"Planning an Effective Waste Management System in a Developing Urban Area: A Case Study of Kotobangon, Indonesia"

Claudya G.E. Massie[1], Isri R. Mangangka[2], Teddy Takaendengan[3]

[1] Students in the Environmental Engineering Study Program, Faculty of Engineering, Sam Ratulangi University, Manado, Indonesia

[2] Lecturer at Environmental Engineering Study Program, Faculty of Engineering, Sam Ratulangi University, Manado, Indonesia

[3] Lecturer at Civil Engineering Department, Manado State Polytechnic, Indonesia

DOI: https://doi.org/10.56293/IJASR.2025.6501

IJASR 2025
VOLUME 8
ISSUE 3 MAY - JUNE **ISSN: 2581-7876**

Abstract: Kotobangon Urban Village, located in East Kotamobagu District, Kotamobagu City, faces significant challenges in waste management. Although a waste collection system is in place, the implementation of the 3R concept (Reduce, Reuse, Recycle) remains suboptimal. As a result, the majority of waste is directly disposed of at the landfill, increasing the environmental burden. Therefore, the planning of a 3R-based Waste Processing Facility (Tempat Pengelolaan Sampah 3R, TPS 3R) is considered a critical solution to enhance waste management effectiveness.

This study analyzes waste types, handling methods, and the socio-economic factors influencing waste generation. Waste containment follows a communal pattern, where residents collect and transport waste to the nearest temporary disposal site (TPS) using plastic bags. Waste composition is dominated by organic waste (56%) and inorganic waste (44%), with an average waste generation rate of 1.004 kg/person/day or approximately 2.5 liters/person/day. The transportation system also adopts a direct communal model.

To reduce the volume of waste ending up in the landfill, increasing community awareness of waste separation and recycling is essential. By implementing a more efficient, environmentally friendly, and economically sustainable waste management system, this study aims to contribute to improving the overall well-being of the residents in Kotobangon Urban Village.

Keywords: Planning, TPS 3R, waste management, storage, collection, transportation.

1. Introduction

Kotobangon Urban Village is located in East Kotamobagu District, Kotamobagu City, North Sulawesi Province, Indonesia. According to data from the Kotobangon Village Office, the population of Kotobangon stands at approximately 2,444 people, and it continues to grow each year. This rapid population growth, along with economic development, has led to a significant increase in the volume of solid waste generated.

The primary issue faced by the village is the absence of an efficient waste management system, resulting in the accumulation of waste and environmental pollution that negatively impacts public health. Inadequate waste management is one of the village's most pressing environmental challenges. This problem stems from several factors, including population growth, which directly correlates with increased waste generation, habitual littering behavior among residents, and a general lack of public knowledge about proper and effective waste management practices.

The lack of adequate waste management infrastructure and limited public awareness of best practices present major challenges. The local community still relies on the traditional "collect–transport–dispose" approach without any form of preliminary processing, which poses serious environmental risks. To address these challenges, the implementation of the 3R (Reduce, Reuse, Recycle) concept through the development of a 3R Waste Processing Facility (*Tempat Pengelolaan Sampah 3R* or TPS 3R) is urgently needed.

By actively involving both the community and local government, it is expected that the volume of waste directed to final disposal sites (TPA) can be significantly reduced, and a culture of sustainability can be cultivated within Kotobangon. This study aims to design a more effective and sustainable waste management system to improve the overall well-being of the local population.

2. Research Methods

This research was conducted in Kotobangon Village, located in East Kotamobagu District, Kotamobagu City, Indonesia.

The study utilizes both primary and secondary data sources. Primary data were collected to determine the quantity and composition of solid waste, as well as to assess the availability and condition of existing waste management facilities in the Kotobangon area. Secondary data include relevant journal references and information on the physical characteristics of Kotobangon Village.

The collected data were then analyzed to estimate waste generation and composition based on the Indonesian National Standard (SNI) 19-3964-1994. Following the analysis, a comprehensive waste management system plan was explicitly developed for Kotobangon Village.

