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Community-based urban waste management: Performance of TPS 3R waste treatment facility in Sleman Regency

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Abstract: Waste treatment facilities reduce, reuse, and recycle (TPS 3R) exist in order to increase community participation in reducing waste at the source. This paper aims to determine the distribution and describe the performance of TPS 3R in Sleman Regency in reducing household waste and realising circular economy activities at the community level. The method used is a quantitative descriptive approach with spatial analysis across 42 TPS 3R units in Sleman Regency. Distribution of TPS 3R is almost evenly spread across all subdistricts and clustered in urban areas. Facilities in urban areas tend to be operational, whereas in rural areas some are not. Population density, accessibility, economic level, and employment type are external factors that affect the sustainability of facilities. This has an impact on internal factors, namely managerial capacity, managers' welfare, and operational financing capacity. Both factors influence the type of innovation undertaken in support of the circular economy.

***Key Words**: 3R Waste Treatment Facility, Community-Based, Urban Waste Management.*

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Introduction

Issues of declining environmental quality have accompanied urban development. Population growth, improvements in the community's economic status, unplanned urban development, and the community's consumptive lifestyle have contributed to an increase in waste generation (Fernández-Braña & Dias-Ferreira, 2023). This phenomenon is currently occurring in Sleman Regency, an area most affected by urbanisation in Yogyakarta due to its role in accommodating educational and tourism activities. The development of higher education institutions in Sleman Regency has consequences for the

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provision of supporting infrastructure, such as boarding houses, services, restaurants, lodgings, and entertainment venues, all of which generate waste. The composition of waste generated depends on the source of the waste, the size and income level of the population, economic activities, and consumption patterns (World Bank, 2024).

Over the past four years, Sleman Regency has been the largest contributor of waste to the Piyungan Regional Landfill. This landfill meets the waste management needs of Bantul Regency, Sleman Regency, and Yogyakarta City. The Piyungan Landfill received an average of 184 tonnes of waste per day in 2019, accounting for 33.7% of the total waste entering the landfill. In 2022, the average daily waste intake increased to 288 tonnes, or 39% (DLHK DIY, 2023). The amount of waste generated in Sleman Regency increased from an estimated 699 tonnes per day in 2019 to 735 tonnes per day in 2021. Waste decreased to 596 tonnes per day in 2022, reflecting a change in the per capita waste production coefficient from 0.65 tonnes per day in 2019–2021 to 0.52 tonnes per day in 2022 (KLHK, 2024). Due to landfill capacity reaching its limit, the waste problem peaked in these three regions in 2023. The DIY Regional Government officially closed the Piyungan landfill on 5 March 2024, and the Governor of DIY issued Governor Circular Letter No. 658/11898 on 19 October 2023 regarding the decentralisation of waste management in districts/cities throughout DIY.

Based on waste sources, the composition of waste in Sleman Regency places households as the highest producers. Households account for 63.7%, businesses for 18.33%, and markets for 9.1%. The rest comes from public facilities and offices. Based on waste type, 46.5% is food waste, 32.77% is plastic waste, and 17.08% is paper waste. The remainder consists of metal, fabric, rubber, leather, and glass, each accounting for less than 1% (KLHK, 2024). The trend of increasing waste generation is driven by household waste, and, by type, it is dominated by organic and plastic waste. This requires intensive waste management. Improper management will increase the risk of declining human health and environmental quality. The negative impacts can include the spread of disease vectors, foul odours from organic waste, open burning that causes air pollution, climate change, and contamination of soil and surface water (Babu et al., 2021).

Community participation is needed in waste management because households generate the majority of waste. One way to do this is through efforts to reduce the amount of waste transported to landfills/waste disposal sites in the form of TPS 3R. According to the Regulation of the Minister of Public Works of the Republic of Indonesia Number 03/Prt/M/2013 concerning the Implementation of Waste Infrastructure and Facilities in the Management of Household Waste and Household-like Waste, TPS 3R needs to fulfil the following requirements: The TPS 3R land must: a) be located within the same administrative boundaries as the TPS 3R service area; b) be government-owned or otherwise proven by a deed or gift; c) have a minimum land area of 200 m^2; d) have community-based environmental activities; e) be easily and safely accessible; f) have a minimum service coverage of 200 households or a minimum waste processing of 3 m^3/day; g) be accepted by the community as a result of a spontaneous awareness of the 3R activities; h) be willing to pay waste processing fees.

