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Research Article

Mass Balance Analysis of Integrated Municipal Solid Waste Management: The Jakarta Recycle Center Program Case Study

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ABSTRACT

With the amount of waste increasing and landfill space becoming critical, the government has undertaken numerous measures to reduce waste, including creation of Integrated Solid Waste Management system through Jakarta Recycle Centre (JRC) Program. An integrated and sustainable waste management system will depend on both the physical and the governance components, with the physical aspect focusing on technical problems. To evaluate the physical aspect of JRC, the flow of the waste needs to be monitored and evaluated to see the success of waste separation and recycling system. This study employs mass balance analysis using data of waste in JRC facilities from January to December 2022. According to the study's findings, JRC system has a significant recycling rate which is around 46,43%. To improve the recycling rate, communication to residents about waste sorting process need to be enhanced. In order to reduce residue from sorting outcomes, it is also crucial to increase the ability and expertise of personnel in waste sorting.

***Keywords**: Integrated solid waste management, Mass balance, Recycle rate*

Introduction

Increasing urbanization will have an impact on consumption patterns so that consumption levels are high compared to rural areas. With population growth, increasing needs, and changes in people's lifestyles, people will have higher consumption levels so that more waste will be produced Metropolitan areas produce a lot of trash due to their high levels of consumption and extremely high population densities, such as Jakarta, Indonesia (Sunarto & Sulistyaningsih, 2018). With a population of 10,467,629 residents in DKI Jakarta and 1.38 million commuters from Bogor, Depok, and Tangerang who carry out activities there every day, the amount of waste disposed of at the Bantargebang Landfill is discovered to be 7,700 tons per day (Naldi et al., 2021).

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Various policy initiatives and waste reduction programs have been issued by the government so that waste reduction can start immediately (Romanowska-Duda et al., 2021). Jakarta also has several policies on waste reduction activities, such as the policy of prohibiting the use of plastic bags for shopping, the implementation of community-based waste management with a garbage bank mechanism and a Community-Based Waste Sorting mechanism, and others (da Silva et al., 2019). However, challenges in implementing the waste reduction system at this source continue to occur due to the less-than-optimal waste management process and the absence of a good waste management system (Vickers, 2017).

Jakarta has created the Jakarta Recycle Center (JRC) program, which seeks to transform a linear waste management system into one that can stimulate resource utilization by raising community involvement and government commitment (Knickmeyer, 2020). The JRC program is then viewed as one of the initiatives that can serve as a model for a waste management system that is thoroughly integrated (Purnamawati, 2021). This JRC program adapts the waste management system in Osaki, Kagoshima, Japan (Espuny et al., 2022), where the solid waste management system is carried out both from a technical and governance perspective (Putri et al., 2018). The purpose of this study is to analyze the mass balance of waste flow in JRC to give an illustration of how waste is being processed and to calculate the recycle rate of waste. Hopefully, this study may be inspiration to create more sustainable waste management with a focus on seeing waste as a resource (Raharjo et al., 2019).

