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How Indonesia's Cities Are Grappling with Plastic Waste: An Integrated Approach towards Sustainable Plastic Waste Management

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Abstract: In Indonesia, plastic constitutes the second largest component of municipal solid waste; however, 58% remains uncollected. Most plastic recycling depends on informal sectors, accounting for only 10% of the total, leaving the remainder to potentially harm the environment. This paper analyzes how cities in Indonesia have tackled their plastic waste problems from the perspective of the integrated sustainable waste management framework. This study focuses on plastic waste management (PWM) in three cities: Bandung, Yogyakarta, and Magelang. Data were collected from 41 semi-structured interviews, a plastic waste composition data analysis, and site visits. The research outcomes include a comprehensive analysis of stakeholder roles, plastic waste flow, plastic waste composition data, and various challenges in PWM. This study identifies three main stakeholders in collecting plastic wastes: the Department of Environment as the main local government body, community-based waste banks, and private waste management companies. Most recyclable plastic waste is recovered through waste banks and private collection services. In 2022, the predominant types of plastic waste in Bandung, Yogyakarta, and Magelang City were soft plastics, thick plastics, and hard plastics, respectively. The challenges for the PWM stem from various aspects in political, legal, and institutional; environmental; financial and technical; and socio-cultural spheres. Positive trends towards an integrated system are observed, although full integration has not yet been achieved. The research recommends a multi-stakeholder cooperative approach involving municipal authorities, waste banks, and private collectors, responsive to local conditions and emphasizing sustainability aspects throughout waste management stages for a sustainable resource recycling in developing countries.

Keywords: integrated sustainable waste management; plastic waste management; Indonesia; multi-stakeholder; municipalities

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1. Introduction

The waste management (WM) sector contributes about 5% of total greenhouse gas emissions, which leads to global warming and climate change, and adversely affects living organisms [1]. Globally, food and green waste is a large composition in municipal solid waste (MSW) at 44%, followed by paper (17%), and plastic (12%) [2]. However, unlike organic waste that can decompose naturally, plastics can take hundreds to thousands of years to break down in nature [2]. In 2019, globally, only 9% of plastic waste was recycled, 19% was incinerated, 50% went to landfills, and 22% was mismanaged [3].

As the world's fourth most populous country, Indonesia generates approximately 42.1 million tons of MSW annually [4], with plastic as the second largest waste content [5]. Nationally, 7.8 Mt of plastic waste is produced per year, and 58% remains uncollected [4]. Approximately 346.5 kton of plastic waste leaks into the marine environment yearly [4], contributing to 10.1% of plastic marine debris globally [6]. However, plastic recycling accounts for only about 10%, while 47% is openly burned, and the remainder is either

sent to landfills, dumped on land, or leaks into waterways [7]. Moreover, 70% of MSW in Indonesia goes to a landfill [8], which mostly operated with open dumping [9], releasing precarious methane gas to the atmosphere.

Indonesia predominantly manages its plastic waste through informal sectors, involving waste pickers and traders [10]. The absence of a specific municipal collection system for plastic waste results in minimal recovery, as, for instance, even in Jakarta, the capital of Indonesia, the plastic recycling rate was only 24% [11]. To address this urgent problem, Indonesia's Nationally Determined Contribution to Paris Agreement has committed to reduce GHG emission in the waste sector by up to 40 Mton CO_2-eq [12]. Moreover, to encourage waste separation at the source and promote a circular economy, the Ministry of Environment and Forestry of Indonesia (MoEF) launched the 'Gerakan Pilah Sampah' (Waste Sorting Movement) in 2019 [13,14]. Furthermore, through Presidential Decree No. 97/2017 (JAKSTRANAS), Indonesia set a target of 30% waste reduction and 70% waste handling towards the Indonesia's 2025 Clean-from-Waste target. Subsequently, each municipality is mandated to develop its own Regional Policy and Strategy (JAKSTRADA) on Waste Management to reach the target.

This study focuses on analyzing the plastic waste management (PWM) in three different sizes and characteristics—Bandung, Yogyakarta, and Magelang—each having formulated the JAKSTRADA. These cities exhibit distinct characteristics, histories, and prominence in WM. Utilizing the integrated sustainable waste management (ISWM) framework [15,16], this study addresses a noted gap identified by Filho et al., who mentioned the lack of studies specifically examining integrated urban waste management in developing countries [17]. Previous studies have often focused on individual actors in municipal solid waste (MSW) management, such as the informal sector [10,18], waste banks [19,20], private waste management companies [21], and governance [8,22]. However, the roles of current multi-stakeholder actors in plastic waste collection in Indonesia have not yet been clearly defined. Therefore, this research explores the roles of three key actors: local government, waste banks, and the private waste management companies. This study highlights multiple case studies of Indonesia's PWM by analyzing the current situation and how it is unfolding to a more integrated system, then providing recommendations to establish a sustainable PWM system. This study offers a learning model, particularly for other developing countries grappling with plastic waste challenges, by promoting an integrated MSW system.

2. Literature Review

2.1. Challenges of MSW Management in Developing Countries

Due to the rapid growth and adoption of high-consumption lifestyles, five developing countries, namely China, India, Brazil, Indonesia, and Mexico, are among the top ten nations generating the MSW [23]. Urban solid waste management is an escalating challenge, particularly in developing countries [24]. In developing countries where unsustainable WM is a common practice, there is a strong relation of the poor system and environmental contamination and health issues [25]. Various challenges impeding MSW implementation were identified, including inadequate public policies for MSW handling, unintegrated municipal plans, limited funding sources, the devaluation of waste from incineration, and the depreciation of solid waste reuse [17,26]. Additionally, factors such as poor infrastructure, a shortage of professional staff, and low involvement of both formal and informal private sectors contribute to the problems.

Tong et al. highlighted that informal collecting and recycling activities play an exceptionally important role from the perspective of the circular economy in the Mekong Delta, Vietnam [27]. In Sri Lanka, the waste collectors are also dominated by the informal sector, with only a few and less harmful categories of waste being recycled [28,29]. A similar issue was identified in Brazil, that waste traders in the informal sector only accept specific materials based on their market value [30]. Meanwhile, in Da Nang City, Vietnam, citizens

were not willing to separate plastic bags because they need to spend time washing and drying them, and they have a low resale value [31].

In Thailand, the role of community-based MSW management or waste banks have contributed to a reduction in waste by approximately 18,000 to 30,000 tons per year [32]. However, the lack of a formalized waste diversion sector impedes the practice of reduce, reuse, and recycle (3Rs) and leads to resource wastage [33]. In the Philippines, the development of sound landfill management should be followed by alternative livelihood opportunities for informal sectors from the dumpsites [34]. According to Serona et al., integrating the informal waste sector into mainstream waste management not only fulfills implementation requirements but also necessitates establishing monitoring and evaluation indicators tailored to local circumstances and current conditions to ensure that targets are achieved [35].

Municipalities in India allocate a very-low-priority budget to MSW, primarily focusing on waste collection and transportation rather than treatment and recycling [36]. A similar situation is likely occurring in Vietnam [37]. In Cambodia, challenges related to the limited availability data hinder the development of MSW management, necessitating reliable data on the quantity, source, and characteristics of MSW [38]. Lastly, despite being the first country in the world to implement a nationwide ban on plastic shopping bags in 2002, Bangladesh faces difficulties in law enforcement, resulting in only 10–15% of plastic waste being managed in the formal WM system [39].

The complexities of solid waste management in developing countries, exacerbated by urbanization; inequality and economic development; cultural and socioeconomic factors; political dynamics and governance structures; and global influences, underscore the ongoing need for comprehensive and integrated frameworks addressing the interconnection of socio-cultural, environmental, economic, and technical aspects [26].

2.2. MSW Management and Plastic Waste Issues in Indonesia

Indonesia has the highest quantity of MSW in ASEAN at 0.68 kg of waste per capita per day [40], with the MSW composition dominated by food waste (42%), plastic (19%), and paper waste (11%), respectively [5]. According to Darus et al., the five most collected types of plastic in the urban areas of Java were rigid PP, PET, HDPE film, HDPE rigid, and PP film [41]. MSW management in Indonesia involves both formal actors, such as municipal agencies and formal businesses, and informal actors, including individuals, groups, and small businesses engaged in unregistered and informally regulated activities [42]. The informal sectors who collect recyclable waste include waste pickers and waste buyers [43]. Plastic wastes can be recovered through a municipal facility in a solid waste processing site with the 3Rs principle (TPS3R). Additionally, individuals have the option to sell their waste directly to waste buyers, waste banks, or private waste management services. Unfortunately, 99% of the waste collected by the formal sector is sent directly to landfills, and only 1% is recovered through a waste bank and TPS3R [13]. The presence of waste-to-energy (WtE) incinerators remains limited; of the 12 cities that planned to implement such facilities, currently, only Surabaya City has an active WtE plant processing 1000 tons of waste per day (GOV1, see Table S2 for nterview code). The absence of advanced waste treatment technologies in developing countries is attributed to a lack of technically skilled human resources, material recovery policies, and financial resources [44].

The common practice of MSW management is collect–transport–dispose, and the informal sector plays a crucial role in recovering plastic waste [8]. Informal waste recyclers in Bandung City handle a substantial 64.6% of the total generated plastic packaging waste per day [45]. In Jakarta, the sorting efficiency of plastic waste collected by waste banks and waste pickers is 34.2% [11]. However, the pandemic prompted the establishment of waste management startups that collect plastic waste and develop digital apps for waste collection, addressing mobility restrictions [21]. Thus, it is also important to consider the contribution of a private waste management company to recover plastic waste.

In conclusion, the plastic waste problem is a crucial issue in Indonesia, especially when Indonesia was ranked as the second-largest contributor of marine plastic debris [46]. Moreover, the high dependence on landfills is causing repeated landfill closures due to overload [47,48] and numerous landfill fires [49–51]. Therefore, an integrated approach is crucial for addressing these problems.

2.3. Integrated Sustainable Waste Management

A significant challenge for the waste management sector is optimizing resource efficiency while concurrently reducing greenhouse gas emissions [52]. Gautam and Agrawal [1] propose the 5-R principle in MSW management, encompassing waste reduction, reutilization, and recycling; recovering energy or materials; and managing residuals in an environmentally comprehensive manner. Therefore, a sustainable waste management hierarchy should prioritize maximizing upstream waste management before implementing the 3R principles and energy recovery [32,53]. The least preferred choice, disposal (landfilling or incineration without energy recovery), should be considered only as a last option (see Figure S1). The similar concept proposed by Japan in 2004 through the creation of a sound-material-cycle society based on two approaches of saving input resources and encouraging material recycling creates a good balance in the material flow [54]. This approach can only be achieved through partnerships among key stakeholders, namely the government, the private sector (including manufacturers, recyclers, retailers), and the general public (comprising households, NGOs, CBOs, schools) [55].

Integrated solid waste management involves addressing solid waste comprehensively by carefully selecting and consistently applying suitable technology, ensuring appropriate working conditions, and establishing a 'social license' between the community and designated waste management authorities, typically local government [56]. Meanwhile, the integrated sustainable waste management framework is based on four principles: equity in establishing an appropriate waste management system; effectiveness in the safe removal of all waste; efficiency to maximize benefits, minimize costs, and optimize resource use; and sustainability tailored to local conditions [16]. Guerrero et al. emphasized that solid waste management is a multi-dimensional issue requiring not only technological solutions but also environmental, socio-cultural, legal, institutional, and economic linkages for the system to function effectively [57].

Wilson et al. supports the feasibility of implementing sustainable waste management in developing nations, emphasizing both physical aspects (collection, disposal, recycling) and 'soft' governance aspects (inclusivity, financial sustainability, and sound institutions and proactive policies) [58]. The ISWM framework was also used to analyze 20 reference cities from both developed and developing countries [59,60]. These reports highlight the use of the framework to examine and compare the cities' solid waste management strategies, understanding what works and what does not. An important lesson learned is that local solutions must be developed to address local problems, but they should share a common theme: all stakeholders in each city must be committed to the issues and prepared to collaborate [59]. Therefore, while the experiences and technologies of developed countries can be informative, they cannot be easily transferred to developing countries without adapting to the local circumstances [44].

Damanhuri and Padmi emphasized that sustainable waste management improvement in developing countries requires socio-economic and socio-cultural integration [61]. In many low- and lower–middle-income countries, recycling rates of around 20–30% are achieved by the informal sector alone [58]. This underscores the essential need to integrate the informal and private sector participations to enhance the efficiency of the system [18,62]. Several good practices of cooperation between local governments and private sectors in developing countries have been documented in previous research, such as in India [63] and various cities in Indonesia [64,65]. Finally, Prata et al. suggested ten stakeholder actions to reduce plastic pollution through an Integrated Waste Management System, including regulating production and consumption; supporting eco-design; increasing the

demand for recycled plastics; reducing plastic usage; using renewable energy for recycling; implementing extended producer responsibility (EPR); improving waste collection systems; prioritizing recycling; utilizing bio-based and biodegradable plastics; and enhancing the recyclability of e-waste [66].

2.4. Plastic Waste Management in Developed Countries

Developed countries have implemented several strategies in plastic waste management to promote a circular economy. These include functioning waste separation programs, integrated processing and treatment approaches with advanced technologies, effective formal recycling systems, and clearly defined policy frameworks [44]. As the leading recycling country in 2017, Germany is recognized as a global reference for its legislation focusing on responsibility, recycling, treatment, and waste disposal schemes [30]. A notable example is the privatization of Germany's waste management system since the 1980s, which also involves government-subsidized plastic recycling plants [67]. Since 1991, the country's Dual System Deutschland (DSD) for plastic recycling, including the "Green Dot" label, has achieved nearly a 100% plastic recovery rate through both incineration and material recycling [67]. Founded by the German packaging industry, this logistical system collects household packaging alongside existing municipal waste collection systems [30]. It retrieves used plastic packaging with the "Green Dot" label not only from households but also from supermarkets through a deposit refund system [68]. Consumers receive a deposit refund, ranging from EUR 0.25 to EUR 0.50, after scanning the Pfand (deposit fee) logo on drinking PET bottles placed inside the collection machine [69]. DSD collects packaging materials only from manufacturers who pay a license fee, which is calculated based on the weight, material type, and annual production volume of the packaging [67]. Additionally, households are subject to two waste fees: a basic usage fee and a performance fee based on the Pay-As-You-Throw (PAYT) model [30].

In another example, Japan initiated the development of a recycled society in 2000 when the government enacted six recycling-related laws based on the Fundamental Law for Establishing a Sound Material-Cycle Society [70]. One of these laws, the 'Containers and Packaging Recycling Law', promotes the EPR principle [28]. This law mandates that manufacturers, consumers, and retailers of plastic products take responsibility for recycling [71]. Consumers are required to dispose of plastic containers and packaging according to recycling identification marks and local municipalities' rules. These items are then collected by municipalities and handed over to authorized plastic recyclers [71]. Similar to Germany, some supermarkets in Japan also collect waste PET bottles from consumers by setting up collection boxes, offering one point for every five bottles, which can be redeemed in the supermarket [71]. Businesses that manufacture or use plastic products are required to recycle them, either by taking the post-packaging back through self-collection routes [72] or by paying a recycling fee to the Japan Containers and Packaging Recycling Association, which contracts out the recycling work [70]. Additionally, the industry places recycling boxes for PET bottles near beverage vending machines, although without a deposit system. Unlike Germany's DSD, which was initiated by the private sector, the Japan Containers and Packaging Recycling Association is a designated organization appointed by five ministries to promote the appropriate recycling of post-consumer products [73]. In Japan, the government plays a major role in plastic waste management through active engagement with the private sector via public-private partnerships [28].