The 3R waste management facility, as a community-based waste management site, is required to carry out collection, sorting, reuse, and recycling activities on a regional scale (Setiadi & Arfiani, 2024). In relation to this, this paper aims to determine the distribution and describe the performance of 3R waste management facilities in Sleman Regency. The results of this paper are expected to provide an overview of the institutional, operational, and service coverage conditions of the facilities, which can be used as evaluation material and to plan the development of TPS 3R management to be more optimal in managing community-based waste.

Methods

The method used is a quantitative, descriptive approach with spatial analysis. Descriptive methods provide realistic descriptions of phenomena based on the facts of the objects being studied (Rukajat, 2018). These facts are presented as numerical and proportional frequencies, based on field data (Creswell & Creswell, 2018). The quantitative approach to examining the value of waste management performance factors at the TPS 3R includes aspects of management, operations, and service coverage. These factors relate to the facility's location.

Study area

The research location is Sleman Regency, Special Region of Yogyakarta, covering an area of approximately 574.82 km^2 (BPS Sleman, 2023). It was chosen as the research location because it spans from urban to rural areas and has the highest household waste and household-like waste production in the Special Region of Yogyakarta. The division of urban and rural physical characteristics is based on the Sleman Regency Spatial Plan (*Rencana Tata Ruang Wilayah Kabupaten* Sleman) document, which classifies areas based on the lowest level of government, namely the village. Of the 86 villages, 58 are characterised as urban, while the remaining 28 are characterised as rural (Sleman Regency Government, 2021).

Community-based waste management facilities operating in this area vary, including waste banks, waste donations, and TPS 3R. This study chose TPS 3R because it has a variety of management models, operations, and social characteristics that may be inseparable from its geographical or spatial characteristics. This is certainly interesting to study because the community-based operational management of TPS 3R waste is one of the community's efforts to participate in waste reduction activities.

Research Data

The unit of analysis in this study was all 42 TPS 3R facilities built in urban and rural areas. Data was collected through a census of 42 TPS 3R managers. The data used were secondary and primary, obtained from questionnaires, in-depth interviews, and field observations. Primary data collection to assess the performance of TPS 3R management used a structured questionnaire with an ordinal scale. The questionnaire was designed considering the local context, the respondents' level of understanding, and ease of analysis (Dillman et al., 2014). This was taken into consideration because TPS 3R administrators have different human resource capabilities, particularly in terms of education and technology proficiency.

In-depth interviews to understand the phenomena occurring in waste management, particularly in terms of operational status and issues encountered that affect waste management performance at the facility. Field observations are important for understanding the actual waste treatment processes and for providing geospatial data on the locations to be analysed, using secondary data on population density and village classification based on document studies from the Sleman Central Statistics Agency (BPS Sleman) and the Sleman Regency Spatial Plan. Secondary data in the form of management and financial reports will be used to reinforce the primary data obtained from questionnaires and in-depth interviews. Government policies at the national and regional levels impose constraints on the management of the 3R TPS, as the government facilitates this programme during its development.