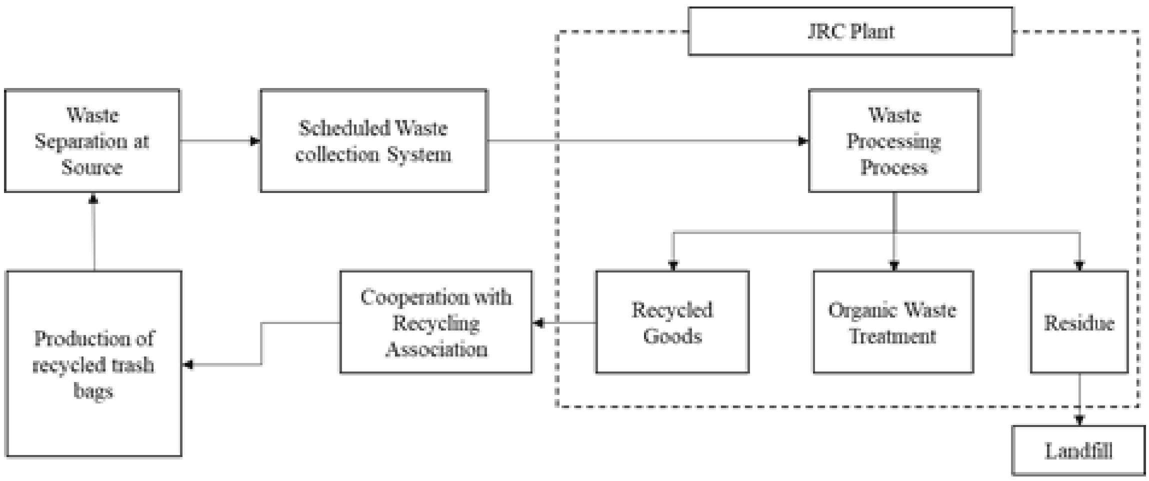

Figure 1. JRC System Flow

According to the Integrated Solid Waste Management (ISWM) idea, waste is managed in an integrated way and is seen as a resource that could be used to generate income (Kalmykova et al., 2018);(Khan et al., 2022). In a sustainable integrated solid waste management system, it is necessary to understand that waste management also prioritizes the hierarchy of waste management, so that waste is considered a resource that can still be recovered. The hierarchy of waste management must be prioritized in a sustainable integrated solid waste management system in order for waste to be seen as a resource that can still be recovered. There are three crucial elements to consider when implementing an integrated waste management system: (1) stakeholders, (2) the waste management system, and (3) sustainability factors.

In the analytical framework to assess integrated solid waste management, UN Habitat then formed a concept of "Two Triangles" as set out in Figure 2 below. The second triangle focuses on waste management governance, whereas the first triangle is primarily concerned with the actual working tools for the waste management system. The completeness of the waste management system is therefore determined by these two triangles (Kurniawan et al., 2021).

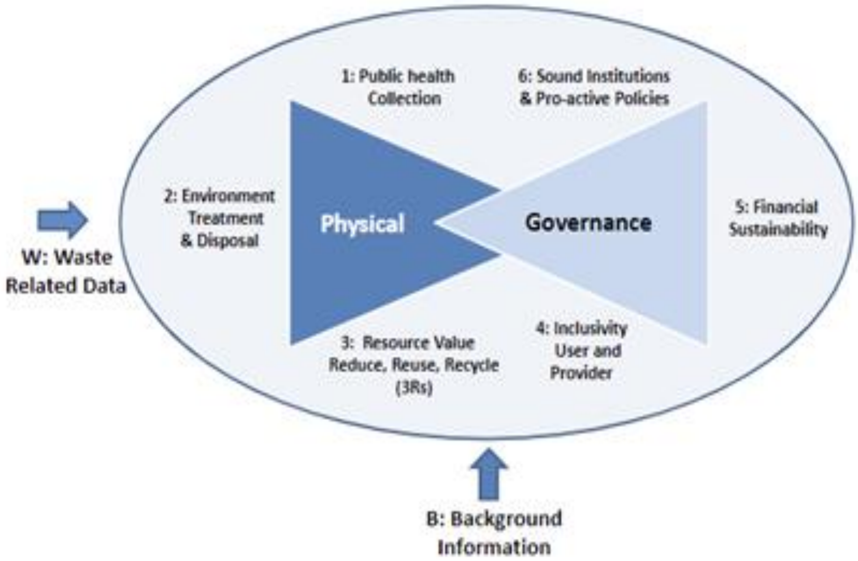

Figure 2. The Integrated Sustainable Waste Management (ISWM) Framework

The waste management system in urban areas then requires various resources, which require a physical and governance related to creating economic and social sustainability (Ghani, 2021). The physical aspect of waste management focuses on the elements of physical devices, and this aspect also considers material values as seen from reduce, reuse, and recycle (3R) activities, as well as aspects of public health protection that depend on the waste collection system, environmental protection during the waste treatment and disposal process, and aspects of public health protection during the waste collection system (Khair et al., 2019). The recycling rate will be the main focus of the physical factor in this study. The recycling rate shows how effectively the current waste management system can recover waste that can be used as a resource material, preventing waste from accumulating and being disposed of in landfills (Wang et al., 2018).