Singapore is the most advanced country in the ASEAN in terms of its waste management system [74]. However, the plastic recycling rate only reached 6% in 2021 [75]; however, around 90% of its waste is incinerated through WtE plants, which generates significant amounts of electricity in the country [76,77]. Since 2019, Singapore has a Zero Waste Masterplan that targets 30% waste reduction to landfills and 70% of the overall recycling rate by 2030 [78]. Through the Resource Sustainability Act, Singapore aims to impose regulatory measures upstream through annual reporting of packaging data and 3R plans by producers of packaged products. This addresses Singapore's priority wastes, including

the EPR framework for plastic packaging no later than 2025 [78]. Several behavioral nudges were also implemented, including disallowance of disposable cutleries in hawker centers and engaging partners across Food and Beverage, retail, commercial, and community sectors to encourage consumers to select the sustainable options at points of consumption, including visual reminders at cashier points, training of cashiers, and providing incentives for using reusables [76,78]. Moreover, since 2001, Singapore has been implementing the National Recycling Programme, in which recycling bins were made available to residents living in both public housing flats and landed properties that will be collected by licensed recycling contractors [76].

In Australia, the overall recycling rate is 13% [79], with most recycling facilities using mechanical recycling as the main processing technology [80]. The PW collection system in Australia consists of curbside recycling collection by contractors or local Council employees, who transfer the waste stream to MRFs where it is sorted, compacted, and baled for sale [80]. In 2019, the government initiated the National Waste Policy Action Plan, including two targets related to plastic wastes, which are to ban plastic waste export by 2020 and phase out problematic and unnecessary plastics by 2025 [74]. In 2021, Australia released its first national plastic plan, aiming to reduce plastic wastes, increase recycling rates, and find alternatives to the unnecessary plastics, including phasing out plastic packaging that does not meet relevant compostable standards, several expanded polystyrene (EPS) packaging, and PVC packaging labels [81].

In conclusion, developed countries have implemented several strategies to manage plastic waste, including regulatory frameworks based on plastic types with clear recycling or waste reduction targets, producer responsibility schemes, fees or taxes on single-use plastic bags, and deposit return schemes. However, some developed countries, such as the U.S., Japan, Australia, and Singapore, still struggle to increase recycling rates because some plastic materials are difficult to recycle [82]. Although the recovery rates in these countries are high, they frequently resort to treating solid waste with landfill and incinerator technologies, which are not the best options from the perspective of a circular economy [83]. Therefore, enhancing the resource circularity of plastic products remains an urgent global challenge that must be addressed to reduce GHG emissions and resource depletion [83,84].

2.5. Trend of Plastic Waste Disposal Method

In previous years, landfilling had been the preferred approach to plastic waste management due to low investment costs, easy construction, and straightforward disposal processes [85]. However, it leads to resource loss and environmental pollution, including marine litter and soil and groundwater contamination [85,86]. When possible, reuse is preferable to recycling due to lower energy and resource usage [87]; however, recycling is seen as a way to reduce the use of virgin materials in plastic manufacturing. Recycling could save 40–100 MJ/kg of energy and reduce the depletion of fossil fuels [85]. Globally, there are several ways to recycle plastic waste, including material, chemical, or feedstock; biological; and thermal recycling [80,87]. With the current global trend of waste management, it is predicted that in 2050, 9000 Mt of plastic waste will be recycled, 12,000 Mt incinerated, and 12,000 Mt landfilled [88]. Theoretically, it is possible to close-loop recycle most thermoplastics, especially ones with similar materials like PET bottles; however, plastic packaging frequently uses a wide variety of different polymers and other materials such as metals, paper, pigments, inks, and adhesives, which increases the difficulty [82].

Mechanical recycling consists of primary and secondary recycling [87]. Primary recycling is closed-loop recycling of single-type plastic waste, where the recycled single-type plastic waste is recovered back into its original intended use. Meanwhile, secondary recycling is open-loop recycling of mixed plastic waste, whereby the recovered plastic waste is repurposed into downcycled products for applications different from its original intended purpose [77]. Chemical recycling involves the transformation of polymers into their monomer structures to produce fuels, chemical products, and new plastic products [80], which is also called tertiary recycling [87]. Chemical recycling is particularly efficient in

processing multilayer packaging and mixed plastic waste streams [80]. Biological recycling processes use microbes, such as bacteria and fungi, to degrade both synthetic and natural plastics [80], which is another example of tertiary recycling [82]. Lastly, thermal recycling produces thermal energy or what are called quaternary products, recovered from the incineration of plastic waste in WtE plants [77]. Pyrolysis, gasification, and hydrothermal treatment are some of the commonly used options for energy recovery [80].

To determine the most suitable disposal method for plastic recycling, it is necessary to understand the waste composition [89]. However, the U.S. Environmental Protection Agency does not view incineration for energy recovery as a waste minimization treatment but rather as an activity that occurs after opportunities for waste minimization have been exhausted [90]. This aligns with the study by Goodship, which states that the best method of plastic waste disposal is waste minimization, ensuring maximum environmental benefit [89]. Even though plastic has a high energy value for incineration [91], burning waste is still not seen as a sustainable option due to the potential release of noxious gases into the atmosphere, as well as high installation, operation, and maintenance costs [82,85]. In developed countries, stringent regulations to prevent the emission of dioxins from incinerators are implemented; however, this treatment remains a challenge in developing countries [44].

In developed countries, the transition to more sustainable options for plastic waste disposal is progressing, although some countries like the U.S. and Australia still rely heavily on landfills [79,92], which typically include leachate and gas collection systems [44]. On the other hand, Japan and Singapore treat the majority of their plastic waste through thermal recycling, at rates of 61% and 96%, respectively [28,77]. Meanwhile, among all countries mentioned, Germany has the highest rate of plastic packaging recycling, primarily driven by material recycling, at 43% in 2019 [93].

2.6. Results of Previous Research Analysis and Originality of Research

The current situation in developing countries highlights the need to develop progressive plastic waste treatment strategies to improve solid waste management efficiency of formal recycling and environmental benefits [44]. It is also clear that in Indonesia, each PWM actor in Indonesia works unintegrated to collect and manage plastic waste, causing inefficient and minimal recovery of plastic waste [94–96]. Moreover, through an examination of the Scopus and Web of Science databases and Google Scholar, it is evident that limited studies have comprehensively analyzed MSW in Indonesia using the ISWM framework [94–99]. However, to the best of our knowledge, no studies to date have analyzed Bandung, Yogyakarta, and Magelang as case studies on plastic waste management using this framework. Furthermore, there are limited studies that have analyzed the integration between the three current options of MSW collection services: formal, community-based, and private sectors. Therefore, this research addresses gaps in the existing literature by conducting a comprehensive study across three cities of varying sizes and characteristics. With a primary emphasis on plastic waste, this study aims to tackle pressing global issues in MSW management. The originality of this research lies in its multiple-case-study approach, grounded in integrated sustainability through the ISWM framework. Additionally, this research is focusing on the relationship between every stakeholder in the waste flow.

3. Materials and Methods

3.1. Case Study Area

This study was conducted using a multiple-case-study approach in three cities, Bandung, Yogyakarta, and Magelang City, which were chosen based on a set of parameters (see Tables 1 and S1). This research design helps to answer the question “how” or “why” [100]. Furthermore, a case study is the most convenient strategy when the research is mostly exploratory, covering detailed observation [101].

Table 1. Comparative data on city contexts and the history and prominence of MSW system in the case studies.

Type of Data	Bandung City	Yogyakarta City	Magelang City
Size and population	167 km^2, ±2.5 million [102]	32.5 km^2, ±376,000 [103]	18.54 km^2, ±120,000 [104]
Base income	IDR 4,048,462 [105]	IDR 1,981,782 [106]	IDR 2,066,007 [107]
Characteristic	Known for its local fashion industry [108]	Renowned as education and cultural heritage city [109]	Recognized for its service city [110]
History and strength of MSW system	• Leuwigajah landfill explosion in 2005, later commemorated as National Waste Awareness Day [22,111] • Advocate of the zero-waste-cities concept 'Kang Pisman' • Local Regulation No. 17/2012 on plastic bag reduction	• Pioneering city of waste banks [112] • 'Laron Sarungan' public facility designed to educate the public about waste segregation	• Established a central waste bank in 2013 • Enacted the local regulatory framework 'Magelang Cantik' to enforce waste segregation through waste banks

Bandung, Yogyakarta, and Magelang City are all located on the island of Java (see Figure 1), which is the most developed region in Indonesia with a high demographic and economic concentration [113].

Figure 1. The red map marker indicates the case study locations on Java Island, Indonesia [114,115].

Bandung City has a challenging history in WM, marked by the most remarkable failure of Leuwigajah landfill in 2005 [22]. The date of the incident, 21 February is commemorated as National Waste Awareness Day. Based on an interview with GOV5 (see Table S2 for interview code), the current operational dumping site, known as the Sarimukti landfill, initially planned as a temporary facility, has limited waste storage capacity, leading to the accumulation of MSW at various points in Bandung City in 2023. Therefore, since 2015, Bandung City runs the zero-waste-cities concept, initiated by an NGO called Yaksa Pelestari Bumi Berkelanjutan (YPBB) in collaboration with the municipal government, especially the Department of Environment (DoE).

Yogyakarta City is recognized as the pioneer of waste banks, an initiative started by a local citizen, Mr. Bambang Suwerda, who established the first waste bank in Yogyakarta Special Region Province in 2008 [112]. Furthermore, in one of the TPS3Rs in Yogyakarta City, there is a public facility called 'Laron Sarungan' designed to educate the public about

waste segregation and the treatment of organic and recyclable waste. This effort is initiated by the municipal government to reduce waste and create an integrated WM system, in the city (GOV12).

Magelang City also features a commendable WM program, evidenced by the establishment of a central waste bank in 2013 under the guidance of the DoE to recover recyclable plastic waste (WBC3). Furthermore, the city has implemented a specific policy, Mayor Regulation 6/2022, addressing the implementation of 'Magelang Cantik' or 'Beautiful Magelang' to significantly reduce waste at its source. This policy emphasizes the community's role in waste segregation through waste banks and encourages regular reporting to the community leader.

In conclusion, the three cities each hold significance in WM, thereby rendering them invaluable as case studies for understanding integrated WM in Indonesia from the perspectives of cities of various sizes.

3.2. Data Collection and Methodology

The primary data were collected from semi-structured interviews, direct observations, and plastic waste data from waste banks. This study also collected secondary data from national- and local-level policy documents and reports, and data from the DoE in each city and related organizations, academic journals, and grey literature (e.g., educational videos and webinars).

3.2.1. Semi-Structured Interviews

Semi-structured interviews were conducted from 29 May to 28 August 2023, and on 1 December 2023, to understand the current situation, explore the development toward an integrated system, and identify challenges in PWM within the case studies. In total, 41 interviews involving 43 participants were carried out, with 5 conducted online and the rest in person. The interviewees were categorized into two groups, which are primary respondents and supporting respondents (see Figure 2).

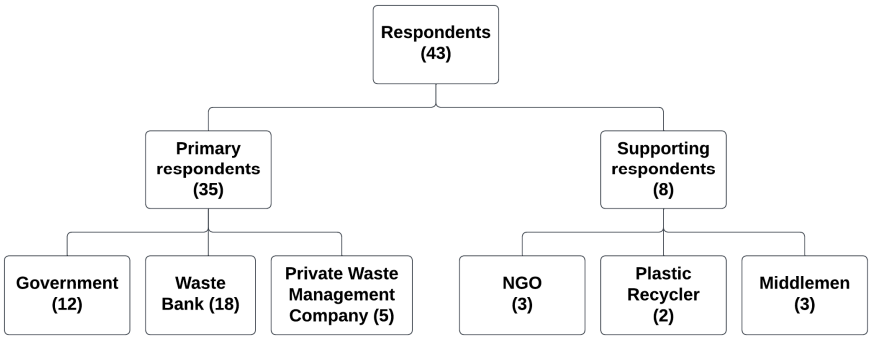


Figure 2. Structure of interview respondent categories.

Primary respondents, comprising the municipal and national government, waste banks, and private waste management companies, play key roles in the waste collection process. Supporting respondents include stakeholders involved in various stages of PWM, such as an NGO focusing on waste issues, a plastic recycler, and middlemen. For the details of each stakeholder's role, please refer to Table S3.

Most interviews lasted between 60 and 75 min (see Table S2). The snowball sampling method was employed, initially selecting a group of people relevant to the research questions, who then referred others with similar characteristics or experiences. As for waste banks, since numerous waste banks are established in the case studies, obtaining input from the DoE and community leaders provides valuable insights for interviews, especially concerning successful projects in the communities. The interview questioning was prepared prior to conducting the interviews (see Table S4).

3.2.2. Direct Observation

This study employed unstructured observations, as they offer insights into interactions, depict comprehensive pictures, capture context and processes, and highlight the influence of physical environments [116]. Both formal and informal sectors of WM within case studies were directly observed, including visits to waste banks, a TPS3R, privately owned recycling facilities, and a landfill site. Direct conversations were conducted while observing some of the PWM facilities, making it easier to understand the current conditions and challenges.

3.2.3. Plastic Waste Data

In order to formulate an integrated solid WM system, accurate and reliable data on waste composition and quantities are essential [117]. The plastic waste data were collected from waste banks in the case studies to understand the types of plastic materials consumed by the community. The data were collected from waste banks due to the absence of data on plastic waste composition from local governments. However, it is essential to note that not all types of plastic waste are recovered through waste banks. Finally, the process of data collection included compiling and selecting data within specific time frames, categorizing it based on plastic types, and then analyzing it (see Figure 3).

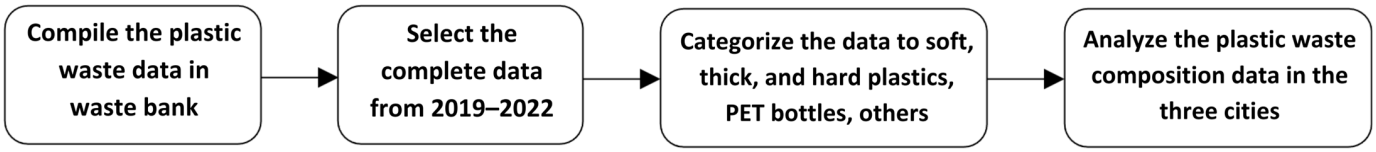


Figure 3. Waste data collection process.

3.3. Integrated Sustainable Waste Management Framework

The ISWM is a model that enables comprehensive analyses of complex, multi-dimensional WM systems in an integral way [57]. It has been used to analyze WM systems, particularly in developing countries [29,57,58,60]. Developed in the mid-1990s by WASTE—an advisor on the urban environment and development based in the Netherlands—in collaboration with various organizations in developing countries, the ISWM framework aims to overcome the limitations of conventional WM methods [15]. This study employed the ISWM framework to analyze the current conditions and challenges of PWM within the case studies, aiming to understand the level of integration among stakeholders, waste system elements, and different aspects of sustainability.

The framework aided in conducting an in-depth analysis by mapping stakeholders, designing interview questions, understanding and collecting waste elements, and defining challenges and solutions. Figure 4 illustrates the dimensions of the ISWM framework: (1) stakeholders involved in the WM process, (2) elements or stages of the waste system, and (3) sustainability aspects in the local environment. This study clarifies the roles, strategies, and interconnections of the three main actors: the government, waste banks, and private waste management companies. It also explains the flow of plastic waste within the case studies and analyzes the composition data collected from waste banks. Moreover, it examines PWM challenges based on the sustainability aspect categorization within the ISWM framework.