Table 1. Research Data

Objective	Variable	Data Source	Collection Technique
To determine the distribution of TPS 3R	location coordinates	geotagging results	field observation
	population density	statistical data from BPS Sleman	document study
	classification of urban village	data from the Sleman Regency Spatial Plan	document study
Describing the performance of TPS 3R	management, operations, service coverage	TPS 3R administrators, management and financial reports	questionnaires, in-depth interviews, and field observations

Source: Researcher, 2024

Research Analysis Method

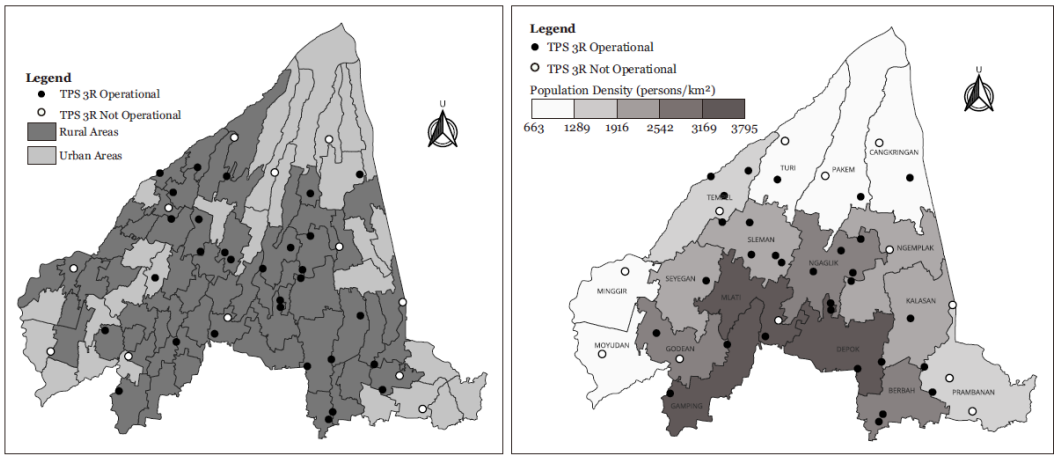
Data analysis was conducted using two approaches, namely spatial analysis and descriptive analysis. Spatial analysis utilised GIS software, including overlay and nearest-neighbour analysis. This enabled the spatial distribution patterns of TPS 3R to be identified based on urban and rural characteristics and population density. Descriptive analysis was conducted using Likert scale questionnaire data processed with cross-tabulation to obtain a typology of TPS 3R performance between rural and urban areas. Cross-tabulation was used to obtain a simple overview of the relationship between each variable so that differences in patterns between groups could be seen (Hair et al., 2023). The dominance or most frequent occurrence in the questionnaire will be described in cross-tabulation and reinforced with in-depth interview results and spatial analysis.

The output of the first analysis is a map of the distribution of TPS 3R based on urban and rural categories, and the distribution of TPS 3R based on population density. The second is a TPS 3R performance matrix in Sleman Regency. From these two outputs, a discussion will then be conducted to interrelate the phenomenon of community-based waste management in these facilities. This will provide insights as material for consideration in policy-making or better management in the future.

Results

Distribution of TPS 3R

The location of TPS 3R shows that it is spread almost evenly across all sub-districts in Sleman Regency. Based on the spatial planning aspects contained in the Sleman Regency Spatial Plan, 37 units or 88% of the total facilities are located in urban areas. Meanwhile, five units or 12% are located in rural areas. The nearest neighbour ratio value is <1, which means that the pattern is clustered, with facilities tending to be located in densely populated areas. This is in line with the directive contained in Regulation of the Minister of Public Works of the Republic of Indonesia Number 03/Prt/M/2013, namely that waste management in urban communities is very complex due to the high volume and composition of waste originating from domestic and commercial activities. The high population density and consumption patterns that result in excessive waste production are some of the factors causing this problem (Tarigan & Dukabin, 2023).



(a) (b)

Figure 1. (a) Distribution of TPS 3R based on urban and rural categories, (b) Distribution of TPS 3R based on population density
Source: Analysis Results 2024

Based on the operational status of the facilities, 76% or 28 units located in urban areas are operational and serve to reduce waste in the community. Meanwhile, nine units are not operational. The reason for the non-operation of these units is due to problems in management, particularly in financial management, which is not accountable, a lack of competent and willing human resources to manage them, and conflicts with the community surrounding the facilities due to pollution, especially air pollution caused by the smell and smoke from open burning of waste. One unit was even temporarily closed because, after the closure of the Piyungan landfill, it was no longer able to transport waste to the landfill, so the management decided to close the unit to avoid social problems with the surrounding community. There are five TPS3R facilities in rural areas, of which only two are operational. The three facilities are not operating due to a lack of workers willing to manage them and low business opportunities, which are not balanced with income and operational costs.

