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Operational Technical Study of Waste Management in The Region of Ponorogo District

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Abstract. Waste is still a problem in various countries, especially developing countries. The problem of waste in big cities is different from small and medium cities. The amount of waste tends to increase along with population growth and an increase in living standards is not accompanied by the availability of adequate infrastructure, especially in waste management operations. Ponorogo Regency is one of the small cities in the province of East Java that has failed for 4 consecutive years to win Adipura because of poor evaluation on aspects of waste management. This study aims to examine the availability of infrastructure, especially technical waste management operations in small cities with a case study in Ponorogo Regency. The results show that in 2026 the projected population of Ponorogo Regency is 147,519 people with a volume of garbage generation of 442,556 m³/day. The amount requires availability of 246 units of carts, 16 units of dump truck, 71 units of containers at the transfer station, as well as the expansion of Mrican landfills to 5.4 hectares.

Keywords: *Waste Management, landfills, infrastructure*

1. Introduction

Waste is almost a problem throughout the world, especially in developing countries. The amount of waste tends to increase along with the growth of the population and the increase in living standards. The biggest residue-producing areas come from housing and commercial areas [1]. The oldest and most commonly used final disposal method is landfill [2]. Landfill is widely used, among others, because it is simple, low investment and operating cost and has a large capacity [3]. However, many urban areas in developing countries use non-sanitary and uncontrolled landfills [1]. This has the potential to cause environmental pollution and health problems [4].

Indonesia is a developing country with an average solid waste production of 0.76 kg / person.day. The average waste production when multiplied by a population of 246,533,673 people will produce 187,366 tons/day in a total area of 1,890,000 km² which is divided into 33 provinces administratively [5]. Waste problems in big cities are different from small and medium cities [6]. Average waste production in small cities is around 0.64 kg/person per day [7]. Waste production varies depending on economic activity, lifestyle, population, number of industries and commercial [8]. However, the characteristics of the resulting waste have almost the same type of typology, where 62.5% in metropolitan cities and 63.55% in small cities come from household waste. Differences can also be observed in other sources such as traditional markets, the commercial sector, and offices. Traditional markets in small cities produce more waste than in metropolitan areas. This is because traditional markets in small cities are still frequently visited [7][9]. Waste that is not managed properly will have implications for the expansion of slums. According to a report published by UN-HABITAT in 2003, nearly one billion people live in slums, or nearly a third of the world's urban population. If current trends persist, two billion people will live in this area by 2030 [10]. Based on these conditions, good waste management is very important. Waste management aims to address aspects of aesthetics, land



use, economic, health and environmental problems associated with improper waste disposal [11][12]. Improper waste management will trigger the emergence of sources of air, land and water contamination, as well as being harmful to human health and the environment [10].

Ponorogo regency is one of the small cities in the province of East Java. The city failed for 4 years in a row to win Adipura. Adipura is a national award for cities in Indonesia that is successful in the areas of cleanliness and environmental management. The failure of the regency of Ponorogo to achieve Adipura was mainly due to the poor evaluation on aspects of waste management, especially the final disposal site. The final landfill for Ponorogo regency is in Mrican village, Jenang district. The area of landfills is only around 1 ha. At this time, the local government of Ponorogo regency is planning an expansion of the landfill.

Previous research has various factors that influence waste management including family size, education level and income, community perception and participation, retribution [13][14]. In addition, gender, environment, availability of land, location of the house illustrate people's behavior towards waste [15]. In developing countries, 90% of the waste produced ends up in open dumps. This is what makes the costs of collection, transportation, and disposal become expensive [16]. The process of collection, transportation, and disposal is influenced by various factors, one of which is infrastructure [11][17][18]. This study aims to analyze the availability of infrastructure, especially technical operational management of waste management in small cities with a case study in Ponorogo regency.

2. Methodology

2.1 Location

Observations were made in the urban areas of Ponorogo including Babadan, Jenang, Siman and Ponorogo district.

2.2 Limitations and scope

- The object of study is urban solid waste, not including hazardous solid waste due to special management needed;
- Ponorogo regency population data used as a basis for projection is population data for 2011-2015;
- Projection of waste generation is carried out in the period of 2017-2026;
- Ponorogo regency waste management area is divided into 2 namely urban and rural areas. In this study using urban areas.

2.3 Data processing and analysis

Data needed for this research are primary data and secondary data. Primary data is obtained through field surveys in the form of existing conditions and interviews with the communities around Mrican temporary landfill and final landfill. Secondary data is data that has been available in related institutions such as the Central Statistics Agency of Ponorogo and the Environmental Agency of Ponorogo in the form of population and availability of waste management infrastructure. The stages of data processing and analysis in this study are as follows :

2.3.1 Calculate the population ratio using the formula:

$$r = \frac{P_t - P_o}{P_o} \times 100\% \quad (1)$$

Where: P_o = total base year population; P_t = total population of the i-year; r = population ratio

2.3.2 Calculate population projections using the exponential method with the formula

$$P_n = P_o \times e^{rn} \quad (2)$$

Where : P_n = total population after n years ahead; P_o = total population in the initial year; r = population growth rate; n = time period in years; e = exponential number = 2.7182818