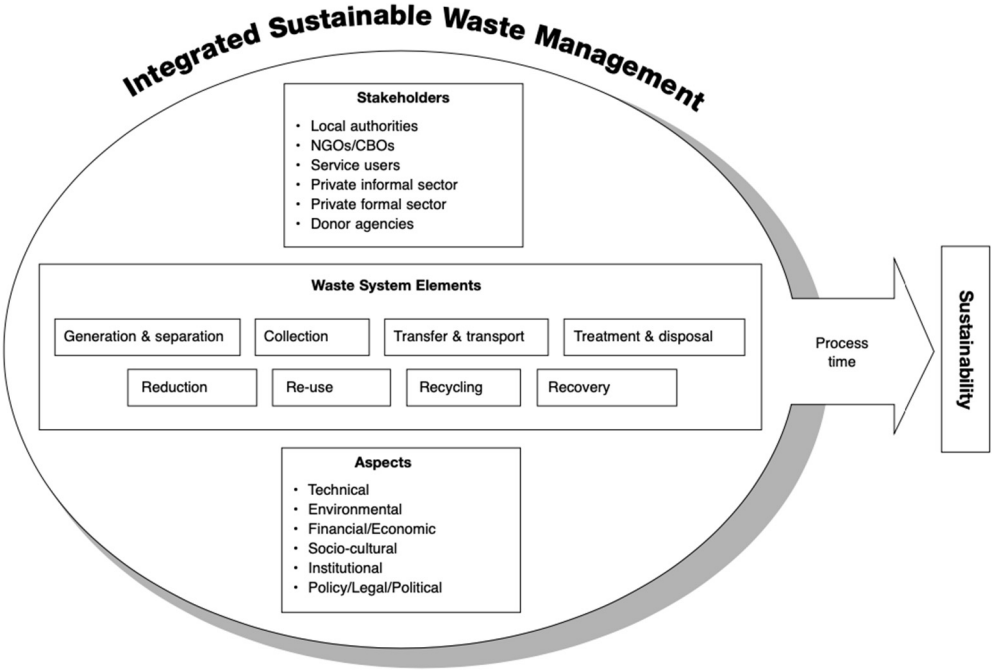


Figure 4. The ISWM model [15,16].

4. Results of Analysis

4.1. Stakeholder Involvement

4.1.1. Governance Strategies

Waste management is a part of environmental affairs, classified under mandatory but non-basic public service affairs, with the responsibility for WM delegated to the city level (Act No. 23/2014 on local government). The national government of Indonesia, particularly the MoEF, has implemented several strategies to address plastic waste issues. These efforts include enacting the EPR regulation (MoEF Regulation No. P.75/2019), which ensures that producers develop a roadmap to reduce plastic use in their packaging and outlines methods for reuse and recycling. Notably, 16 out of 353 companies are already in compliance with this regulation (GOV1). Furthermore, MoEF also supports the establishment of various WM facilities in cities, such as waste-to-energy incinerators, waste-to-RDF plants, and waste-to-material facilities. Additionally, the MoEF is fostering public engagement to encourage behavioral change and promoting the development of waste banks as well as private sector involvement in WM initiatives.

In Bandung City, the Kang Pisman program was established in 2018 following the previous Kawasan Bebas Sampah (KBS), or the 'waste-free area' program, which had been established in 2015. Kang Pisman stands for 'kurangi, pisahkan, manfaatkan', meaning 3Rs. The objective is to create a decentralized waste management system that emphasizes the segregation and recycling of waste, as stipulated by Local Regulation No. 09/2018. The program encourages the independent, community-based WM, with plastic waste being sorted and processed at its source. As of 2022, 180 out of 1591 Rukun Warga (RW) or neighborhood–community units had implemented the program [102,118]. However, the number of participating RWs has dropped to approximately 40 due to the impact of COVID-19 (GOV5). The DoE in Bandung City is instrumental in driving the Kang Pisman program, which includes community leader assistance, door-to-door waste collection, and waste segregation educational efforts. In the program, recyclable plastic waste is gathered via waste banks in each district. The DoE incentivizes central waste bank workers to collect recyclable plastic wastes from community waste banks. In addition, at the beginning of 2023, the municipal government launched an RDF facility at Cicukang Holis WM facility, which has the capacity to process up to 10 tons of residual MSW per day, including damaged plastic waste unsuitable for material recycling [119,120].

In January 2023, the Yogyakarta municipality launched the Gerakan Zero Sampah Anorganik (GZSA) or 'zero inorganic waste initiative', as directed by Circular Letter No. 660/6123/SE/2022 from the Mayor of Yogyakarta City. This initiative bans the landfilling of inorganic waste, stipulating that only organic and residual wastes are permitted in the municipal waste collection. Under the GZSA policy, residents are required to segregate recyclable plastics at the source. The DoE of Yogyakarta City advises that such recyclables be sold to waste banks, middlemen, or private waste management companies. As of June 2023, there has been a significant 30% reduction in the volume of waste reaching landfills in comparison to the previous year (GOV8). However, as the regulation is relatively new, the practice of mixing plastic waste with other MSW persists (GOV12). The urgency of the GZSA initiative has been further intensified by a waste crisis in Yogyakarta City, which ensued following the temporary closure of the Piyungan landfill from July to September 2023 for site expansion (GOV8).

In Magelang City, the municipal government, particularly the DoE of Magelang City, plays a pivotal role in Magelang City's WM, operating independently without reliance on outsourced services (GOV7). The recovery of plastic waste is primarily managed through waste banks, with a central waste bank of the city coordinating the collection of plastic waste from waste bank units under the DoE's supervision. The DoE aids the central waste bank by providing logistical support such as vehicles and fuel for waste collection.

4.1.2. Waste Bank Recovery Efforts

According to MoEF Regulation No. 14/2021, a waste bank is a facility for managing waste based on the 3Rs principle, serving as an educational tool for behavior change in waste management and the implementation of a circular economy. Waste banks can be managed by communities, businesses, and/or local governments. A waste bank unit (WBU) serves a neighborhood–community unit's administrative region. Meanwhile, a waste bank central (WBC) caters to a broader area, often spanning an entire city, primarily acting as a collection aggregator. While WBUs are encouraged to foster a cultural and community-centric approach, WBCs are expected to operate with a professional business orientation (GOV1). The waste bank activities in the case studies are shown in Figures S2–S4.

WBUs generally operate on a weekly basis, although some may function less frequently, with certain WBUs in Magelang City operating daily. Volunteers often help with sorting and cleaning in the post-collection of waste. However, some WBUs sell the waste directly to a WBC or middlemen without further sorting. WBUs benefit financially from the differential between purchase and sale prices of waste. Additionally, members in some WBUs can redeem their deposits for daily necessities, e.g., cellular data, utilities, or even loans. Furthermore, WBUs are responsible for maintaining detailed records of waste transactions for monthly reports to the DoE. Local government support for WBUs is typically non-monetary, comprising the provision of operational equipment and training sessions. Monetary rewards are dispensed only during annual waste bank competitions.

In Bandung City, a WBC was established in January 2022 through the merger of two former WBUs named Resik and Hijau Lestari, under the local government-owned enterprise called UPTD Pengelolaan Sampah. The UPTD operates under the DoE to deliver WM services in the city. The WBC has five waste storage facilities to further process the waste. The WBC was established to help organize the WBUs and stabilize the price of plastic waste so that they do not depend on changing prices from middlemen. The WBC picks up and buys plastic waste not only from WBUs, but also from schools, government offices, and businesses in the city. The total of WBUs in the city is 288 units [118], encompassing approximately 5000 individual members (WBC1). Moreover, the WBC is open during daily working hours, allowing individuals to sell their plastic waste at their convenience. This study observed four WBUs in the city, namely Oh Darling, Dabaresih, Sembara, and Bumi Inspirasi. While all are well-functioning units, Oh Darling and Dabaresih stand out as examples of effective management, due to being led by their respective neighborhood–community leaders. Almost all families living in the two WBUs already collect their plastic

waste for the waste banks. Members typically deposit earnings in the WBU, with the option to withdraw their savings at the end of the year, or immediate cash-outs. Furthermore, the collected waste at Oh Darling is picked up every two weeks by the WBC, totaling approximately 400 kgs each time. Meanwhile, in the two other waste banks, Sembara and Bumi Inspirasi, which are run by the community, it was noted that not everyone in the neighborhoods participates in waste collection.

In Yogyakarta City, there are a total of 614 waste banks [121]. These waste banks are coordinated by the Waste Bank Forum, an entity established by the DoE in 2022 to facilitate the organization of WBUs within the city. (At the time of the data collection period, the WBC in Yogyakarta City had not yet been established; it only began in October 2023. Therefore, this study did not include the role of the WBC in Yogyakarta City in the analysis.) In the same year, the forum initiated a program for the purchase and sale of handicrafts made from plastic waste (see Figure S5). GOV9 reports that since the forum's inception, under the leadership of the city's regional secretary, waste banks have received increased attention and engagement from the leaders of neighborhood–community areas. This study explored seven WBUs, namely Tigo Setunggal, Suryo Resik, Lintas Winongo, Gema Berseri, Sulolaras, Pelangi, and Bumi Lestari. The WBUs are mostly led and run by mothers or housewives in the communities. In addition to waste collection, some waste banks, such as Suryo Resik, Lintas Winongo, Sulolaras, and Pelangi, create handicrafts from rejected plastic waste (e.g., multilayer plastics) to make products like bags, wallets, and artificial flowers (see Figure S6a). As in Bandung, operating costs of WBUs are primarily covered by the profits generated from selling waste; however, a WBU stated that their waste bank does not aim to generate a profit from waste collection (WBU5). Some rewards, like giving daily products and going on staycations, are given to people who actively sort their waste in the WBU to encourage waste segregation (WBU6, WBU11).

In Magelang City, the WBC was established much earlier in December 2013. As a result, the WBC has been organizing WBUs from the onset. The WBC collects plastic waste from the WBUs once every two weeks to one month. As of 2023, the WBC had 116 members, comprising 57 WBUs, 24 offices, 13 schools, and 22 individuals. The WBC receives support from the DoE of Magelang City, i.e., two cars, gasoline, and drivers for waste collection. However, the daily operations of the WBC are independently managed, as it is endorsed to function as a professional business organization (WBC3). In Magelang City, this study interviewed four WBUs: Nirwana, Bersemi, Rukun Makmur, and Bougenville. Similar to Yogyakarta City, these WBUs are predominantly run by mothers in the community. Each month, the Nirwana waste bank sells up to 300 kgs of waste to the WBC. In addition to waste collection, these four WBU also create handicrafts from waste materials (see Figure S6b), generating additional income for the communities. While some WBUs generate revenue through waste selling and purchasing activities, Bougenville has innovated by establishing a small grocery store where goods can be purchased using waste savings (see Figure S7), a one-of-a-kind establishment in the city (WBU15).

4.1.3. Private Sector Involvements

The term private sector in this context refers to the formal private sector, which encompasses registered businesses holding official licenses, employing organized labor, and typically involving some degree of capital investment and modern technology [122]. Formal private companies are engaged in a wide array of activities within waste management systems, including waste collection, resource recovery, incineration, and landfill operations [123]. This research narrows the focus to the role of the private sector as plastic waste collectors in the case studies.

The private waste management sector has experienced rapid growth over the past three years, and it is projected that within the next decade, this sector could emerge as the primary system of waste management in the country (GOV1). This study conducted interviews with three prominent waste management companies operational within the case study areas: Daur Resik, Rapel, and Duitin. These companies function as recycling

aggregators, collecting plastic waste from a diverse range of sources, including households, offices, schools, cafes, restaurants, and even WBUs. Daur Resik's primary operations are in the Yogyakarta Special Region Province, but the company also has a mobile presence in several other cities, including in Magelang City, utilizing their vehicles for waste collection. However, Daur Resik's operations in Magelang City are limited to a single location, offering services only once a month. Rapel's operation is concentrated in the Yogyakarta Special Region Province. Meanwhile, Duitin offers its services in multiple locations, including in Bandung and Yogyakarta cities.

All three businesses are driven by digital transformation. Rapel and Duitin leverage mobile apps to streamline their systems (see Figure S8), whereas Daur Resik utilizes social media platforms, like Instagram, to promote their services to the public. Due to their app-based approach, Rapel and Duitin customers can conveniently upload their sorted waste at any time, providing flexibility to sell their waste. The primary role of these three entities is to collect plastic waste at the upstream level and sell it to buyers, such as plastic recyclers or other parties in need of the waste. They accept and purchase plastic waste without requiring customers to pay a regular fee.

Compared to the other two, Daur Resik offers broader acceptance for plastic waste, including mostly rejected types such as multilayer plastics and bottle labels, though they do not offer payment for these items. In contrast, Duitin only takes rigid plastics, i.e., plastic containers and other hard plastics. Meanwhile, Rapel accepts a variety of plastic waste, from rigid to flexible types, but does not include the rejected plastics mentioned above. On the other side, some waste collectors employed by Rapel and Duitin are individuals who used to work in informal sectors, such as waste pickers and itinerant waste buyers. Thus, the involvement of these private sector actors helps to formalize informal waste collection activities. Additionally, these businesses play a role in educating the community about waste segregation at the source through their digital platforms.

Concerning their relationship with local authorities, these companies have acknowledged support from the local government; however, this does not extend to any forms of incentives. Discussions with local government officials regarding waste management practices are occasionally held (WMC2, WMC4). However, there is a lack of formal integration of these entities into the existing municipal waste collection system.

4.2. Realities and Challenges of Waste System Elements/Stages

4.2.1. Plastic Waste Flow

Lack of proper waste segregation and collection disrupts waste management flow, hinders the recycling of valuable materials, and leads to unsustainable practices such as open burning and dumping at prohibited sites [44]. Despite efforts to encourage waste segregation in the three cities, the majority of people still dispose of their waste in a mixed manner (GOV5, GOV7, GOV12). Plastic waste collected by municipal service is typically mixed with other types of MSW and is gathered by a community using push carts or three-wheel vehicles (see Figure S9). This waste is initially transferred to Tempat Penampungan Sementara (TPS) or a temporary waste transfer station and eventually sent to landfills. In certain areas within the case studies, waste is directly transferred to TPS3R facilities; however, these are limited in number (five in Bandung City, two in Yogyakarta City, and four in Magelang City) and primarily focus on organic rather than plastic waste. At a TPS3R, plastic waste is manually sorted, sometimes with the support of sorting facilities, as observed in Yogyakarta and Magelang City. However, the quality of plastic waste entering the municipal collection line is generally low due to its mixture content. At the end, some of this plastic waste is sold to middlemen or recyclers, within or outside the cities. The remainder is either disposed of in landfills or, in the case of Bandung City, some is processed into RDF at a specialized facility. The flow of plastic waste in the case studies is depicted in Figure 5.