In order to determine the recycling rate, the Mass Balance Analysis is needed so we can see the flow of the waste. The planning process for MSW management entails creating a balance of trash created, accounting for the effectiveness of selective collection and recycling, and determining the required processing capacity of waste management facilities. Understanding the volume of garbage created and its morphological makeup is essential for creating a trustworthy balance, which is why Mass Balance Analysis is needed (Mahidin et al., 2020). The application of mass balance analysis can provide an overview of the flow of materials, especially in waste management so that it can be the basis for evaluating the performance of waste management systems (Verma & Borongan, 2022). Waste has a very diverse content, but in this study, waste is considered a complete material, and then the amount of output and residue produced is calculated. By applying Mass Balance Analysis, the results of this calculation can be a strong consideration in policy making to evaluate the performance of the waste management system (Chen et al., 2018).

Methods

Pesanggrahan Subdistrict. This area was chosen as the study site since it was the first to be put up as a model for the JRC implementation area. Through analysis of the waste report at JRC Facilities, this study adopted a quantitative methodology.

The first stage in preparation for the Mass Balance Analysis is to collect data on the amount of waste (Hettiarachchi, 2019). In this example, the waste that is counted is collected from residences and documented as entering the JRC facility. Food waste, garden trash, inorganic waste, hazardous garbage, and residues are the types of waste collected by the waste collection system.

The waste will then be handled according to its type based on its incoming weight. Organic waste will be processed through composting and BSF maggot conversion, with each waste quantity being weighed before processing. Further processing of inorganic waste will involve a more precise separation of recyclable items and will be weighed according to each type. After the amount of waste is entered, the mass flow of waste is calculated and analyzed. The amount of waste recycled is then compared to the total amount of waste dumped in the Bantargebang Landfill, and the waste recycling rate is calculated as a result. Data from waste reports from January to December 2022 were used.

Results and Discussion

The calculation begins by entering the value of the amount of waste that enters the JRC facility. Incoming waste is the amount of waste collected from the waste collection system at housing in the Model Area. In a period of 1 year, the amount of waste that enters the JRC facility is 364,803 kg/year, which is stated in Table 1. This waste then goes into an organic processing facility and sorting inorganic waste. However, there is also waste that is picked up by informal workers, who take several types of recyclable waste with high economic value, such as plastic and paper. This waste then goes to informal waste collection points. Beside that, hazardous materials have entered other facilities that are operated by formal institutions that are responsible for hazardous waste management. Some waste from the collection process is still classified as "residual waste," and it is immediately disposed of in the Bantargebang landfill.

Based on the data gathered, the following are the numbers of wastes entering and exiting the JRC's processes.

Table 1. Input of waste into JRC facilities

Input of Waste		
Food waste	137.557,46	kg/a
Garden Waste	21.431,25	kg/a
Inorganic waste	56.443,19	kg/a
Hazardous waste	6.945,75	kg/a
Residu	155.785,09	kg/a
Total input of waste	**378.162,74**	**kg/a**

Organic waste consists of food waste and garden waste, which are then processed using the Black Soldier Fly (BSF) maggot conversion method and composting. In BSF processing, the processed waste is food waste, and for composting, it is food waste mixed with garden waste. From this organic processing process, there is still a residue of 17% of the total incoming organic waste. From the results of compost processing, the amount of compost product produced within one year is 8,151 kg/year, which is then distributed to residents.