The formulas used in this study are as follows:

$$\text{Sample Waste Volume per Capita} = \frac{Vs}{u}$$

$$\text{Sample Waste Weight per Capita} = \frac{Bs}{u}$$

$$\text{Percentage of Waste Composition (X)} = \text{Weight X (kg)/Total waste weight (kg)} \times 100\%$$

Where:
Vs = Total volume of waste sample
Bs = Total weight of waste sample
u = Number of individuals sampled

3. Results and Discussion

3.1. Results

Kotobangon Village is located in East Kotamobagu District, Kotamobagu City, Indonesia. Geographically, the village is bordered by the following administrative areas:

- To the north: Biga Village
- To the south: Tumobui Village
- To the west: Mogolaing Village
- To the east: Moyag Village

Since its official designation as an urban village on January 1, 1981, Kotobangon has become one of the ten urban villages within East Kotamobagu District. The village is administratively divided into 22 neighborhood units (*RT*) and 9 community units (*RW*). Kotobangon covers an area of approximately 2,882 square meters and has a relatively high population density, with a total population of 2,444 residents.

3.1.1. Analysis of Waste Generation and Volume

Sampling to calculate waste generation was carried out 8 times in 8 consecutive days based on SNI 19-3964-1994. The waste collected was household waste. Sampling was carried out from December 5, 2024 to December 12, 2024, with the results as seen in the figure 1. below

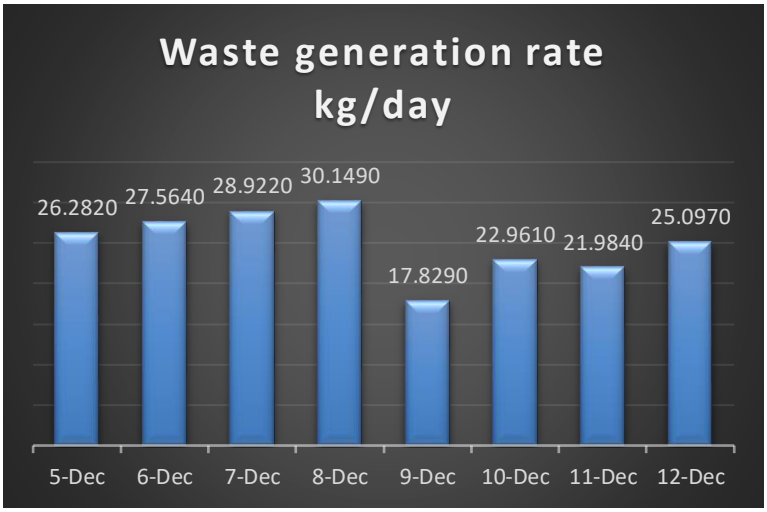

Figure 1. Rate of waste generation in Kotobangon Subdistrict

Figure 1 illustrates the daily waste generation rate in Kotobangon Village over an eight-day period, ranging from December 5 to December 12. The data show fluctuations in waste generation, with the highest volume recorded on **December 8 (Sunday)** at **30.149 kg/day**, followed by **December 7 (Saturday)** at **28.922 kg/day**. These peaks coincide with the weekend, suggesting that household and social activities during holidays contribute significantly to increased waste generation.

The lowest recorded value was on **December 9 (Monday)**, at **17.829 kg/day**, which may indicate reduced activity at the beginning of the workweek. The overall daily average waste generation during the observation period was **25.099 kg/day**.

These findings highlight the influence of daily behavioral patterns and weekly routines on the volume of waste produced. Understanding such trends is essential for designing an adaptive and responsive waste collection schedule, especially during high-generation periods like weekends.

From the waste weight analysis, it was determined that the per capita waste generation is **1.004 kg/person/day**. This figure indicates that each individual living or performing daily activities at home contributes significantly to the total amount of household waste generated each day.

To calculate the **volume of waste**, the following formula was used:

$$\text{Volume (L/person/day)} = \frac{\text{(Waste Weight (kg/person/day)}}{\text{Waste Density}\left(\frac{\text{kg}}{\text{m3}}\right)} \; x\; 1000$$
$$= \frac{1.004}{400} \; x\; 1000$$
$$= 2.5 \text{ L/person/day}$$

Thus, the estimated **waste volume per capita** is **2.5 liters per person per day**.

When compared to the **Indonesian National Standard SNI S-04-1993-03**, which specifies the waste generation standards for small and medium-sized cities in Indonesia, the **waste volume** generated in Kotobangon Village, at **2.50 liters/person/day**, falls within the standard range for permanent housing, which is **2.25–2.50 liters/person/day**. However, the **waste weight**, recorded at **1.004 kg/person/day**, significantly exceeds the standard value of **0.350–0.400 kg/person/day**.