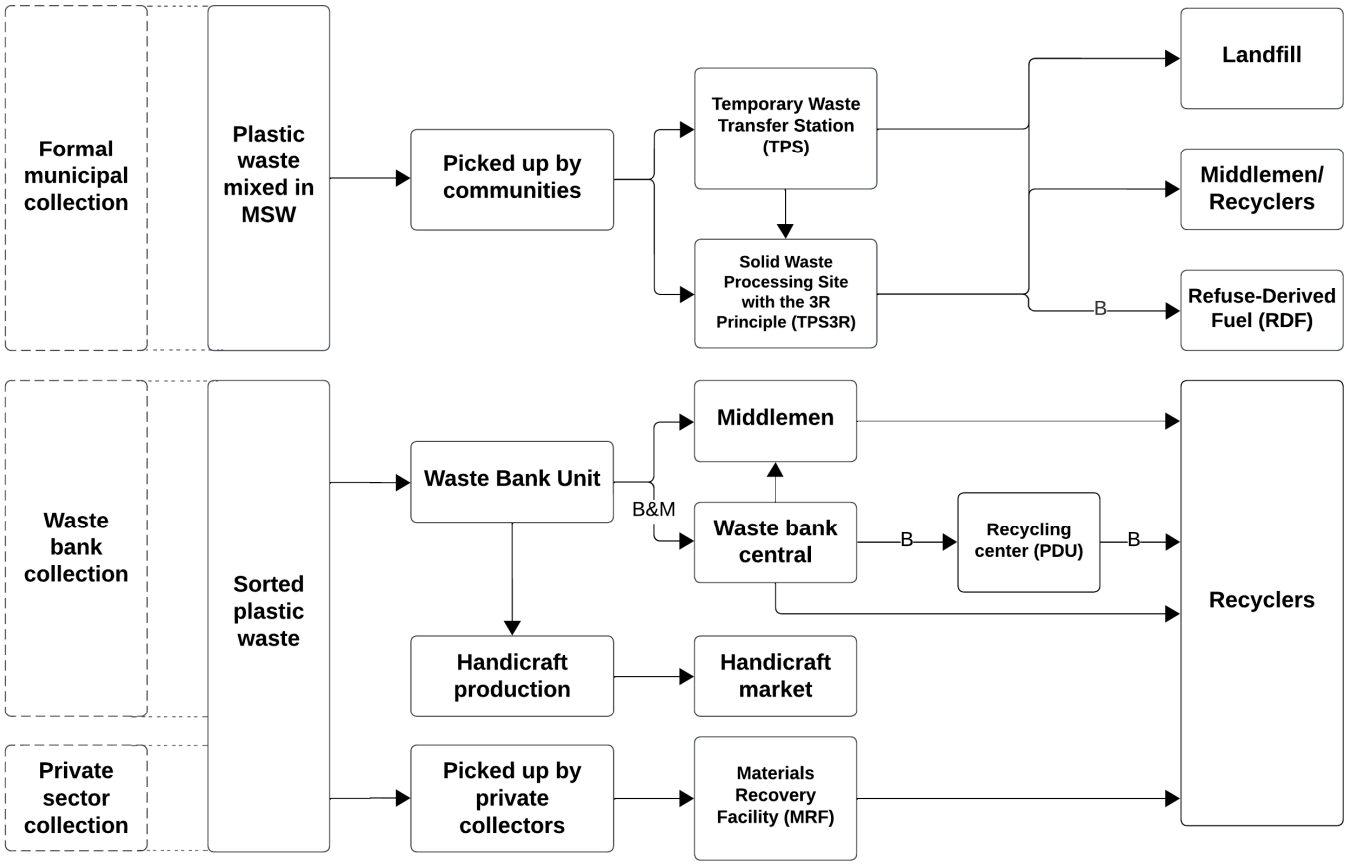


Figure 5. Plastic waste flow in the case studies (B: Bandung City, M: Magelang City).

Plastic waste entering the waste bank collection typically has high value and is already clean and sorted. Community members take their waste to the nearest WBU. These WBUs either sell the waste to middlemen or, in the cases of Bandung and Magelang, to the WBC. Additionally, some WBUs create handicrafts from rejected plastics, such as sachets. Middlemen subsequently sell the collected waste to recyclers, while the WBC may sell either to middlemen or directly to recyclers. In Bandung, however, WBCs first transport their collected plastic waste to pusat daur ulang (PDU) or a recycling center for further sorting, cleaning, and baling before it is sold to recyclers. The PDU Cicabe in Bandung City, which was observed in this study, specializes in storing plastic waste (see Figure S10). For additional context, middlemen are categorized by their operational scale into small, middle, and large, with only the larger ones able to sell to recyclers after performing pre-treatment processes such as grinding and pressing [10,124] and WBU5.

Finally, within the formal private sector, companies like Rapel and Duitin offer services to pick up sorted plastic waste directly from residents' homes (see Figure S11), while Daur Resik collects it from various predetermined locations within its service area, and customers are required to bring their plastic waste to these spots (see Figure S12). The waste is transported to their respective MRF for further processing, including shredding and washing, before being sent to plastic recyclers. These three businesses, however, do not engage in further processing such as palletization or manufacturing new products from the collected waste.

4.2.2. Plastic Waste Composition

The composition of waste materials is crucial for the potential recovery and recycling of resources [125]. To analyze plastic waste composition in the case studies, this study collected data from waste banks across the three cities. In Bandung and Magelang City, data were obtained from the WBC. Meanwhile, in Yogyakarta City, the data were compiled

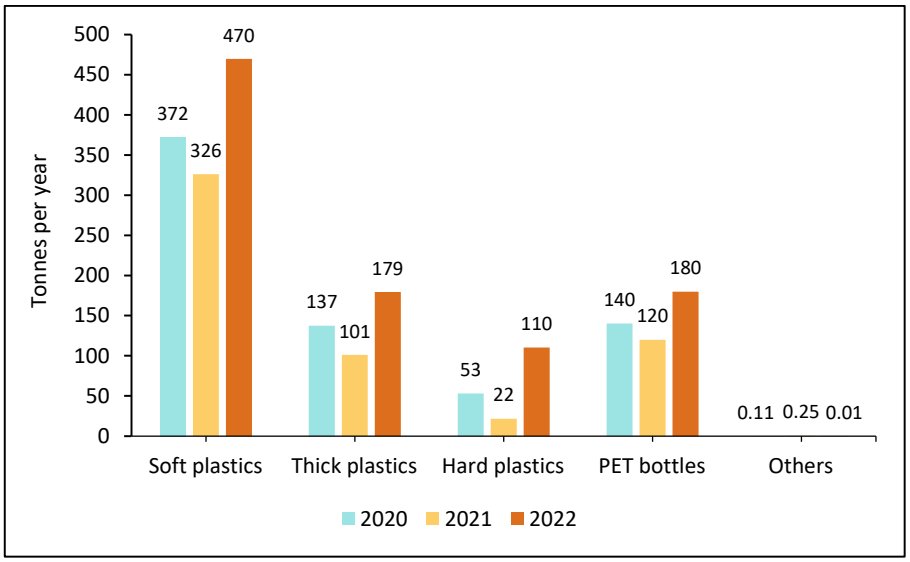
from three WBUs that have comprehensive records of plastic waste from 2020 to 2022. The total amount of plastic waste collected through waste banks in the three cities has risen annually (see Table S5). Table S6 details the types of plastic waste received by waste banks in the case studies. It reveals that the types of plastics accepted are largely similar across the three cities, with the exception that the WBC in Bandung City accepts Styrofoam, and the WBC in Magelang City accepts multilayer plastics. In 2022, WBU activities resumed after a period of inactivity during the pandemic, resulting in an increased amount of several types of plastic waste collected.

In Bandung City, soft plastic usage is higher compared to other types (see Figure 6a), as the city has five warehouses for storing collected plastic waste, with one serving as the main sorting facility. This ensures effective separation, particularly of soft plastics (WBC2). This high prevalence of soft plastics may also be linked to the city's local fashion industry (see Table 1), which requires a significant amount of plastic packaging [126]. Furthermore, several previous studies have demonstrated a positive correlation between a city's size, population growth, and income and its MSW consumption [127–129]. However, studies on plastic waste composition and its relationship to city characteristics remain limited.

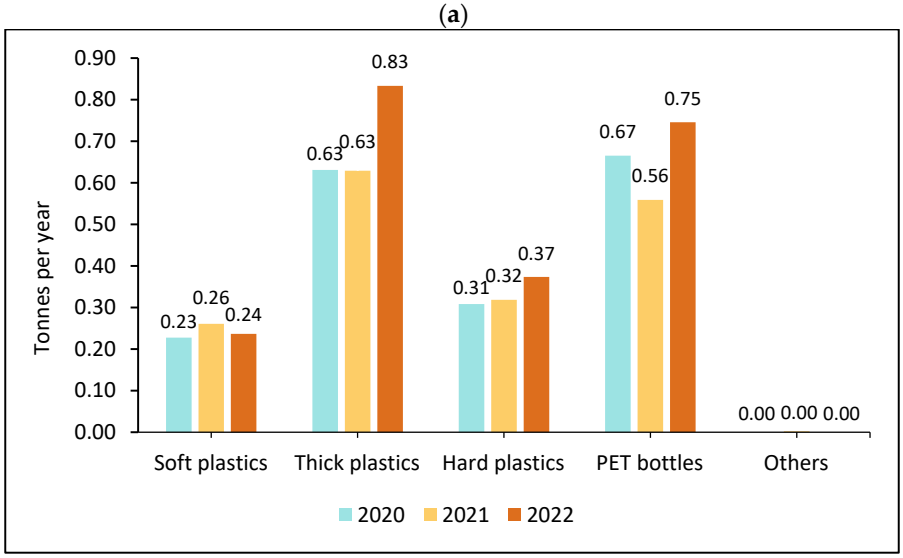
As a metropolitan city, Bandung has the largest-size population and income compared to other cities (see Table 1). According to Thanh et al., who studied plastic waste composition in Can Tho City, Vietnam—a city with a population over 1 million—plastic shopping bags were identified as the major component of plastic waste [129]. On the other hand, a study by Gwada et al. found that in Watamu Ward, Kenya, which has a population only about one-fifth that of Magelang City, the predominant plastic waste composition was low-density polyethylene (LDPE), including plastic shopping bags [89,130]. These studies suggest that city size alone cannot solely determine plastic waste composition.

Figure 6b shows the plastic waste composition in Yogyakarta City, involving a total of 326 households. The chart illustrates that PET bottles and thick plastics constitute the two highest proportions of plastic waste. Since the city is well known as an education city, one factor that contributes to the high consumption of PET bottles is the substantial influx of students from other cities who come to study and live in boarding houses within the city. Therefore, they tend to use disposable plastic packaging, like PET bottles (WBU8). Previous studies have shown the correlation that the education level has to waste generation [127,131,132]. Additionally, the higher value of PET bottles compared to other plastics may encourage collection and sale to waste banks. Furthermore, the higher consumption of thick plastics can be attributed to the daily products used in households. Finally, due to COVID-19, the plastic waste collected was lower compared to 2022 because fewer people went out to gather or carry out shopping.

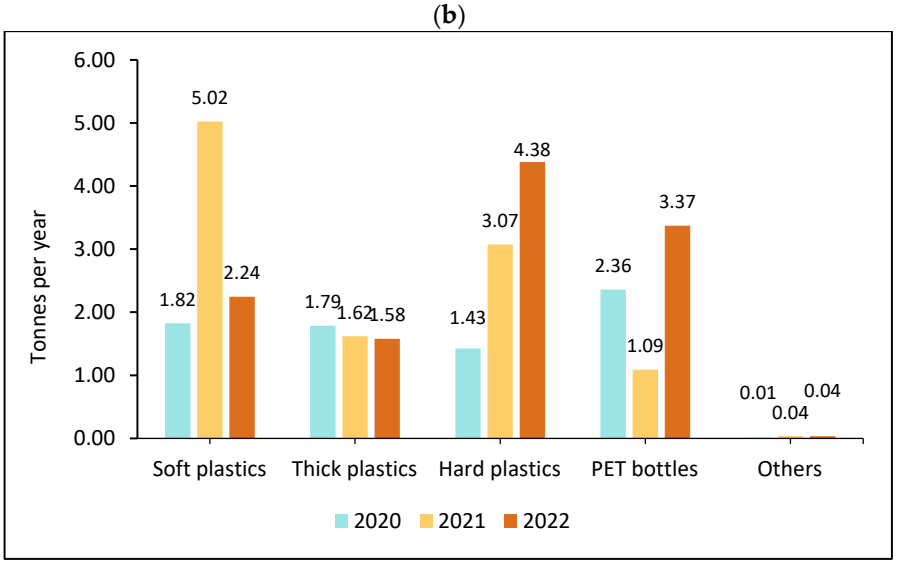
As the smallest-sized city, Magelang generates a relatively insignificant amount of plastic waste from consumer products, such as PET bottles or other rigid plastic food packaging (WBC3). This aligns with a previous study by Triasi et al., which found that urban areas tend to have a higher volume of recyclable waste, including plastic, than organic waste, compared to areas with lower population densities [128]. This trend is also attributed to the community's preference for home cooking, a practice where many cooking ingredients purchased from the market are commonly wrapped in transparent soft plastics (WBC3). Moreover, in 2021, the number of soft plastics collected was significantly increased due to the widespread use of plastic for wrapping food and other items to enhance hygiene during the COVID-19 pandemic (WBC3).



(**a**)



(**b**)



(**c**)

Figure 6. Plastic waste composition in the case studies: (**a**) in Bandung City; (**b**) in Yogyakarta City; (**c**) in Magelang City.

If we compare the final values (2022) to the initial values (2020), we can calculate the percentage increase in plastic waste materials for the case studies (see Figure 7). The chart indicates that in Bandung City, thick plastics and PET bottles experienced substantial increases of 31% and 29%, respectively, with hard plastics more than doubling in tonnage (108%). Meanwhile, Yogyakarta City showed the highest growth rate in thick plastics (32%), with moderate increases in hard plastics (19%) and PET bottles (12%). In Magelang City, PET bottles saw a significant rise of 43%, while the increase in hard plastics was remarkable, more than tripling the initial value at 206%. Furthermore, although Others also saw a high increase in tonnage over the two-year period, their total weight remains very small compared to other types. In conclusion, the case studies indicate that hard plastics, PET bottles, and thick plastics hold high potential as recyclable materials. Although not all types of rigid plastics are easily recyclable, they are of higher value and easier to collect rather than soft plastics [82,133]. Particularly, the recycling industry shows a strong interest in higher-value plastics, such as PET bottles and high-density polyethylene (HDPE) containers [134].

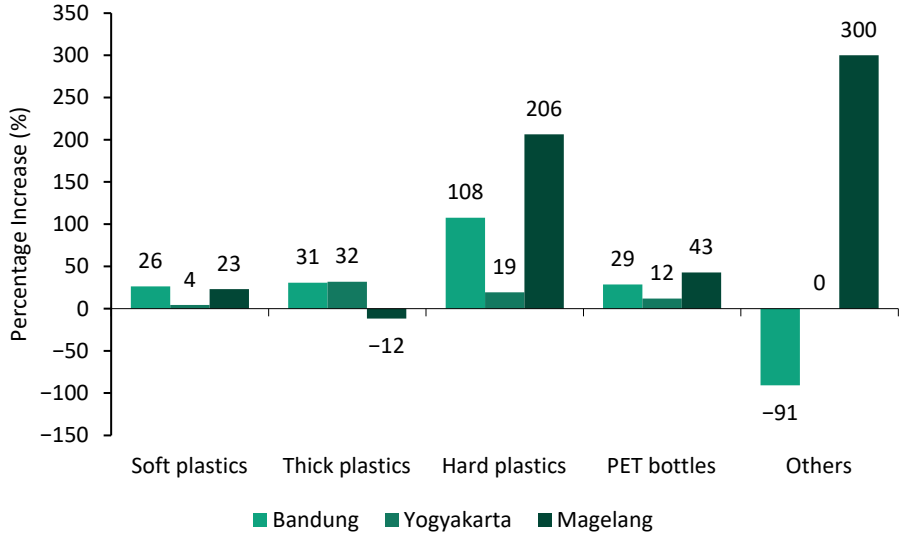


Figure 7. Percentage increase by plastic waste types in the case studies.

From the waste composition data in the case studies, it is evident that city characteristics such as size and population growth do not solely determine waste composition. However, specific local attributes, such as the fashion industry in Bandung, the educational environment in Yogyakarta, and also the availability of waste sorting infrastructure, could impact waste composition. In a smaller city like Magelang, local habits, such as a preference for home cooking, can lead to a high amount of soft plastic wastes.