Table 2. Input of Organic Waste

Organic Waste Processing		
Organic Waste Input	**158.988,71**	kg/a
Food Waste*	137.557,46	kg/a
Garden Waste*	21.431,25	kg/a
*including contaminant		
Residue	23.180,55	kg/a

Table 3. Organic Waste Processing in Composting and BSF

Organic Waste Processing		
Composting Process		
Food waste	57.524,71	kg/a
Garden Waste	18.306,57	kg/a
Total Waste Input to Compost	75.831,29	kg/a
Compost Product	8.151,00	kg/a
Black Soldier Fly Process		
Food waste	59.976,87	kg/a

The entering garbage for the sorting of inorganic waste is 56,443.19 kg/year, which is stated in Table 4, and a more thorough waste separation is done during this sorting process, resulting in clean recyclable materials. The waste that had been divided into several recyclable materials was brought to the recycling association for additional processing, while the residue from the sorting procedure reached 45.28%, according to the calculation results.

Table 4. Inorganic Waste Separation Process

Inorganic Waste Separation		
Inorganic Waste Input	56.443,19	kg/a
Informal Waste Pickers	1.337,75	kg/a
Waste goes to Separation Processs	55.105,44	kg/a
Recovered Recyclables Material	31.489,51	kg/a
Residue to Landfill	24.953,68	kg/a

Table 5. recyclables from Inorganic Material

Main Category	Recyclables	Percentage	Amount (kg/a)
Paper	Low Quality Paper	19,56%	10.776,82
	Box	1,77%	974,64
	Newspaper	0,00%	-
	High grade paper	0,23%	125,12
Plastic	Toys, buckets	3,57%	1.968,41
	White HDPE	4,03%	2.219,10
	Printed HDPE	3,49%	1.923,41
	PVC	0,09%	49,57
	Packaging	1,34%	737,71
	PP (Online Packaging)	2,05%	1.131,97
	White PP or PE	7,92%	4.362,97
	Printed PP	4,79%	2.637,84
	Aluminium Foil	2,16%	1.189,32
	Styrofoam	0,75%	414,16
	Blue PET Bottle	0,61%	333,86
	White PET Bottle	0,76%	417,23
	Coloured PET Bottle	0,04%	23,87
	HD Inject	0,00	0,46
	PP Cup	0,01%	6,17
Hazardous Waste	Hazardous waste	0,03%	17,31
Glass	Glass Bottle	3,17%	1.746,53
Metal and Can	Metal and Can	0,79%	433,05
Recovered Recyclables Material (kg/a)			**31.489,51**

The figure of Mass Balance Analysis in JRC facilities then showed in Figure 3.