In general, facilities constructed in residential areas with low densities cannot function. On the other hand, operationally viable facilities are typically located in densely populated areas. According to government policy, each TPS 3R must be able to serve a minimum of 200 households, or 1,200 people, assuming that each household has six members. Long distances between homes and issues with low population density will raise service costs, particularly for transport. In the meantime, the community's capacity to cover waste collection costs is typically still limited in these areas.

The performance of TPS 3R is evaluated based on management, operational service, and service coverage indicators. The institutional form of the facility manager can be managed by a community self-help group (*Kelompok Swadaya Masyarakat*/KSM) or a village-owned enterprise (*Badan Usaha Milik Kalurahan*/BUMKal). KSM provides autonomy for community groups in certain areas to manage these facilities independently and effectively, whereas BUMKal management is supervised by the village as a capital contributor and is responsible for the business's operations to the village government. All TPS 3R units in rural areas are in the form of KSM. Meanwhile, 24% or nine units in urban areas are in the form of BUMKal, with the rest being KSM. Management and task distribution indicators show that the management of operating TPS 3R is well-organised.

Table 2. Performance of 3R TPS in Sleman Regency

Indicator		Area	
		Rural	Urban
Management	Institutional form	All KSM	KSM dominance
	Management and division of tasks	All active TPS 3R are not operating optimally	Some are operating optimally
	Regular meetings and reporting	Some active TPS 3R carry out regular activities	Most active TPS 3R carry out regular activities
	Cooperation with other parties	None	Some cooperate
	Sustainability of financing	Relying on community contributions	Generally supported by contributions and sales of educational services
	Workers' insurance	Mostly unavailable	Some workers have employment insurance
Operational	Collection	All perform	All perform
	Sorting	Some perform optimally	Most perform optimally
	Scrap sales	All perform	All perform
	Composting	Do not perform	Some do not perform
	Residue disposal	All perform	All perform
	Biomass (BSF)	Do not perform	Most do not perform
	RDF/Industry	Do not perform	Most do not perform
	Animal feed	Do not perform	Most do not perform
	Occupational Health and Safety	Available	Available
Service coverage	Customers	Does not meet standards	Dominance meets standards
	Area coverage	Part of the area around the hamlet	Generally, covers the surrounding hamlets
	Community education	Incidental, limited to face-to-face meetings	Routine and through various communication channels

Source: Analysis Results 2024

The criteria for optimal management are that the manager is able to implement the division of tasks and carry them out in accordance with the established operational procedures. In addition, holding regular meetings and compiling activity reports are important points as a form of responsibility and an effort to evaluate the business. Only 17 units (61% of 28 units) in urban areas are well managed. Meanwhile, two units in rural areas have suboptimal governance, managers in urban areas who hold regular meetings and compile reports number 20 units or 71%.

The management of TPS 3R units is permitted to collaborate or cooperate with other parties. Collaboration or cooperation can include waste collection and processing activities, the development of processing technology, and the utilisation of processing residues. A total of 13 units, or 46% of the facilities operating in urban areas, have established such collaborations. Three units are collaborating in the development of waste processing technology and the utilisation of processing residues as raw material for refuse-derived fuel (RDF). This collaboration initiative is an effort to optimise waste management and minimise the generation of residues because, since the closure of the Piyungan landfill, the government, through the Environment Agency, has been unable to transport waste from these units optimally.

Indicators related to financing sustainability still face several challenges. Most TPS 3R units still rely on community contributions as a source of funding for daily operations and government assistance for building maintenance and processing machinery, including three-wheeled motorcycles for collecting waste from waste sources. This dependence means that financing capacity fluctuates due to factors such as the level of community participation in contributions and inconsistent government financial support. Innovations in the form of waste management education services for the community through comparative study packages, training, or similar programmes have not yet been implemented by all units, as they require time, workforce, and trained service capabilities.