It is obvious that the most crucial aspect of integrated waste management is characterizing waste to determine its fate [128]. Therefore, it is vital in these case studies to analyze waste composition data to identify which types of waste have high recycling potential, which materials are low value in the recycling chain [44], and which plastic wastes are problematic and require government intervention [135].

4.2.3. Challenges Involved with Plastic Waste Composition

The effective segregation of plastic waste is crucial for securing material supplies for the recycling industry (RC1). Separation not only facilitates easier recycling by preventing polymer contamination but also enhances market value, enabling use as pure substances or in new material blends [89]. In Yogyakarta and Magelang City, both DoEs have observed that plastic waste separation practices are still ineffective and not circular, leading to the majority of waste being disposed of in landfills (GOV2, GOV3, GOV7). In Bandung, GOV5 noted the beneficial role of waste pickers at TPS in recovering plastic waste, enabling it to

enter the recycling chain. However, this also indicates the lack of municipal involvement in enforcing effective segregation prior to waste collection. Moreover, the collection of plastic waste is difficult because individuals need to clean the plastics before selling them to waste banks or private collection services (WMC2). This is in contrast to paper waste, which does not require pre-cleaning and is therefore more frequently collected, as evidenced by the Rapel service's higher paper collection rates compared to plastic.

Several types of plastics are observed to be unrecoverable in the case studies (see Figure 8), owing to various factors. The small size of sachets makes them difficult to collect [134], the low weight and bulky nature of Styrofoam complicate its transfer, and the complex plastic content, such as in multilayer plastics or aluminum-coated plastics, hinders recycling. Plastic containers consisting of a single polymer are simpler and more economical to recycle [82]. On the other hand, multi-material plastics, such as multilayer sachets, are difficult to identify and standardize for recycling and remanufacturing [80]. Moreover, waste banks in the case studies generally accept only those wastes that middlemen are willing to buy, and middlemen in turn only take plastics that have a market demand. For instance, some middlemen accept plastic shopping bag waste, while others do not. This leads to variations and changes over time in the types of waste accepted at WBUs. In contrast, the waste collected by WBCs tends to be more consistent, partly due to local government initiatives promoting rejected-plastic-waste-type collection. On the other hand, as we discussed earlier in Section 4.1.3., a private waste management company also collects different types of plastic wastes, leading to the rejection of some.

Figure 8. Most rejected plastic waste in the case studies [136–138].

According to a plastic recycler (RC2) that is capable of recycling multilayer plastics and accepting plastic waste from Yogyakarta and Magelang Cities, businesses capable of recycling multilayer packaging in Central Java are very limited, mostly only focusing on waste that middlemen can purchase. RC2 transforms multilayer plastics into new products (see Figure S13). However, the owner acknowledged that their operation is small-scale, restricted by budget, recycling technology, lack of sorting machine machinery, and manpower limitations.

4.2.4. Challenges Involved with Collection and Transfer

In Yogyakarta City, the collection and delivery of recyclable plastic waste are primarily managed by middlemen (GOV2). Therefore, following the implementation of the GZSA Program, the middlemen have been overwhelmed with orders to collect waste from WBUs. As a result, the frequency of middlemen collecting waste from the WBUs has taken a longer time from once to twice a week. This change has led to WBUs needing to store waste for

longer periods, posing challenges due to limited storage capacities and potential damage from rain. Extended storage of plastic waste poses a significant fire hazard during the dry season (NGO2). On the other hand, Magelang and Bandung are facing additional problems related to small routes for collecting plastic waste from WBUs (WBC1, WBC3), resulting in difficult access that leads to longer collection times [44].

4.2.5. Challenges Involved with Treatment and Recycling Process

The effectiveness of the TPS3R is further compromised by inadequate staffing for waste segregation. In Yogyakarta, only 10% of the 3 tons of MSW entering the facility can proceed to the recycling chain, with the remainder sent to a landfill (GOV12). In Magelang, the TPS3R operations are not fully realized due to high operational costs, particularly for sorting machines that require electricity. On the other hand, the DoE in all three cities encourage WBUs to create handicrafts (see Figure S6) from rejected plastic waste, like sachets. However, not all WBUs have the necessary skills to undertake such activities (WBU5, WBU9). Moreover, most of these products face limitations in quality and cannot be mass-produced due to their handmade nature (RC2). The use of handicrafts made from recycled plastics is also not widespread within the community, resulting in a limited customer base. Most developing countries tried to produce eco-friendly bags using plastic packaging in the 2000s. Several communities successfully conducted a similar project such as KILUS in the Philippines, which created job opportunities for women and provided quality education to children [139]. However, this is not a fundamental solution to manage plastic waste for all local communities in developing countries.

4.3. Realities and Challenges of Sustainability Aspects

4.3.1. Political, Legal, Institutional

Politics inevitably plays an important role in improving waste management efficiency, and the relationship between central and local governments affects the overall system [44]. The political leadership within the cities and communities still plays a role in PWM in the case studies. Changes in mayoral leadership may disrupt well-established waste management programs due to new leaders often not adhering to their predecessors' policies, leading to a lack of program sustainability. Moreover, there have been instances where neighborhood–community leaders show indifference to the establishment of waste banks, thus affecting community compliance with waste collection. YPBB has observed that waste management in Indonesia frequently becomes politicized, with crisis-driven solutions fostering short-term perspectives (NGO1). Moreover, the next challenge is the inadequate enforcement of waste segregation laws. Related to the Kang Pisman project, YPBB argues that community spirit alone cannot sustain this project; it requires government intervention and strict law enforcement to ensure compliance with waste segregation practices. However, YPBB has noted the local government's budgetary constraints in monitoring adherence to the Kang Pisman project, which leads to the lack of implementation of comprehensive programs for improving PWM efficiency [44].

A following obstacle is the lack of specific national policy regulating the collection and recycling process of individual products of plastic waste, as plastic waste is generally regulated under the MSW policy (see Figure S14). Although MoEF Regulation No. P.75/2019 related to EPR has been enacted, it is still in the stage of preparing a waste reduction plan document by producers [135]. Therefore, it is necessary to regulate the properties of individual plastic post-consumer products, as observed in Japan [70]. On the other hand, it is observed that only Bandung City has enacted plastic bag reduction policy at the level of local regulation. Such legal gaps in PWM present challenges such as a limited market for recycled products (GOV5, NGO2).

In Yogyakarta, there is a shortfall in follow-up actions after plastic waste collection by WBUs. The DoE of Yogyakarta City should investigate the types of waste collected by WBUs instead of simply selling it to middlemen (GOV2). Moreover, in the case studies,

there is no subsequent action by local government regarding the plastic waste composition data from the waste banks for evaluating overall consumption in the cities.

4.3.2. Environmental/Health

In TPS3R facilities, workers are observed to be at risk of injury from sharp objects while manually separating plastic waste from mixed MSW (see Figure 9a). This manual sorting process not only generates unpleasant odors but also poses daily health risks to workers. Furthermore, the working conditions at a TPS3R struggle to maintain cleanliness due to the mixing of organic and plastic wastes (see Figure 9b). Moreover, a TPS3R in Yogyakarta City also has a significant accumulation of mixed plastic waste on the floor, leading to a dirty environment and unpleasant working conditions (see Figure S15a). In contrast, the TPS3R in Magelang City demonstrates better practices with the use of divided bins for separating plastic waste (see Figure S15b).

(**a**) (**b**)

Figure 9. A TPS3R facility in Magelang City: (**a**) waste workers manually sort plastic waste from mixed MSW; (**b**) the situation of the TPS3R sorting area.

Additionally, the sorting activities at waste banks and in the PDU in Bandung City reveal challenges, such as when workers are required to cut and separate plastic drink cups from their lids without any protective kits, which can expose them to potential harm from the sharp tools and contamination from the waste (see Figure S16a). Moreover, a private waste management company encounters difficulties with its open space storage, which not only exposes plastic waste to weather damage but also complicates the sorting of plastics wastes by type (WMC3) (see Figure S16b).

4.3.3. Financial and Technical

The first challenge regarding the financial aspect is regarding the low waste retribution from the community, leading to an insufficient budget for waste treatment. Meanwhile, retribution should be the backbone of the system (GOV1). In the three case studies, community retribution for MSW management ranged only from IDR 2000 to IDR 30,000. This amount is inadequate for operating a sanitary landfill, which requires a budget approximately ten times greater than the current retribution scheme. Even for operating open dumping landfills, the current retribution falls short, with the gap being filled by the provincial government's budget.

Furthermore, the limited local budget allocated for waste management could lead to resources constrained for TPS3R and infrastructure facilities for waste banks, consequently reducing plastic waste recovery in the cities. For example, in Bandung and Yogyakarta Cities, the conveyor belts used for waste sorting are not optimally designed for the site conditions or the available workforce. In Bandung, the effective operation of the conveyor

belt requires at least ten people, but with only four workers available, the belt often goes unused (see Figure S17a). Meanwhile, in Yogyakarta, the existing 4 m long sorting conveyors are too short and fast for effective waste sorting, suggesting that a length of 10 to 15 m would be more suitable (see Figure S17b). GOV1 suggests that the ideal local budget range for WM should be between 2% and 3%. However, in the case studies, Bandung City allocated only 1.2% of its local budget to the WM sector [140], while Yogyakarta and Magelang allocated 1.04% [141] and 1% (GOV7), respectively.

Another issue pertains to the instability of plastic waste prices, which poses a challenge for waste banks and the private sector when setting prices for the community. During the data collection, it was observed that the price of plastic waste was decreasing. This decline was attributed to an oversupply of materials in the industry (GOV6), and the influx of imported plastic waste, which lowers the price of local plastic waste (WBC3). Additionally, global market dynamics, particularly fluctuations in oil prices, also play a role (NGO2 and RC1). This price volatility can also lead to operational challenges for waste banks. Sometimes, middlemen were unwilling to purchase plastic waste when prices were too low (WBC3), causing waste accumulation in waste banks.

Further challenges related to a technical aspect. Case studies show the inadequate facilities for separating different types of plastic waste from other materials at TPSs and in the waste trucks that transport the MSW. Moreover, in a TPS3R in Magelang City, the technology used to recover flexible plastic waste from mixed MSW has faced several breakdowns due to the presence of hard waste, such as animal bones or small bolts. Furthermore, the limitation of plastic waste processing equipment in a TPS3R can hinder the production of value-added recycled products, resulting in a low return on investment [28]. For instance, in Bandung, the technological capabilities include shredding and compressing of plastic waste (see Figure S18); however, the shredding facility is often underused due to workforce and space limitations (WBC1). Meanwhile, TPS3R facilities in Yogyakarta and Magelang are equipped only with compressing technology.

In addition, space limitation also affects WBUs that often need to provide their own space for activities and waste storage. Interviews revealed that most WBUs are located in the homes of their leaders, and the absence of dedicated space can hinder the establishment of new waste banks.

4.3.4. Socio-Cultural

In Bandung City, since the establishment of the KBS and Kang Pisman projects, plastic waste management has significantly improved through communal activities in each RW (GOV5). There is strong collaboration between communities, fostering an effective system for managing their waste. Additionally, it has been observed that communities in Bandung are not overly concerned with the fluctuating prices of plastic waste in waste banks (WBU1, WBU3).

In Yogyakarta City, the strength of cooperation within communities and the dedicated efforts of waste bank committees have contributed to the sustainability of waste bank initiatives. A waste bank leader in Yogyakarta shared that the waste bank has survived for 11 years, primarily due to strong neighborhood support and residents' willingness to participate in waste separation (WBU6). However, interviews reveal that despite the numerous waste banks in Yogyakarta, many residents still resist collecting their plastic waste, choosing instead to dispose of it in a mixed manner where the majority ends up in landfills. Moreover, Yogyakarta's status as a cultural heritage city attracts numerous tourists, leading to increased waste generation. Being a tourist destination could also create more opportunities for recycling plastic waste in the city [142]. Unfortunately, the majority of plastic waste in the public or tourist areas is not disposed separately (GOV6, WBU5), highlighting the municipal system's inadequacy in managing waste segregation in public areas. However, in Yogyakarta, fluctuations in plastic waste prices do not significantly affect community willingness to segregate waste (WBU6, WBU8, WBU11).

Meanwhile, in Magelang City, community habits regarding plastic waste are still problematic. Residents often treat plastic waste as single-use and do not segregate it (GOV7, WBU12, WBU15). According to the leader of the WBC, the volatility of plastic prices affects people's behavior in waste segregation. The leader of a WBU also mentioned that people are motivated to join the waste bank due to small rewards offered by the committee. Yet, some areas report that their residents are not influenced by price fluctuations (WBU12, WBU14).

Across the three cities, one significant challenge consistently mentioned by the stakeholders is the lack of citizen awareness regarding waste segregation. However, fostering awareness involves more than just public education; it also requires improvements in the MSW system to efficiently handle separated plastic waste. This underscores the idea that while community awareness and willingness to segregate waste are essential, these efforts would be ineffective if the waste management infrastructure is not adequately equipped to process segregated waste.

5. Discussion

5.1. Is the Current Plastic Waste Management Transitioning to An Integrated System?

For a system to qualify as integrated, it needs to be inclusive, financially sustainable, and rest on a base of sound institution and proactive policies [58,59]. In the case studies, while the practice of sorting plastic waste for recovery is observed, with waste directed either to waste banks or private waste management, the distribution of these services is not widespread and remains limited. Consequently, most of the community still disposes of plastic waste mixed with other MSW. This scenario does not align with the principle of user inclusivity that stipulates that all waste generators should have their waste removed regularly and reliably [59] (p. 143).

Furthermore, financial sustainability in waste management is a demand-driven business, a policy-driven activity, and a public good [59]. Related to resource management, recycling occurs primarily for two economic reasons: either for the market value of secondary materials as a business or as a policy-driven activity aimed at avoiding the costs associated with disposal [59] (p. 169). The case studies indicate that several types of plastic waste commonly used in society are not recovered, showing that plastic waste management predominantly functions as a market-driven activity. As recycling should be pursued regardless of market conditions [30], therefore, in the case studies, policy intervention is further needed to enforce the management of rejected plastics [135].

The third aspect concerns sound institutions and proactive policies. In the case studies, the commitment of city leaders and the DoE to sustainable waste management and resource recycling is pronounced. However, this dedication is not consistently reflected by the community leaders in some areas in the cities, which can result in minimal support from the ward government for waste bank activities. On the other hand, unlike Bandung and Yogyakarta that already enacted a solid waste master plan as a mayor regulation, Magelang City has yet to formalize such a regulation. It currently exists only as an office document (GOV7); formalizing this into a mayor regulation would strengthen the efforts towards resource recycling and an integrated approach to waste management.

To sum up, there is a noticeable positive trend in the plastic waste management towards an integrated system, as evidenced by the promotion of the 3Rs through various programs and the enactment of local policies. However, this system cannot yet be characterized as fully integrated, since the ISWM concept emphasizes that local solutions should be tailored to local problems, suggesting that a uniform approach may not always be effective. Therefore, a multi-stakeholder approach, tailored to the specific needs and conditions of each city, is essential, which will be further discussed in the next section.

5.2. The Cooperation of Government, Community, and Private Sectors

In order to achieve a truly inclusive system, provider inclusivity is equally important [60]. Provider inclusivity entails enabling non-governmental stakeholders to initiate WM activities and inviting their participation in the system [59] (p. 169). The DoE in the

case studies appears to emphasize the role of waste banks in collecting plastic waste; however, it does not pay much attention to the existing role of the private sector. The current private waste management companies in developing countries that utilize digitalization not only facilitate the recovery of recyclable materials but also enable community involvement through online transactions via mobile apps for waste collection [21]. Moreover, it was observed that private sectors continued plastic waste collections even during the COVID-19 pandemic, unlike many waste banks, which became mostly inactive. Therefore, engaging the private waste management company in the city's plastic waste flow is crucial to maximize plastic waste collection.