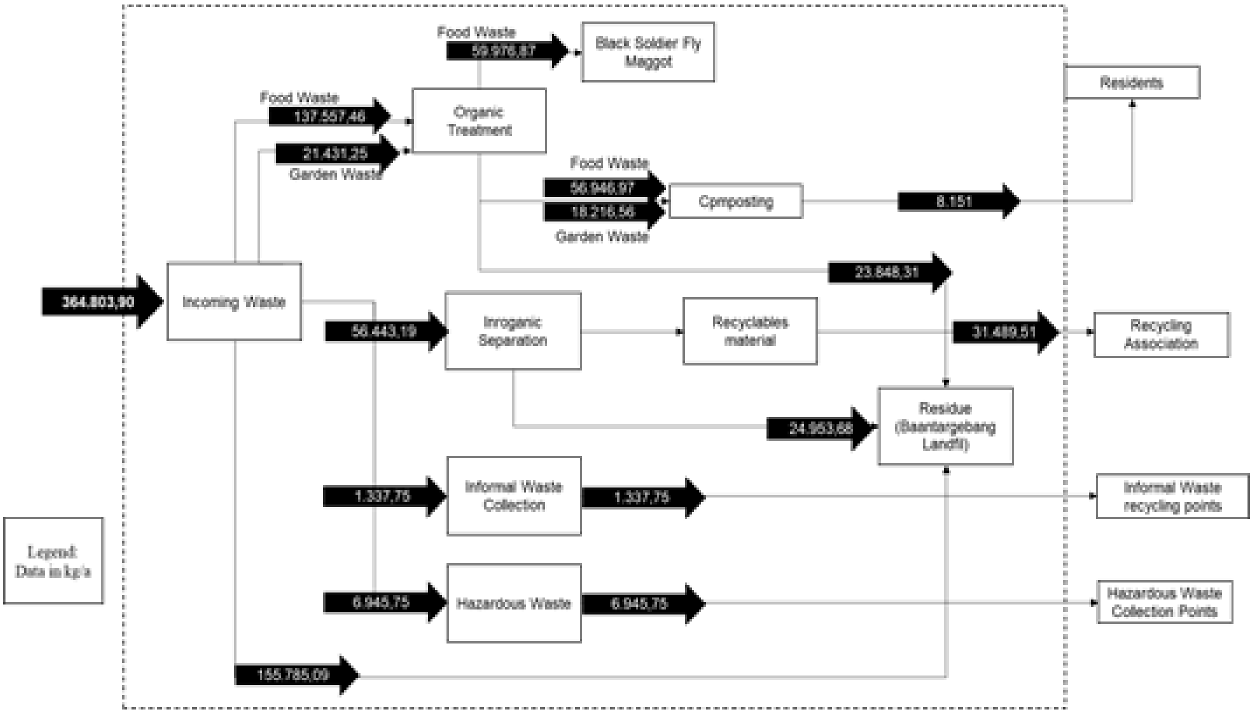

Figure 3. Mass Balance Analysis of Waste in JRC Facilities

Discussion

The integrated waste management system at JRC is a waste management system by increasing community participation in waste segregation, where waste segregation is mandatory (Romanowska-Duda et al., 2021). Based on this waste segregation activity, the waste that enters the JRC facility is waste that has been separated into food waste, garden waste, inorganic waste, hazardous waste, and residue.

Based on the calculation results, it can be seen that the waste that enters the JRC facility is properly processed. For processing food waste through the composting method, mass shrinkage occurs which is quite high considering that the composting process has a fairly high waste reduction rate. This composting process then proves to be able to reduce organic waste in large enough quantities (Kalmykova et al., 2018).

The amount of residue is still extremely considerable, which suggests that the sorting of inorganic waste was not carried out properly. These calculations show that the pollutants in inorganic waste are still fairly significant, resulting a relatively modest recovery of recycled materials. The recycling association then picks up the sorted waste so it may be recycled into new products. In turn, this might lead to a greater adoption of the circular economy.

According to the entire estimate using the JRC facility's processing system, the recycle rate is 46.43%. The JRC plant can thereby reduce trash disposed of in landfills by 46.43%, according to this value. This value then shows how the JRC waste management system can encourage the creation and utilization of waste as a resource. The less waste that is disposed of in landfills and more waste that is used as a resource, the less environmental damage there will be. Waste management can then become activities that help apply a circular economy by engaging in recycling. According to the entire estimate using the JRC facility's processing system, the recycle rate is 46.43%. The JRC plant can thereby reduce trash disposed of in landfills by 46.43%, according to this value. This value then shows how the JRC waste management system can encourage the creation and utilization of waste as a resource. The less waste that is disposed of in landfills and more waste that is used as a resource, the less environmental damage there will be. Waste management can then become activities that help apply a circular economy by engaging in recycling (Bartolacci et al., 2019).

With this mass balance analysis, it can then be shown regarding the mass balance and also the performance of the recycling program. Conducting more active outreach to the community regarding the waste sorting system at home is one way to boost the recycling rate (Muhashiby et al., 2021). In order to reduce residue from sorting outcomes, it is also crucial to increase the ability and expertise of personnel in waste sorting.

Conclusion

Based on mass balance analysis calculations, it is found that the recycling rate in the JRC system can reach 46.43%. This value shows the performance of waste sorting and recycling activities at the JRC facility so that it can reduce waste to Bantargebang landfills significantly. This recycling performance can still be improved further by maintaining the quality of waste segregation by residents by means of more intensive outreach and increased sorting competence.

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