In terms of worker protection, all workers are covered by health insurance, but employment insurance is only available in some units located in urban areas. The lack of comprehensive worker protection places workers in vulnerable working conditions, given that waste management activities carry a relatively high risk of accidents and exposure to hazards. Administrators' lack of awareness of the need to provide this protection is an obstacle to granting workers their social security rights.

The operational aspect describes waste management activities that must be carried out in each TPS 3R unit in accordance with government standards. In addition, innovations are possible to strengthen the realisation of a circular economy. The management process consists of collection, sorting, scrap sales, composting, and residue disposal. All operating units have carried out collection, scrap sales, and residue disposal activities. However, waste sorting in units located in rural areas has not been optimally implemented. Meanwhile, in urban areas, only 24 units or 86% have implemented optimal waste sorting. Composting is the most difficult task, as evidenced by the fact that none of the units in rural areas carry out composting, while only 16 units, or 57% of units, in urban areas do so. Factors hindering composting include the need for intensive time, large space requirements, and intensive labour, which are not proportional to the selling price of the compost produced.

Innovations in waste management are being developed to increase added value, particularly financial income for TPS 3R. Innovations in the utilisation of organic waste or food scraps have been developed through biomass conversion using black soldier flies (BSF) or maggot cultivation, which has been implemented in five units in urban areas. BSF can reduce organic waste quickly and has a high market value. The challenge in this biomass conversion activity is that it requires intensive management and skilled labour. Selling food as animal feed for fish, pigs, or poultry is another way to cut down on food waste. The most practical option is to sell food waste as animal feed, which doesn't require specialised or skilled labour. Another industrial processing innovation is the production of Refuse Derived Fuel (RDF). Due to the high cost of equipment procurement, this activity can only be carried out in three units.

The minimum service coverage for each unit is 200 households. In reality, units in rural areas are only able to reach 100 to 147 households. In comparison, 71% of units in urban areas are able to serve around 200 to 1,500 households. However, 29% of units did not reach the target, serving only 50 households. This is because the facilities are newly built and have not yet optimised their services due to constraints in disposing of waste at landfills as a result of landfill closures. Based on the service area coverage, 28% of the operating units can reach more than three villages, while the rest are still focused on managing waste in the hamlets around the unit location. Units that focus only on the hamlets around their location do so only because the number of households served is small; in urban areas, it is generally because the household density in the area has reached service capacity.

Discussion

Community-based waste management faces various dynamics in its implementation in the field. Strong institutions, government support, and local community participation are all important factors that affect the success of community-based waste management systems in developing nations (Fernández-Braña & Dias-Ferreira, 2023; Nasser, 2024). The operation of TPS 3R is influenced by variations in institutional types, population density, spatial context, and community welfare levels, according to findings from Sleman Regency. Densely populated areas in Sleman Regency exhibit a clustering pattern in the spatial distribution of TPS 3R facilities. This has a direct effect in that well-operating facilities are dominant in these areas, confirming that settlement morphology has a significant influence on the continuity and sustainability of waste management activities. Population density is one of the determining factors in assessing the efficiency of services from a spatial perspective (Longley et al., 1997).

The fact on the ground is that population density generally occurs in urban areas. In rural areas with relatively low population density, it is found that the performance of 3R waste management facilities is not running well and is even unable to operate. This shows an imbalance in capacity between rural and urban areas, especially in addressing the challenges of operational burdens and community participation (Parinduri et al., 2024). Spatially sensitive considerations are needed when selecting the location of community-based waste management facilities, taking into account each region's geographical, demographic, and socio-economic context. The high percentage of organic waste from resident activities, specifically food waste, which accounts for 46.5% of total waste, is one of the issues urban areas faces. Therefore, after assessing various considerations regarding regional characteristics, it is only then possible to determine technological innovations, especially in organic waste management, which is one of the emphases in waste management (Babu et al., 2021).