Integrating the private sector into the municipal collection system also implies an expansion of the local government's role, transforming it into a contracting body in addition to its primary responsibility of providing services tailored to local needs [58]. The integration of PWM efforts also necessitates the DoE, as the local government body primarily responsible for WM, to ensure minimal or ideally no disposal of recyclable plastic waste mixed with MSW. The current situation still provides households with the option to dispose it with other mixed MSW, which is collected by municipal services. Thus, there is a need for a firm commitment to policy enforcement and education across various platforms, including both conventional door-to-door methods and digital learning initiatives.

However, the extent of integration should align with the local needs and financial conditions of each city. It is essential to foster cooperation beyond the three stakeholders mentioned above, to realize a penta-helix approach involving public entities, private sectors, academia, civil society, and waste management entrepreneurs and/or environmental activists [143]. Effective communication among all players in the system is crucial for building a robust ISWM. Reliable and accurate data from key stakeholders, such as local governments, community waste banks, private sectors, and academics, are necessary to develop a data-driven PWM scheme that gains acceptance across all involved parties.

5.3. Limitation and Future Research

This study is subject to certain limitations. First, the primary focus is on the three key actors in PWM: the government, waste banks, and the private sector. However, it is important to note that a variety of other formal and informal private actors also play significant roles in the case studies but were not the main focus of this analysis. Second, this study encompasses observations from only three private waste management companies, which limits the breadth of the analysis within the private sector. Third, the research only considers plastic waste data collected in waste banks. Consequently, these findings should not be generalized as representative of the overall plastic waste generation and composition in each of the cities studied.

The limitations and findings of this study pave the way for future research opportunities. Firstly, since the primary nature of this research is a qualitative analysis, its findings may not be broadly generalizable to all developing countries. Future research should therefore encompass a more extensive range of cities and countries to analyze PWM practices considering their unique local realities and challenges. Secondly, upcoming studies could expand on this research by exploring the integration of both informal and formal private sectors into the current community waste bank collection systems. Thirdly, given the exploratory nature of this research based on a case study approach, there is room for future explanatory research. This could involve conducting surveys to quantitatively assess the current state of PWM to provide more definitive insights.

6. Conclusions

It is clear that plastic waste management poses a global challenge, especially in urban areas of developing countries. This study employs the integrated sustainable waste management (ISWM) framework to analyze plastic waste management strategies in three urban areas of Indonesia: Bandung, Yogyakarta, and Magelang City. The Department of Environment, as the main local government body responsible for waste management, has

made significant efforts to improve the system and educate the public on waste separation. Waste banks focus on collecting plastic waste from communities, while private waste management companies play a crucial role by integrating digital transformation strategies to collect waste from diverse sources. However, it has been observed that waste collection among these stakeholders is not integrated, leading to mixed disposal methods with the majority ending up in landfills.

This study also analyzed the flow and composition of plastic waste, revealing that in 2022, the predominant types of plastic collected at waste banks in Bandung, Yogyakarta, and Magelang City were soft plastics, thick plastics, and hard plastics, respectively. The data show that hard plastics, PET bottles, and thick plastics have high potential as recyclable materials. However, certain types such as multilayer plastics, instant noodle packaging, Styrofoam, clear thin food packaging, pouches for refillable products, and bottle labels are predominantly rejected. Several sustainability challenges were identified across different aspects. Politically, legally, and institutionally, challenges include political instability and low enforcement of waste segregation laws. Environmentally, issues arise from poor working conditions at waste facilities, which can affect workers' health and degrade material quality, along with unsafe plastic sorting activities. Financially and technically, the system struggles with budget constraints and technical handling of waste. Socio-culturally, inconsistent recycling behaviors and low waste separation rates further complicate the situation.

This study concludes that while there are positive trends toward an integrated system in plastic waste management, the system cannot yet be characterized as fully integrated due to various deficiencies, including solutions that are not adapted to local contexts and a lack of multi-stakeholder cooperation. Utilizing these findings, local governments and private sectors involved in waste management can re-evaluate their approaches through the ISWM method, particularly to maximize plastic waste collection. Such considerations have the potential to improve plastic waste management in cities at various levels and with different characteristics, offering valuable insights for other developing countries facing similar challenges.

7. Recommendation

Based on the analysis results, it is evident that the three stakeholders (the DoE, waste bank, and private waste management company) operate unintegrated in the collection of plastic waste. It is indeed a crucial aspect to develop interdisciplinary collaboration to formulate comprehensive solutions for plastic waste management [144]. Despite local governments endorsing plastic waste collection through community waste banks, there is currently no system in place to integrate waste bank collections with municipal collections. As a result, many residents still dispose of valuable plastic waste in regular dustbins along with other mixed MSW. Furthermore, the analysis of plastic waste composition reveals that each stakeholder accepts different types of plastic, primarily those that have market value. This discrepancy leads to certain types of plastic waste remaining unrecovered and being dumped in landfills or the environment. Additionally, the analysis of sustainability aspects highlights several factors that do not align with the local conditions of each city, further hindering progress towards sustainability. Therefore, this research proposes that there should be integration among the three stakeholders in the plastic waste collection system.

In Bandung City, the recovery of plastic waste can be enhanced through waste banks with the support of private sectors. Bandung City already has a promising Kang Pisman program; however, there is a lack of a feature in the system that can distribute the concept to all 191 wards in the city (GOV5). Therefore, private sector services can set up waste transfer stations in areas where waste banks are not active. This allows the local government to work with the private waste management company in engaging local people to organize the collected plastic waste and upload it to the company's app for later pickup and recycling. The app could facilitate waste characterization by allowing residents to upload details of their plastic waste, including type and weight, which would then inform private waste collectors when to pick up the waste. Areas with active WBUs can continue their

current practice of selling collected waste from the community to the WBC. This shared responsible strategy allows the local government to focus on strengthening the policy of waste segregation across the city, rather than solely focusing on educating the community about Kang Pisman. The role of government control of the current waste management policies is vital to the success of the project.

In Yogyakarta City, given that the GZSA project is relatively new and currently exists only as a circular letter, it should be escalated to a mayor's regulation to ensure stronger enforcement. As Yogyakarta has the highest number of WBUs compared to other cities and the community is already familiar with the concept, the waste bank should be the primary mechanism for plastic waste collection. However, due to the city's popularity with tourists, it is also vital to involve a private waste management company in providing plastic waste drop points in public spaces. This will enable visitors to dispose of their plastic waste responsibly. Additionally, since some WBUs experience challenges in locating waste buyers due to the limited capacity of middlemen, it is crucial for the DoE to facilitate cooperation between a WBU and the private waste management company. Although some private sector entities are already collecting waste from certain WBUs, this study revealed that some WBUs are still unaware of these private sector services.

Lastly, in Magelang City, a smaller urban area with limited private sector options, it was noted that most WBUs interviewed were not aware of private sector involvement in waste management. Thus, this study proposes a focus on establishing more WBUs throughout the city, positioning waste banks as the dominant force in plastic waste recovery. Given that the WBC in Magelang has been established for a longer period compared to the other cities studied, it should be well equipped to lead and support other WBUs. This approach would allow the WBC to not only act as a waste aggregator but also focus more on educating the community about waste separation. The responsibility of collecting waste from a WBU could be shared through cooperation with local middlemen, thereby fostering joint efforts.

These systemic changes lay the groundwork for a more effective and sustainable approach to plastic waste management. Moreover, it is essential to understand the local conditions and assess the waste composition data to plan the suitable system of plastic waste management in each city. To visually represent these strategies, the recommended flow of plastic waste in these case studies is illustrated in Figure 10.

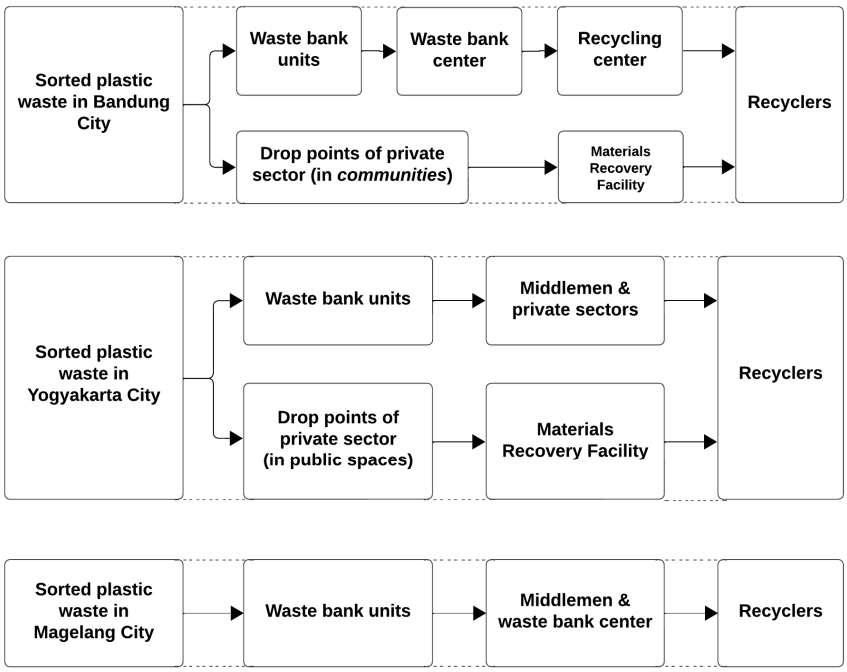


Figure 10. Recommendation of plastic waste flow in the case studies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16103921/s1, Figures S1–S18 and Tables S1–S6. References [145–147] are mentioned in Supplementary Materials.

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References

1. Gautam, M.; Agrawal, M. Greenhouse Gas Emissions from Municipal Solid Waste Management: A Review of Global Scenario. In *Carbon Footprint Case Studies: Municipal Solid Waste Management, Sustainable Road Transport and Carbon Sequestration*; Muthu, S.S., Ed.; Springer: Singapore, 2021; pp. 123–160.
2. Kaza, S.; Yao, L.C.; Bhada-Tata, P.; Van Woerden, F. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*; World Bank Publications: Washington, DC, USA, 2018.
3. OECD Environment. Available online: https://www.oecd.org/environment/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm (accessed on 28 April 2024).
4. World Bank. *Plastic Waste Discharges from Rivers and Coastlines in Indonesia*; World Bank: Washington, DC, USA, 2021.
5. Ministry of Environment and Forestry of Indonesia. National Waste Management Information System (Sistem Informasi Pengelolaan Sampah Nasional-SIPSN). Available online: https://sipsn.menlhk.go.id/ (accessed on 1 October 2023).
6. Lestari, P.; Trihadiningrum, Y. The impact of improper solid waste management to plastic pollution in Indonesian coast and marine environment. *Mar. Pollut. Bull.* **2019**, *149*, 110505. [CrossRef]
7. World Economic Forum. Radically Reducing Plastic Pollution in Indonesia: A Multistakeholder Action Plan. 2020. Available online: https://pacecircular.org/sites/default/files/2021-03/NPAP-Indonesia-Multistakeholder-Action-Plan_April-2020_compressed%20(1).pdf (accessed on 10 November 2023).
8. Damanhuri, E.; Handoko, W.; Padmi, T. Municipal Solid Waste Management in Indonesia. In *Municipal Solid Waste Management in Asia and the Pacific Islands: Challenges and Strategic Solutions*; Pariatamby, A., Tanaka, M., Eds.; Springer: Singapore, 2014; pp. 139–155.
9. Andriani, D.; Atmaja, T.D. The potentials of landfill gas production: A review on municipal solid waste management in Indonesia. *J. Mater. Cycles Waste Manag.* **2019**, *21*, 1572–1586. [CrossRef]
10. Damanhuri, E.; Padmi, T. The Role of Informal Collectors of Recyclable Waste and Used Goods in Indonesia. In *Post-Consumer Waste Recycling and Optimal Production*; Damanhuri, E., Ed.; IntechOpen: Rijeka, Croatia, 2012; p. Ch. 2.
11. Putri, A.R.; Fujimori, T.; Takaoka, M. Plastic waste management in Jakarta, Indonesia: Evaluation of material flow and recycling scheme. *J. Mater. Cycles Waste Manag.* **2018**, *20*, 2140–2149. [CrossRef]
12. Government of Indonesia. Enhanced Nationally Determined Contribution Republic of Indonesia. 2022. Available online: https://unfccc.int/sites/default/files/NDC/2022-09/23.09.2022_Enhanced%20NDC%20Indonesia.pdf (accessed on 5 October 2023).
13. Ministry of Environment and Forestry of Indonesia. National Plastic Waste Reduction Strategic Actions for Indonesia. 2020. Available online: https://www.unep.org/ietc/resources/policy-and-strategy/national-plastic-waste-reduction-strategic-actions-indonesia (accessed on 3 August 2023).
14. Ministry of Environment and Forestry of Indonesia. Gerakan Nasional Pilah Sampah Dari Rumah Resmi Diluncurkan. Available online: https://ppid.menlhk.go.id/berita/siaran-pers/5068/gerakan-nasional-pilah-sampah-dari-rumah-resmi-diluncurkan (accessed on 5 December 2023).
15. Anschütz, J.; IJgosse, J.; Scheinberg, A. *Putting Integrated Sustainable Waste Management into Practice: Using the ISWM Assessment Methodology: ISWM Methodology as Applied in the UWEP Plus Programme (2001–2003)*; WASTE: Gouda, The Netherlands, 2004.
16. van de Klundert, A.; Anschütz, J. *Integrated Sustainable Waste Management–The Concept*; WASTE: Gouda, The Netherlands, 2001.

