustainable development through economic incentives and market mechanisms that motivate residents and enterprises to participate in waste management and resource utilisation [10]. It guides funds to relevant green economy projects and industries and promotes the sustainable development of the urban economy [10]. In this context, "waste-free cities" will welcome new development opportunities and move towards a greener, more environmentally friendly, sustainable future.

4.4.1. Creating economic incentives

Governments can promote the development of waste-free cities through economic incentives. For example, it can implement incremental and differential charging systems for waste disposal and promote waste separation and recycling among residents and enterprises [10]. In addition, governments can incentivise enterprises to invest in innovative waste treatment and resource utilisation technologies through financial subsidies, tax incentives, or rewards.

4.4.2. Development of waste trading markets

The government can stimulate the market value of waste by establishing a trading platform and formulating trading rules to promote waste reuse and recycling and realise enterprises' economic benefits [10].

5. Conclusion

The waste management cases of Shanghai and Xiamen illustrate the cities' initiatives to create waste-free cities. Innovative approaches and collaboration between government, business and the

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public have led to waste reduction, resource utilisation and non-hazardous waste. Shanghai emphasises planning and technological innovation, promoting green infrastructure, waste separation and circular economy, and developing innovative waste treatment technologies. Xiamen focuses on cross-sectoral collaboration and public participation, establishing coordination mechanisms, strengthening integrated planning and implementation, raising environmental awareness, and promoting corporate participation in green supply chain management. By combining these approaches, the two cities have reduced waste generation, improved resource efficiency, and contributed to sustainable development goals. Other cities can learn from these experiences.

The limitations of this thesis are mainly in the research methodology, perspective, and literature content. Literature review and case studies were used and lacked empirical evidence. In the future, a combination of quantitative and qualitative methods can be used to analyse urban waste management practices in depth and improve the reliability of the study. Focused on urban waste management and should have covered rural areas. Future research could expand the scope to include rural waste management. Literature citations are limited, and some need to be updated. Future research could increase the number of citations and focus on the latest research findings to improve the value of the paper. There are limitations in the research methodology, perspective and literature content, which could be improved and optimised for future research.

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