This elevated waste weight is primarily attributed to the high proportion of **organic waste**, which typically has a high moisture content. Additionally, the **high population density** in Kotobangon contributes to increased waste generation. The situation is further exacerbated by **inadequate waste management infrastructure**, which leads to the accumulation of wet waste prior to transportation to the final disposal site (TPA).

These findings emphasize the need for improvements in waste processing, particularly for organic waste, as well as the urgency of upgrading local waste handling infrastructure to reduce environmental risks and improve public health conditions.

3.1.2. Waste Composition

Waste in Kotobangon Village was categorized into three main types: plastic waste, paper waste, and organic waste/food residues. The sorting was conducted based on the guidelines outlined in SNI 19-3964-1994, which classifies waste according to its physical characteristics.

Table 1. Presents the calculated results of the waste composition:

Waste Type	Waste Weight (kg)	Percentage (%)
Plastic	48.087	24%
Paper	39.281	20%
Organic	113.420	56%

Figure 2 shows the waste composition distribution in Kotobangon Village. The results indicate that **organic waste** dominates the total waste composition, accounting for organic waste/food residues **56%**, followed by **plastic** at **24%**, and **paper** at **20%**. The high proportion of organic waste suggests a significant potential for composting or other biological waste treatment methods, which could contribute to reducing the burden on the landfill and support a more sustainable waste management system.

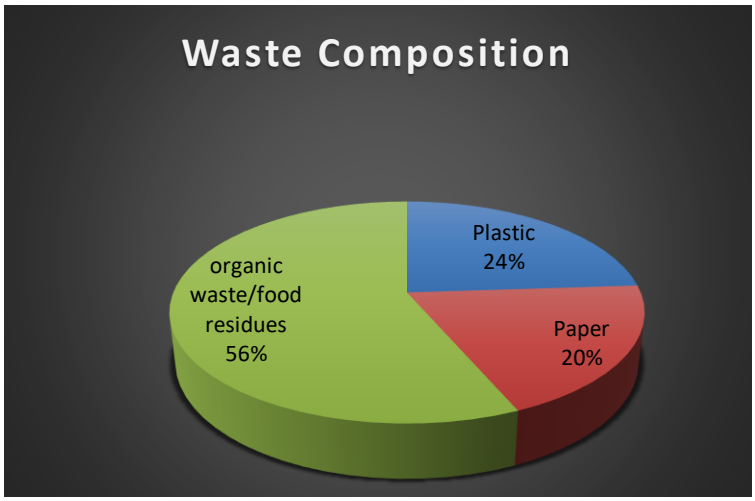

Figure 2. Waste Composition

3.1.3. Total Waste Generation in Kotobangon Sub-District

In Kotobangon Sub-District, waste management has become a significant concern for the local community. Unfortunately, the low awareness among residents regarding the importance of proper waste management has led to indiscriminate disposal practices. As a result, waste accumulation continues to increase, polluting the surrounding environment and posing threats to the cleanliness and health of the sub-district.

To calculate the total waste generated in Kotobangon, data on the population and the waste generation rate is required. The current population of Kotobangon is recorded at **2,444 people**. This results in a total daily waste volume of approximately **6.134 m³/day**.

3.2 Discussion

3.2.1. Waste Management Planning in Kotobangon Sub-District

a. Storage (Waste Containment)

The storage system in Kotobangon follows a **direct communal model**, where waste from households is directly collected and placed into the nearest **Temporary Disposal Site (TPS)** using plastic garbage bags as containers.

b. Collection

The waste collection system also adopts a **direct communal approach**. Waste is collected by residents from the source and brought to the nearest TPS. From there, it is transported by scheduled **motorized waste carts**. Before being transferred to the final disposal site (TPA), the waste is first processed at the **3R-based TPS** (Reduce, Reuse, Recycle).

The planned collection frequency is **three times per week**, with **two collection shifts per day**: the first at **06:00 AM** and the second at **02:00 PM**. This schedule optimizes waste collection while minimizing the number of personnel required. From the analysis results, **6 waste collection motor carts** are required for Kotobangon Sub-District.

c. Transportation

The waste transportation process is carried out by a sanitation crew using **one municipal garbage truck** operated by **four workers**. The transportation frequency is **twice a week**, covering the distance from the 3R TPS in Kotobangon to the **Final Disposal Site (TPA)** in Kotamobagu, which is approximately **9 km** away.

d. Waste Processing

In the effort to reduce the amount of waste disposed at the final landfill, waste processing in Kotobangon Sub-District is categorized into three main types: **organic waste**, **plastic waste**, and **paper waste**, each with specific handling strategies.