17. Filho, W.L.; Brandli, L.; Moora, H.; Kruopiene, J.; Stenmarck, Å. Benchmarking Approaches and Methods in the Field of Urban Waste Management. *J. Clean. Prod.* **2016**, *112*, 4377–4386. [CrossRef]
18. Ezeah, C.; Fazakerley, J.A.; Roberts, C.L. Emerging Trends in Informal Sector Recycling in Developing and Transition Countries. *Waste Manag.* **2013**, *33*, 2509–2519. [CrossRef]
19. Brasika, I.B.M.; Hendrawan, I.G.; Karang, I.W.G.A.; Pradnyaswari, I.G.A.I.; Pratiwi, N.P.O.M.K.; Wiguna, I.G.M. Evaluating the collection and composition of plastic waste in the digital waste bank and the reduction of potential leakage into the ocean. *Waste Manag. Res.* **2023**, *41*, 676–686. [CrossRef] [PubMed]
20. Kubota, R.; Horita, M.; Tasaki, T. Integration of community-based waste bank programs with the municipal solid-waste-management policy in Makassar, Indonesia. *J. Mater. Cycles Waste Manag.* **2020**, *22*, 928–937. [CrossRef]
21. Kurniawan, T.A.; Dzarfan Othman, M.H.; Hwang, G.H.; Gikas, P. Unlocking digital technologies for waste recycling in Industry 4.0 era: A transformation towards a digitalization-based circular economy in Indonesia. *J. Clean Prod.* **2022**, *357*, 131911. [CrossRef]
22. Damanhuri, E.; Wahyu, I.M.; Ramang, R.; Padmi, T. Evaluation of municipal solid waste flow in the Bandung metropolitan area, Indonesia. *J. Mater Cycles Waste Manag.* **2009**, *11*, 270–276. [CrossRef]
23. Nanda, S.; Berruti, F. Municipal solid waste management and landfilling technologies: A review. *Environ. Chem Lett.* **2021**, *19*, 1433–1456. [CrossRef]
24. Azevedo, B.D.; Scavarda, L.F.; Caiado, R.G.G. Urban solid waste management in developing countries from the sustainable supply chain management perspective: A case study of Brazil's largest slum. *J. Clean Prod.* **2019**, *233*, 1377–1386. [CrossRef]
25. Ferronato, N.; Torretta, V. Waste Mismanagement in Developing Countries: A Review of Global Issues. *Int. J. Environ. Res. Public Health* **2019**, *16*, 1060. [CrossRef] [PubMed]
26. Batista, M.; Goyannes Gusmão Caiado, R.; Gonçalves Quelhas, O.L.; Brito Alves Lima, G.; Leal Filho, W.; Rocha Yparraguirre, I.T. A framework for sustainable and integrated municipal solid waste management: Barriers and critical factors to developing countries. *J. Clean. Prod.* **2021**, *312*, 127516. [CrossRef]
27. Tong, Y.D.; Huynh, T.D.X.; Khong, T.D. Understanding the role of informal sector for sustainable development of municipal solid waste management system: A case study in Vietnam. *Waste Manag.* **2021**, *124*, 118–127. [CrossRef] [PubMed]
28. Ono, S.; Hewage, H.T.S.A.; Visvanathan, C. Towards Plastic Circularity: Current Practices in Plastic Waste Management in Japan and Sri Lanka. *Sustainability* **2023**, *15*, 7550. [CrossRef]
29. Gunarathne, A.D.N.; Tennakoon, T.P.Y.C.; Weragoda, J.R. Challenges and opportunities for the recycling industry in developing countries: The case of Sri Lanka. *J. Mater. Cycles Waste Manag.* **2019**, *21*, 181–190. [CrossRef]
30. Azevedo, B.D.; Scavarda, L.F.; Caiado, R.G.G.; Fuss, M. Improving urban household solid waste management in developing countries based on the German experience. *Waste Manag.* **2021**, *120*, 772–783. [CrossRef] [PubMed]
31. Tran, V.C.M.; Le, H.S.; Matsui, Y. Current status and behavior modeling on household solid-waste separation: A case study in Da Nang city, Vietnam. *J. Mater. Cycles Waste Manag.* **2019**, *21*, 1462–1476. [CrossRef]
32. Pharino, C. Integrated Waste Management System Overview. In *Challenges for Sustainable Solid Waste Management: Lessons from Thailand*; Pharino, C., Ed.; Springer: Singapore, 2017; pp. 1–13.
33. Agamuthu, P.; Babel, S. Waste management developments in the last five decades: Asian perspective. *Waste Manag. Res.* **2023**, *41*, 1699–1716. [CrossRef] [PubMed]
34. Serrona, K.R.; Yu, J. Finding urban waste management solutions and policies: Waste-to-energy development and livelihood support system in Payatas, Metro Manila, Philippines. *J. Environ. Sci.* **2009**, *21*, S40–S43. [CrossRef]
35. Serrona, K.R.B.; Yu, J.; Aguinaldo, E.; Florece, L.M. Developing a monitoring and evaluation framework to integrate and formalize the informal waste and recycling sector: The case of the Philippine National Framework Plan. *Waste Manag. Res.* **2014**, *32*, 882–895. [CrossRef]
36. Vij, D. Urbanization and Solid Waste Management in India: Present Practices and Future Challenges. *Procedia Soc. Behav. Sci.* **2012**, *37*, 437–447. [CrossRef]
37. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Country Profile Vietnam. 2018. Available online: https://www.giz.de/en/downloads/giz2018_Vietnam-Country-Profile_web.pdf (accessed on 7 February 2024).
38. Pheakdey, D.V.; Van Quan, N.; Khanh, T.D.; Xuan, T.D. Challenges and Priorities of Municipal Solid Waste Management in Cambodia. *Int. J. Environ. Res. Public Health* **2022**, *19*, 8458. [CrossRef] [PubMed]
39. Mourshed, M.; Masud, M.H.; Rashid, F.; Joardder, M.U.H. Towards the Effective Plastic Waste Management in Bangladesh: A Review. *Environ. Sci. Pollut. Res.* **2017**, *24*, 27021–27046. [CrossRef] [PubMed]
40. Jain, A. Waste Management in ASEAN Countries. 2017. Available online: https://www.unep.org/resources/report/waste-management-asean-countries-summary-report (accessed on 20 October 2023).
41. Darus, N.; Tamimi, M.; Tirawaty, S.; Muchtazar, M.; Trisyanti, D.; Akib, R.; Condorini, D.; Ranggi, K. An overview of plastic waste recycling in the urban areas of Java Island in Indonesia. *J. Environ. Sci. Sustain. Dev.* **2020**, *3*, 402–415. [CrossRef]
42. Aprilia, A. Waste Management in Indonesia and Jakarta: Challenges and Way Forward. In Proceedings of the 23rd ASEF Summer University, Virtual, 20 September–15 November 2021; pp. 1–18.
43. Sembiring, E.; Nitivattananon, V. Sustainable solid waste management toward an inclusive society: Integration of the informal sector. *Resour Conserv. Recycl.* **2010**, *54*, 802–809. [CrossRef]
44. Mmereki, D.; Baldwin, A.; Li, B. A comparative analysis of solid waste management in developed, developing and lesser developed countries. *Environ. Technol. Rev.* **2016**, *5*, 120–141. [CrossRef]

45. Chaerul, M.; Fahruroji, A.R.; Fujiwara, T. Recycling of plastic packaging waste in Bandung City, Indonesia. *J. Mater. Cycles Waste Manag.* **2014**, *16*, 509–518. [CrossRef]
46. Jambeck, J.R.; Geyer, R.; Wilcox, C.; Siegler, T.R.; Perryman, M.; Andrady, A.; Narayan, R.; Law, K.L. Plastic waste inputs from land into the ocean. *Science* **2015**, *347*, 768–771. [CrossRef] [PubMed]
47. CNN Indonesia. TPA Piyungan Ditutup, DI Yogyakarta Terancam Darurat Sampah. 2023. Available online: https://www.cnnindonesia.com/nasional/20230725154639-20-977652/tpa-piyungan-ditutup-di-yogyakarta-terancam-darurat-sampah (accessed on 30 November 2023).
48. Ramdhani, Arief: Sudah Melebihi Kapasitas, Area Tampung TPA Sarimukti di Bandung Barat Diperluas. 2023. Available online: https://bandung.kompas.com/read/2023/05/10/153150178/sudah-melebihi-kapasitas-area-tampung-tpa-sarimukti-di-bandung-barat?page=all%5C (accessed on 30 November 2023).
49. Aida, P. 5 Kebakaran TPA di Indonesia Selama September 2023. 2023. Available online: https://www.kompas.com/tren/read/2023/09/20/103000265/5-kebakaran-tpa-di-indonesia-selama-september-2023?page=all (accessed on 30 November 2023).
50. Ramadhan. BNPB: Ada 14 Kejadian Kebakaran TPA Sampah Sepanjang Juni-Oktober 2023. 2023. Available online: https://www.antaranews.com/berita/3778569/bnpb-ada-14-kejadian-kebakaran-tpa-sampah-sepanjang-juni-oktober-2023 (accessed on 30 November 2023).
51. Ruhulessin. Sepanjang 2023, 14 TPA di Indonesia Alami Kebakaran. 2023. Available online: https://www.kompas.com/properti/read/2023/10/11/103000821/sepanjang-2023-14-tpa-di-indonesia-alami-kebakaran#google_vignette (accessed on 30 November 2023).
52. Turner, D.A.; Williams, I.D.; Kemp, S. Greenhouse gas emission factors for recycling of source-segregated waste materials. *Resour Conserv. Recycl.* **2015**, *105*, 186–197. [CrossRef]
53. Pariatamby, A.; Fauziah, S.H. Sustainable 3R Practice in the Asia and Pacific Regions: The Challenges and Issues. In *Municipal Solid Waste Management in Asia and the Pacific Islands: Challenges and Strategic Solutions*; Pariatamby, A., Tanaka, M., Eds.; Springer: Singapore, 2014; pp. 15–40.
54. Takeda, N.; Wang, W.; Takaoka, M. *Solid Waste Management*; Kyoto University Press: Kyoto, Japan, 2014.
55. JICA (Japan International Cooperation Agency). The Study on National Waste Minimisation in Malaysia. 2006. Available online: https://openjicareport.jica.go.jp/pdf/11831229.pdf (accessed on 4 December 2023).
56. Hoornweg, D.; Bhada-Tata, P. What a Waste: A Global Review of Solid Waste Management. 2012. Available online: https://policycommons.net/artifacts/1513146/what-a-waste/2185670/ (accessed on 4 December 2023).
57. Guerrero, L.A.; Maas, G.; Hogland, W. Solid waste management challenges for cities in developing countries. *Waste Manag.* **2013**, *33*, 220–232. [CrossRef]
58. Wilson, D.C.; Velis, C.A.; Rodic, L. Integrated sustainable waste management in developing countries. *Proc. Inst. Civ. Eng. Waste Resour. Manag.* **2013**, *166*, 52–68. [CrossRef]
59. UN-Habitat. Solid Waste Management in the World's Cities: Water and Sanitation in the World's Cities 2010. Earthscan. 2010. Available online: https://unhabitat.org/solid-waste-management-in-the-worlds-cities-water-and-sanitation-in-the-worlds-cities-2010-2 (accessed on 17 December 2023).
60. Wilson, D.C.; Rodic, L.; Scheinberg, A.; Velis, C.A.; Alabaster, G. Comparative analysis of solid waste management in 20 cities. *Waste Manag. Res.* **2012**, *30*, 237–254. [CrossRef] [PubMed]
61. Damanhuri, E.; Padmi, T. Current Situation of Waste Recycling in Indonesia. In *3R Policies for Southeast and East Asia*; Kojima, M., Damanhuri, E., Eds.; ERIA: Jakarta, Indonesia, 2009; pp. 23–52.
62. Shekdar, A.V. Sustainable solid waste management: An integrated approach for Asian countries. *Waste Manag.* **2009**, *29*, 1438–1448. [CrossRef] [PubMed]
63. Kashyap, P.; Visvanathan, C. Formalization of Informal Recycling in Low-Income Countries. In *Municipal Solid Waste Management in Asia and the Pacific Islands: Challenges and Strategic Solutions*; Pariatamby, A., Tanaka, M., Eds.; Springer: Singapore, 2014; pp. 41–60.
64. Putra, H.P.; Damanhuri, E.; Sembiring, E. Integration of formal and informal sector (waste bank) in waste management system in Yogyakarta, Indonesia. In *MATEC Web of Conferences*; EDP Sciences: Les Ulis, France, 2018; p. 02007.
65. Jatmika, B.; Sekito, T.; Dote, Y.; Subanu, L.P. Community-Based Waste Management in Magelang Municipality Indonesia. 2016. Available online: http://library.jsce.or.jp/jsce/open/00074/2016/60-07-0010.pdf (accessed on 3 January 2024).
66. Prata, J.C.; Patrício Silva, A.L.; da Costa, J.P.; Mouneyrac, C.; Walker, T.R.; Duarte, A.C.; Rocha-Santos, T. Solutions and Integrated Strategies for the Control and Mitigation of Plastic and Microplastic Pollution. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2411. [CrossRef] [PubMed]
67. Žmak, I.; Hartmann, C. Current state of the plastic waste recycling system in the European Union and in Germany. *Teh. Glas.* **2017**, *11*, 138–142.
68. Schmidt, S.; Laner, D. The environmental performance of plastic packaging waste management in Germany: Current and future key factors. *J. Ind. Ecol.* **2023**, *27*, 1447–1460. [CrossRef]
69. Allen-Taylor, K.O. A study of the extended producer responsibility (epr) scheme for plastic waste management in germany. *J. Glob. Ecol. Environ.* **2022**, *16*, 1–10. [CrossRef]
70. Plastic Waste Management Institute. An Introduction to Plastic Recycling. 2022. Available online: https://www.pwmi.or.jp/ei/plastic_recycling_2022.pdf (accessed on 26 April 2024).

71. Yu, J.; Osanai, S.; Toshiki, K.; Liu, X.; Tanabe, T.; Manago, G.; Wang, S.; Serrona, K.R.B.; Okubo, K.; Ikeda, R. New Challenges for Sustainable Plastic Recycling in Japan. In *Global Blue Economy*; CRC Press: Boca Raton, FL, USA, 2022; pp. 395–412.
72. Amano, M.; Ness, B. PET Bottle System in Sweden and Japan. 2004. Available online: https://www.lumes.lu.se/sites/lumes.lu.se/files/amano_michiko.pdf (accessed on 24 April 2024).
73. Ministry of Economy, Trade and Industry, Japan. The Containers and Packaging Recycling Law. 2003. Available online: https://www.jcpra.or.jp/Portals/0/resource/association/pamph/pdf/law2003_eng.pdf (accessed on 3 December 2023).
74. Soudachanh, S.; Campitelli, A.; Salhofer, S. Identifying Priorities for the Development of Waste Management Systems in ASEAN Cities. *Waste* **2024**, *2*, 102–121. [CrossRef]
75. Singapore Environment Council. Unlocking Sustainable Packaging Opportunities in Singapore. 2022. Available online: https://sec.org.sg/pdf/reports/unlocking-sustainable-packaging-opportunities-in-Singapore.pdf (accessed on 22 April 2024).
76. Wong, C.; Wood, J.; Paturi, S. Managing Waste in the Smart City of Singapore. In *Tropical Constrained Environments and Sustainable Adaptations: Businesses and Communities*; Azzali, S., Thirumaran, K., Eds.; Springer: Singapore, 2021; pp. 225–241.
77. Lee, K.J.L.; Wong, S.F. Comparative environmental and socioeconomic assessment on mixed plastic waste management: A Singapore case study. *Sci. Total Environ.* **2023**, *893*, 164884. [CrossRef]
78. Ministry of the Environment and Water Resources National Environment Agency. Zero Waste Masterplan Singapore. 2019. Available online: https://www.mse.gov.sg/resources/zero-waste-masterplan.pdf (accessed on 26 April 2024).
79. Pickin, J.; Wardle, C.; O'Farrell, K.; Nyunt, P.; Donovan, S. National Waste Report 2020. 2020. Available online: https://www.dcceew.gov.au/environment/protection/waste/national-waste-reports/2020 (accessed on 24 April 2024).
80. Hossain, R.; Islam, M.T.; Ghose, A.; Sahajwalla, V. Full circle: Challenges and prospects for plastic waste management in Australia to achieve circular economy. *J. Clean. Prod.* **2022**, *368*, 133127. [CrossRef]
81. Department of Agriculture, Water and the Environment. National Plastics Plan of Australia 2021. 2021. Available online: https://www.agriculture.gov.au/sites/default/files/documents/national-plastics-plan-2021.pdf (accessed on 24 April 2024).
82. Hopewell, J.; Dvorak, R.; Kosior, E. Plastics recycling: Challenges and opportunities. *Philos. Trans. R. Soc. B Biol. Sci.* **2009**, *364*, 2115–2126. [CrossRef]
83. United Nations Environment Programme. Turning off the Tap. How the World Can End Plastic Pollution and Create a Circular Economy. 2023. Available online: https://www.unep.org/resources/turning-off-tap-end-plastic-pollution-create-circular-economy (accessed on 21 December 2023).
84. Gabisa, E.W.; Ratanatamskul, C.; Gheewala, S.H. Recycling of Plastics as a Strategy to Reduce Life Cycle GHG Emission, Microplastics and Resource Depletion. *Sustainability* **2023**, *15*, 11529. [CrossRef]
85. Pandey, P.; Dhiman, M.; Kansal, A.; Subudhi, S.P. Plastic waste management for sustainable environment: Techniques and approaches. *Waste Dispos Sustain. Energy* **2023**, *5*, 205–222. [CrossRef]
86. United Nations Environment Programme. Drowning in Plastics–Marine Litter and Plastic Waste Vital Graphics. 2021. Available online: https://www.unep.org/resources/report/drowning-plastics-marine-litter-and-plastic-waste-vital-graphics (accessed on 21 December 2023).
87. Idumah, C.I.; Nwuzor, I.C. Novel trends in plastic waste management. *SN Appl. Sci.* **2019**, *1*, 1402. [CrossRef]
88. Geyer, R.; Jambeck, J.R.; Law, K.L. Production, use, and fate of all plastics ever made. *Sci. Adv.* **2017**, *3*, e1700782. [CrossRef]
89. Goodship, V. Plastic Recycling. *Sci. Prog.* **2007**, *90*, 245–268. [CrossRef] [PubMed]
90. U.S. Environmental Protection Agency. Energy Recovery from the Combustion of Municipal Solid Waste. Available online: https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw (accessed on 25 April 2024).
91. Subramanian, P.M. Plastics recycling and waste management in the US. *Resour. Conserv. Recycl.* **2000**, *28*, 253–263. [CrossRef]
92. U.S. Environmental Protection Agency. Plastics: Material-Specific Data. Available online: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data (accessed on 23 April 2024).
93. European Environment Agency. Early Warning Assessment Related to the 2025 Targets for Municipal Waste and Packaging Waste. 2022. Available online: https://www.eea.europa.eu/publications/many-eu-member-states/early-warning-assessment-related-to (accessed on 26 April 2024).
94. Maryanti, D.F. Performance of Community-Based Solid Waste Management for Integrated and Sustainable Solid Waste Management. The Case of Bogor City, Indonesia. 2017. Available online: https://luk.staff.ugm.ac.id/rawa/sampah/KMS_STUDI_20180724054702.pdf (accessed on 26 April 2024).
95. Hertati, D.; Arif, L. Nurhadi: Stakeholders Collaboration Model in Integrated Waste Management in Gresik District, East Java. *Nusant. Sci. Technol. Proc.* **2022**, *2022*, 126–131. [CrossRef]
96. Premakumara, D.G.J.; Abe, M.; Maeda, T. Reducing municipal waste through promoting integrated sustainable waste management (ISWM) practices in Surabaya city, Indonesia. *WIT Trans. Ecol. Environ.* **2011**, *144*, 457–468. [CrossRef]
97. Sunarto, S.T. Integrated sustainable waste management in Malang City, East Java, Indonesia. In *AIP Conference Proceedings*; American Institute of Physics Inc.: College Park, MD, USA, 2018.
98. Zurbrügg, C.; Gfrerer, M.; Ashadi, H.; Brenner, W.; Küper, D. Determinants of sustainability in solid waste management-The Gianyar Waste Recovery Project in Indonesia. *Waste Manag.* **2012**, *32*, 2126–2133. [CrossRef] [PubMed]
99. Satori, M.; Megantara, E.N.; Primiana, F.M.S.I.; Gunawan, B. Review of the influencing factors of integrated waste management. *Int. J. GEOMATE* **2018**, *15*, 34–40. [CrossRef]
100. Yin, R.K. *Case Study Research: Design and Methods*; Sage Publications: Thousand Oaks, CA, USA, 2003.