Institutional aspects are fundamental to the development of waste management technology, as technical innovations such as BSF or RDF cultivation can only function optimally with strong governance, given the investment and capital required. This can be seen in the 3R waste management facility located in an urban area, which has been able to develop commercially because there are more business and partnership opportunities than in rural areas. Community participation will be successful not only by the level of community involvement, but also by the ability of local institutions to adapt to market mechanisms and technological developments (Arnstein, 1969). This can also be seen in the ability to meet minimum service standards as stipulated in Regulation of the Minister of Public Works of the Republic of Indonesia Number 03/Prt/M/2013, which requires that each TPS 3R unit serve 200 households. In rural areas, this cannot be implemented. Policies that fail to account for local uniqueness often do so because they do not consider social, economic, and spatial variations. Therefore, different models of guidance and partnerships are needed between these regions.

The TPS 3R in Sleman has implemented innovations in realising waste management activities based on the circular economy. Although this has not yet been fully implemented across every unit, or rather only a few, there have been activities such as processing residues into RDF, composting, and maggot farming to develop business units. This certainly reflects a community movement to promote resource recovery so that waste management is not limited to waste disposal. Placing waste in a circular economy requires a regenerative system in which waste is a new resource that has economic value (Ellen MacArthur Foundation, 2024). There are issues that need to be highlighted, particularly in terms of independence or sustainability of operational financing. Although the TPS 3R in urban

areas has been running well, there is a gap in its dependence on government investment funding. This creates vulnerability in the event of policy changes or budget uncertainties. Therefore, it is hoped that managers will be able to continue to pursue funding initiatives so that they can become independent.

The increasing trend of waste is feared to cause a decline in waste sorting activities at the source or in households. This will be a burden for the TPS 3R unit because the quality of waste input will determine the efficiency of the processing. Therefore, the TPS 3R unit needs to regularly and routinely educate the community as partners in order to participate in protecting the environment. Education can take the form of socialisation, training, and even incentives for the community who have sorted its waste. This is in order to strengthen the understanding of social norms and control public perception (Ajzen, 2020). This will enable waste management to go beyond mere knowledge and become a habit and responsibility that must be carried out by all parties. This social intervention is expected to encourage behavioural change in the community.

Based on the results and several enriching discussions that have been conducted, there are differences in conditions between TPS 3R units located in urban and rural areas. Units located in urban areas have been operating due to the availability of resources supporting the business process in waste management, but their business models need to be improved to strengthen waste management activities oriented towards the circular economy. As for units located in rural areas, they need strategies to survive and be useful to the surrounding area. This is because they have limited human and environmental resources. Therefore, policymakers need to develop specific measures to optimise performance in these units. Waste management is an activity that changes human habits, so it cannot be limited to the construction of infrastructure but must also be able to raise awareness of the responsibility for the waste produced by each individual.

Conclusions

The distribution of TPS 3R in Sleman Regency is fairly even across all subdistricts and tends to cluster in urban areas. Facilities in urban areas tend to be operational, albeit with varying levels of performance, while in rural areas, most existing facilities are not operational. Population density, accessibility, economic level, and types of employment are the main external factors influencing the sustainability of TPS 3R facilities. This has an impact on internal factors such as the managerial capabilities of managers, their level of welfare, and their ability to finance operations. The presence of internal and external factors has influenced the innovation of activities aimed at supporting the circular economy. There are suggestions for further research and policy planning, namely the need for a study related to universal indicators that still accommodate local needs, so that they can have a direct impact on the differences in characteristics between regions, because the findings show that units in urban areas have been running due to the availability of resources that support the business process in waste management. Units located in rural areas have limited human and environmental resources. Therefore, policymakers need to develop specific measures to optimise performance in these units. Waste management involves changing human behaviour, so it cannot be limited to infrastructure development but must also raise awareness of individual responsibility for the waste each person produces.

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