- ***Organic Waste***

Organic waste, such as fruit peels and vegetable scraps, will be processed into **compost**. This initiative aims to reduce biodegradable waste and produce **natural fertilizer** that can be used in local agriculture or gardening activities. The compost produced will be sold and also utilized for **urban greening programs** in the area.

- ***Plastic Waste***

To address the increasing volume of plastic waste, plastic materials are first **sorted and washed** at the 3R TPS facility before being processed. The cleaned plastics will then be **crafted into handicrafts or reusable items**, which will subsequently be **sold**, providing both economic and environmental benefits.

- ***Paper Waste***

Usable paper is separated from damaged or soiled paper. After proper **sorting**, the recyclable paper will be collected and **transported to paper recycling facilities**, where it will be **recycled and marketed**. This approach not only reduces landfill waste but also supports circular economy practices.

3.2.2. Planning of 3R Temporary Waste Storage Facility (TPS 3R)

The waste management planning in Kotobangon Sub-District involves active community participation in managing waste from its sources. The establishment of a 3R Temporary Waste Storage Facility (TPS 3R) must meet the criteria set by the Directorate General of Human Settlements (Ditjen Cipta Karya, 2017), as follows:

1. The TPS 3R site must be located within the same administrative boundary as the service area it serves.
2. The area should have a high vulnerability to waste problems, based on the Local Sanitation Strategy (SSK) and statistical data from the Central Bureau of Statistics (BPS).
3. The land ownership should belong to the local/regional government, be designated for public/social facilities, or be community-owned.
4. The minimum area allocated for the TPS 3R site must be **200 m²**.
5. The facility should be located as close as possible to the waste service area.
6. The facility should serve a minimum of **400 households (KK)**.
7. Residents are required to contribute a **waste management fee**.

Based on the previously calculated waste generation, the land area required for the construction of the TPS 3R facility in Kotobangon Sub-District is presented below:

Table 2. TPS 3R Land Area Planning

No.	Description	Area (m²)
1	Waste Receiving Zone (Dropping Area)	35
2	Recyclable Waste Sorting Area	30
3	Shredding Area and Shredding Machine	10
4	Composting Area	20
5	Temporary Waste Storage Area	15
6	Office Area	15
7	Sanitation Facilities (Toilet & Hand Washing Area)	6
8	Equipment and Material Storage Warehouse	15
9	Machine Maintenance Workshop	15
10	Guard Post	6
11	Vehicle Access and Parking Area	36
12	Additional/Operational Movement Space	160
	Total	**350 m²**

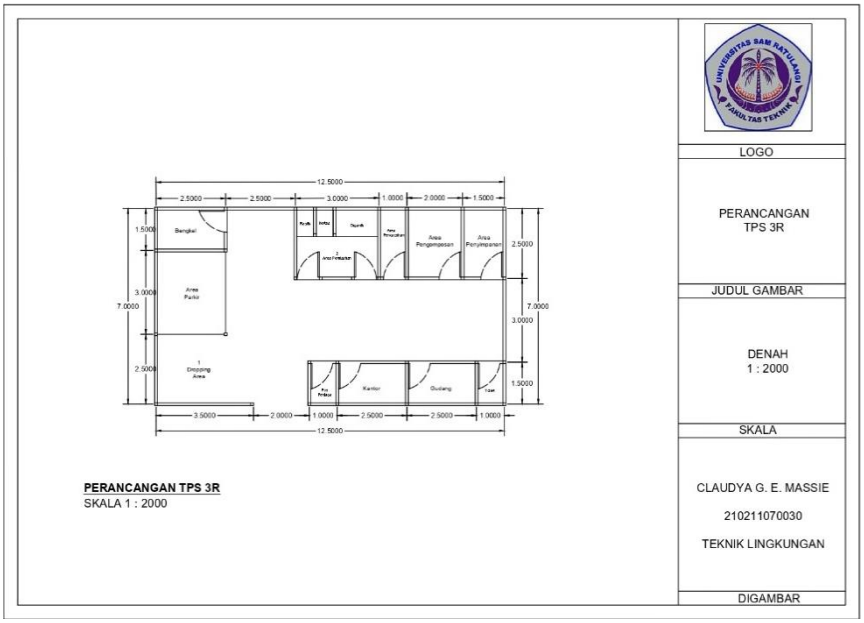

Figure 3. Layout of TPS3R

4. Conclusion

Based on the findings obtained from this final project research, the following conclusions can be drawn:

1. The amount of waste generation in Kotobangon Sub-district, based on weight, is 1.004 kg/person/day. The measured volume of waste is 2.51 liters/person/day. The composition of the waste consists of 56% organic waste/food residues, 24% plastic waste, and 20% paper waste.
2. The dominant characteristics of the waste are organic materials such as food scraps and leaves, along with inorganic materials including plastics and paper. There is no optimal waste segregation system in place; therefore, the waste is generally mixed before disposal.
3. The waste management system in Kotobangon Sub-district includes storage, collection, transportation, and processing under Law No. 18 Article 19 of 2008. This study proposes the development of a 3R-based (Reduce, Reuse, Recycle) Integrated Waste Management Facility (TPS 3R), equipped with supporting infrastructure such as a dropping area, sorting room, shredding room, composting area, temporary storage area, office, warehouse, machine maintenance workshop, guard post, as well as sanitation and parking facilities.

Acknowledgements

The author would like to express sincere gratitude to all parties involved in this research, especially for granting permission and support during the fieldwork in Kotobangon Sub-district, Kotamobagu City.

References

1. Andika, P. (2021). *Planning of Waste Management System in Ngepung Village, Kedamean Sub-district, Gresik Regency.*
2. Akbar, D. (2007). *Generation and Composition of Domestic Waste in Lempeh Sub-district, Sumbawa Regency.*
3. Badratin, N. (2023). *Planning of Temporary Waste Processing Facility (TPS 3R) in Peukan Bada Sub-district, Aceh Besar Regency.*
4. Chandra, B. (2006). *Introduction to Environmental Health*. Jakarta: EGC.
5. Nafi'ah, C., Fadilah, K., & Lukita, C. (2023). *Planning of Integrated Waste Processing Facility (TPST) at the Regional Final Disposal Site (TPA) of Banjarbakula, South Kalimantan.*
6. Damanhuri, E., & Padmi, T. (2010). *Integrated Waste Management*. Course Module, Waste Management. Bandung: ITB Publisher.

7. Felincia, M., Isri, M., & Teddy, T. (2024). *Arrangement of Waste Management System for Sustainable Coastal Area in Bitung Karangria, Manado City*.
8. Ika, L. (2021). *Purposive and Snowball Sampling Techniques*.
9. Jein, W., Teddy, T., & Roski, L. (2024). *Planning of Village Waste Management System (Case Study: Pungkol Village, Tatapaan Sub-district, South Minahasa Regency)*.
10. Jonatan, L. (2021). *Planning of TPS 3R Facility in Mapanget Sub-district, Manado City*.
11. Febriana, K., Wahjuni, S., & Ismayana, A. (2019). *Optimization of Garbage Truck Distribution Using Genetic Algorithm in Bogor City Waste Management System*.
12. Leuhery, L. (2011). *Study on Reliability of Solid Waste Control Patterns: A Case Study in Balikpapan City, East Kalimantan*.
13. Linda, N., Yuni, L., & Firdha, A. (2019). *Design Planning of TPS 3R Facility in Rajabasa Sub-district, Bandar Lampung City*.
14. National Standard of Indonesia (SNI) 19-3964-1994. *Method for Sampling and Measuring Urban Waste Generation and Composition*.
15. National Standard of Indonesia (SNI) 19-2454-2002. *Technical Procedures for Urban Waste Management Operations*.
16. National Standard of Indonesia (SNI) S-04-1993-03. *Specification Standard for Waste Generation in Small and Medium Cities in Indonesia*.
17. Suryati, H. (2003). *Study of Waste Processing in Bandar Lampung City*. Master's Thesis. University of North Sumatra.
18. Subekti, S. (2010). *Community-Based 3R Household Waste Management*. Proceedings of the National Seminar on Science and Technology, Vol. 1 No. 1, 3.