101. Eisenhardt, K.M. Building Theories from Case Study Research. *Acad. Manag. Rev.* **1989**, *14*, 532–550. [CrossRef]
102. Statistics Indonesia. Bandung Municipality in Figures. 2022. Available online: https://bandungkota.bps.go.id/publication/2022/02/25/60310fb12862b40d688a3578/kota-bandung-dalam-angka-2022.html (accessed on 15 December 2023).
103. Statistics Indonesia. Yogyakarta Municipality in Figures. 2024. Available online: https://jogjakota.bps.go.id/publication/2024/02/28/6a6d984e3d10d2113c9d3f3b/kota-yogyakarta-dalam-angka-2024.html (accessed on 1 April 2024).
104. Statistics Indonesia. Magelang Municipality in Figures. 2022. Available online: https://magelangkota.bps.go.id/publication/2022/02/25/4e98869f09ab770a3dfe9f8b/kota-magelang-dalam-angka-2022.html (accessed on 15 December 2023).
105. Idris, M. Info UMR Bandung Raya 2024. Available online: https://money.kompas.com/read/2024/01/10/105932126/info-umr-bandung-raya-2024-kota-bandung-cimahi-dan-kabupaten (accessed on 18 April 2024).
106. Statistics of Indonesia. Upah Minimum Kabupaten/Upah Minimum Provinsi di DI Yogyakarta (Rupiah). 2021–2023. Available online: https://yogyakarta.bps.go.id/indicator/6/272/1/upah-minimum-kabupaten-upah-minimum-provinsi-di-di-yogyakarta.html (accessed on 25 December 2023).
107. Statistics of Indonesia. Upah Minimum Kabupaten/Kota di Provinsi Jawa Tengah 2021–2023. Available online: https://jateng.bps.go.id/indicator/6/708/1/upah-minimum-kabupaten-kota-di-provinsi-jawa-tengah.html (accessed on 25 December 2023).
108. Tarigan, A.K.M.; Sagala, S.; Samsura, D.A.A.; Fiisabiilillah, D.F.; Simarmata, H.A.; Nababan, M. Bandung City, Indonesia. *Cities* **2016**, *50*, 100–110. [CrossRef]
109. Yogyakarta Municipality. Visi Misi Kota Yogyakarta. Available online: https://www.jogjakota.go.id/page/visi-misi (accessed on 27 December 2023).
110. Statistics Indonesia. Profil Ketenagakerjaan Kota Magelang Hasil Sakernas Agustus Tahun 2014–2018. 2018. Available online: https://magelangkota.bps.go.id/publication/2019/12/31/2c648b65e64e6b22ab73a4a9/profil-ketenagakerjaan-kota-magelang-hasil-sakernas-agustus-tahun-2014-2018.html (accessed on 25 December 2023).
111. Lavigne, F.; Wassmer, P.; Gomez, C.; Davies, T.A.; Sri Hadmoko, D.; Iskandarsyah, T.Y.W.M.; Gaillard, J.; Fort, M.; Texier, P.; Boun Heng, M.; et al. The 21 February 2005, catastrophic waste avalanche at Leuwigajah dumpsite, Bandung, Indonesia. *Geoenviron. Disasters* **2014**, *1*, 10. [CrossRef]
112. Usis, T. Sampah, Amanah, Rupiah. The Coordinating Ministry for Maritime and Investment Affairs. 2021. Available online: https://maritim.go.id/uploads/magazine/20230512100508-2023-05-12magazine100503.pdf (accessed on 5 September 2023).
113. World Bank. *Indonesia—The Rise of Metropolitan Regions: Towards Inclusive and Sustainable Regional Development*; World Bank: Washington, DC, USA, 2012.
114. On The World Map. Java Location on the Indonesia Map. Available online: https://ontheworldmap.com/indonesia/islands/java/java-location-on-the-indonesia-map.html (accessed on 17 November 2023).
115. World Atlas. Administrative Divisions of Java. Available online: https://www.worldatlas.com/islands/java-island.html (accessed on 17 November 2023).
116. Mulhall, A. In the field: Notes on observation in qualitative research. *J. Adv. Nurs.* **2003**, *41*, 306–313. [CrossRef] [PubMed]
117. Pichtel, J. *Waste Management Practices: Municipal, Hazardous, and Industrial*; CRC Press: Boca Raton, FL, USA, 2005.
118. Department of Environment of Bandung City. *Laporan Kinerja Instansi Pemerintah DLH Kota Bandung 2022*; Department of Environment of Bandung City: Bandung, Indonesia, 2022.
119. Brilyana, Y.A. Kota Bandung Dapat Bantuan Pembangunan 3 TPST Berteknologi RDF. Available online: https://www.bandung.go.id/news/read/8322/kota-bandung-dapat-bantuan-pembangunan-3-tpst-berteknologi-rdf (accessed on 13 December 2023).
120. Chiemchaisri, C.; Charnnok, B.; Visvanathan, C. Recovery of plastic wastes from dumpsite as refuse-derived fuel and its utilization in small gasification system. *Bioresour. Technol.* **2010**, *101*, 1522–1527. [CrossRef] [PubMed]
121. Department of Environment of Yogyakarta City. *Jumlah Bank Sampah di Kota Yogyakarta*; Department of Environment of Yogyakarta City: Yogyakarta, Indonesia, 2023.
122. Furedy, C. *Social Aspects of Solid Waste Recovery in Asian Cities*; York University: Toronto, ON, Canada, 1990.
123. van de Klundert, A.; Lardinois, I. Community and private (formal and informal) sector involvement in municipal solid waste management in developing countries. *WASTE Consult. Advis. Urban Environ. Dev. Nieuwehaven* **1995**, *201*, 2801.
124. Tuori, M.A. Strengthening Informal Supply Chains: The Case of Recycling in Bandung, Indonesia. 2012. Available online: http://hdl.handle.net/1721.1/79317 (accessed on 15 December 2023).
125. Bisinella, V.; Götze, R.; Conradsen, K.; Damgaard, A.; Christensen, T.H.; Astrup, T.F. Importance of waste composition for Life Cycle Assessment of waste management solutions. *J. Clean. Prod.* **2017**, *164*, 1180–1191. [CrossRef]
126. Jestratijevic, I.; Vrabič-Brodnjak, U. Sustainable and Innovative Packaging Solutions in the Fashion Industry: Global Report. *Sustainability* **2022**, *14*, 13476. [CrossRef]
127. Chen, Y.-C. Effects of urbanization on municipal solid waste composition. *Waste Manag.* **2018**, *79*, 828–836. [CrossRef] [PubMed]
128. Triassi, M.; De Simone, B.; Montuori, P.; Russo, I.; De Rosa, E.; Di Duca, F.; Crivaro, C.; Cerullo, V.; Pontillo, P.; Díez, S. Determination of Residual Municipal Solid Waste Composition from Rural and Urban Areas: A Step toward the Optimization of a Waste Management System for Efficient Material Recovery. *Sustainability* **2023**, *15*, 13378. [CrossRef]
129. Thanh, N.P.; Matsui, Y.; Fujiwara, T. Assessment of plastic waste generation and its potential recycling of household solid waste in Can Tho City, Vietnam. *Environ. Monit. Assess* **2011**, *175*, 23–35. [CrossRef] [PubMed]
130. Gwada, B.; Ogendi, G.; Makindi, S.M.; Trott, S. Composition of plastic waste discarded by households and its management approaches. *Glob. J. Environ. Sci. Manag.* **2019**, *5*, 83–94. [CrossRef]

131. Monavari, S.M.; Omrani, G.A.; Karbassi, A.; Raof, F.F. The effects of socioeconomic parameters on household solid-waste generation and composition in developing countries (a case study: Ahvaz, Iran). *Environ. Monit Assess* **2012**, *184*, 1841–1846. [CrossRef]
132. Bandara, N.J.G.J.; Hettiaratchi, J.P.A.; Wirasinghe, S.C.; Pilapiiya, S. Relation of waste generation and composition to socio-economic factors: A case study. *Environ. Monit Assess.* **2007**, *135*, 31–39. [CrossRef] [PubMed]
133. Shen, L.; Worrell, E. Chapter 13-Plastic Recycling. In *Handbook of Recycling*; Worrell, E., Reuter, M.A., Eds.; Elsevier: Boston, MA, USA, 2014; pp. 179–190.
134. Garcia, J.M.; Robertson, M.L. The future of plastics recycling. *Science* **2017**, *358*, 870–872. [CrossRef] [PubMed]
135. Johannes, H.P.; Kojima, M.; Iwasaki, F.; Edita, E.P. Applying the extended producer responsibility towards plastic waste in Asian developing countries for reducing marine plastic debris. *Waste Manag. Res.* **2021**, *39*, 690–702. [CrossRef] [PubMed]
136. A1 Safety & Packaging NZ. Polystyrene Food Containers. Available online: https://www.a1safetynpackaging.co.nz/category/337-polystyrene-food-containers (accessed on 10 December 2023).
137. Brimantoro, T. Penggantian Logo AQUA Telah Mendapat Persetujuan BPOM. . .. Available online: https://www.tribunnews.com/bisnis/2018/02/22/penggantian-logo-aqua-telah-mendapat-persetujuan-bpom-kata-arif-mujahidin#google_vignette (accessed on 10 December 2023).
138. Ridwell. Multi-Layer Plastic Recycling Is Here. Available online: https://blog.ridwell.com/meet-mlp (accessed on 10 December 2023).
139. Serrona, K.R.B.; Yu, J.-S. Women-led Community-based Plastic Recycling in Metro Manila, Philippines: A Case Study of KILUS Multi-purpose Cooperative. *Proc. Annu. Conf. Jpn. Soc. Waste Manag. Experts* **2008**, *19*, 302. [CrossRef]
140. Anugrah, B.; Guevarrato, G.; Gurnadi, R. Wasanti: Penganggaran dan Kebijakan dalam Manajemen Pengelolaan Sampah: Studi Kasus Kabupaten/Kota di Indonesia. 2020. Available online: https://seknasfitra.org/wp-content/uploads/2023/01/Penganggaran-dan-Kebijakan-dalam-Manajemen-Pengelolaan-Sampah-Studi-Kasus-KabupatenKota-di-Indonesia.pdf (accessed on 24 December 2023).
141. Government of Yogyakarta City. Peraturan Walikota (PERWALI) Kota Yogyakarta Nomor 32 Tahun 2022 Tentang Masterplan Pengelolaan Persampahan Kota Yogyakarta Tahun 2022–2031. 2022. Available online: https://peraturan.bpk.go.id/Details/214150/perwali-kota-yogyakarta-no-32-tahun-2022 (accessed on 1 November 2023).
142. Mihai, F.-C.; Gündoğdu, S.; Markley, L.A.; Olivelli, A.; Khan, F.R.; Gwinnett, C.; Gutberlet, J.; Reyna-Bensusan, N.; Llanquileo-Melgarejo, P.; Meidiana, C.; et al. Plastic Pollution, Waste Management Issues, and Circular Economy Opportunities in Rural Communities. *Sustainability* **2022**, *14*, 20. [CrossRef]
143. Calzada, I.; Cowie, P. Beyond Smart and Data-Driven City-Regions? Rethinking Stakeholder-Helixes Strategies. *Reg. Mag.* **2017**, *308*, 25–28. [CrossRef]
144. Rinanda, R.; Sun, Y.; Chang, K.; Sulastri, R.; Cui, X.; Cheng, Z.; Yan, B.; Chen, G. Plastic Waste Management: A Bibliometric Analysis (1992–2022). *Sustainability* **2023**, *15*, 16840. [CrossRef]
145. Department of Environment of Magelang City. *Neraca Sampah Kota Magelang 2022*; Department of Environment of Magelang City: Magelang, Indonesia, 2022.
146. Lestari, A.P.; Bijaksana, A.F.; Ibrahim, R.M. The Governance of Solid Waste Institutions in Indonesia. 2019. Available online: https://waste4change.com/research/the-governance-of-solid-waste-institutions-in-indonesia-part-ii-regional-government?lang=en (accessed on 3 October 2023).
147. Ministry of Environment and Forestry of Indonesia: Waste Composition in Indonesia. Available online: https://sipsn.menlhk.go.id/sipsn/public/data/komposisi (accessed on 10 December 2023).