2.3.3 Based on the regulation of the Minister of Public Works of the Republic of Indonesia No. 03/PRT/M/2013, projected waste generation can be calculated by:

$$\text{projected waste generation} = \text{volume of total garbage} \times \text{total population} \quad (3)$$

2.3.4 Calculate planned waste management infrastructure requirements based on Minister of Public Works of the Republic of Indonesia No. 03/PRT/M/2013, such as:

- Collecting tool requirements:

$$\text{Number of fleets} = \frac{\text{volume of garbage}}{\text{tool capacity} \times fp \times rt} \quad (4)$$

Where fp = value of tool compaction factor = 1.2; rt = rotation of collecting equipment

- Transport equipment requirements:

$$\text{Number of containers} = \frac{\text{volume of garbage}}{\text{tool capacity} \times fp \times rt} \quad (5)$$

- Transfer station requirements:

$$\text{Number of transfer stations} = \frac{\text{volume of garbage}}{\text{volume of container}} \quad (6)$$

- Capacity (K) of landfill:

$$\text{Capacity of landfill} = x \times Tr \quad (7)$$

$$K = \frac{\text{carrying capacity of landfill}}{\text{volume certain year of garbage}} \quad (8)$$

Where x = expansion plan; Tr = height of plan generation; K = landfill capacity

3. Results and Discussion

3.1 Total waste

Population growth in Ponorogo regency tends to increase every year as projected following the amount of waste generated in Table 1. The amount of urban solid waste generation in Ponorogo regency is 2 liters/person/day. The amount is still below the specified standard amount of 2.75-3.25 liters/person/day (Indonesian National Standard No. 19-3983-1995). However, this amount may increase in the future. This is influenced by several factors including population growth, increased economic activity, urbanization and lifestyle changes [19][20].

Table 1. Projection of population in the city of Ponorogo for 2017-2026.

Year	Projection amount	
	Population (person) ^a	Waste (m ³ /day) ^b
2017	221.915	665.745
2018	212.072	636.215
2019	202.665	607.994
2020	193.675	581.025
2021	185.084	555.252
2022	176.874	530.623
2023	169.029	507.086
2024	161.531	484.593
2025	154.366	463.098
2026	147.519	442.556

^a Projected population using the exponential method with an average ratio of population growth in Ponorogo regency of -4.5371%;

^b The projected solid waste generation is based on Indonesian national standards 19-3983-1995 on the specification of solid waste generation for small cities and medium cities in Indonesia with an assumption of 3 lt/person/day

3.2 Temporary landfill and garbage carrier vehicles

Calculate how much the needs of the temporary landfill and garbage transport fleet can be known based on the projected generation of waste that has been calculated in the previous section.

3.2.1 Collecting tools

Garbage collection is carried out by motorized carts to collect garbage from settlements where it is not possible to reach the garbage truck directly. Motorized carts transport garbage to a temporary garbage shelter. Collection is done directly every day. This collection method is also carried out in Hanoi, Vietnam where the collection is done directly using the pushcart system and the container system. Pushcart is used in a narrow area of the road that is passed by garbage trucks. Garbage collection officials collect solid waste in plastic bags dropped by residents along the road [21].

Conditions that are not much different occur in Mojokerto city, where people throw garbage in the trash in front of the house. The people of Mojokerto are not used to waste separation and reduction, so only about 1.1% of households sort waste, while 1.9% also try to reduce the amount of waste they produce [7][22]. Calculation of the need for a garbage collection tool can be calculated by dividing the volume of waste generation by the capacity of the garbage collection tool multiplied by compaction and irritation factors. In this study using a cart with a capacity of 2 m³ and the number of rites as much as 2 times so that the calculation is obtained as contained in Table 2. Based on the calculation results shown in Table 2. it can be concluded that the more volume of waste generation, the more fleet is needed.

Table 2. Projected for garbage collection equipment in Ponorogo regency for 2017-2026.

Year	Waste generation (m ³ /day)	Number of fleets (unit)
2017	665.745	139
2018	636.215	133
2019	607.994	127
2020	581.025	122
2021	555.252	116
2022	530.623	111
2023	507.086	106
2024	484.593	101
2025	463.098	97
2026	442.556	93

3.2.2 Garbage carrier fleets

The fleet of garbage is needed to transport garbage from temporary shelters. In this place various containers are ready to be transported to the final disposal site. The container system is also placed in front of large residential buildings, office buildings, markets, etc. To collect garbage placed by residents who live in this area. After that, this waste is collected and transported by truck to landfills [7][21].

The availability of garbage transporters is very important because of the lack of damaged vehicles and roads [11] and other inadequate infrastructure that will affect the characteristics of waste [18]. The size and type of vehicle and the frequency of transfers depend on the amount of waste produced and the financial capacity of the government. Mojokerto city only has 65 carts, 26 rickshaws, and 4 dump trucks [23]. This fleet is only enough to collect around 80% of the waste produced. The shortage of the transport fleet triggers the occurrence of bad waste management such as backyard burning and littering [24]. In addition, the lack of garbage containers will make transport distances longer, increasing the likelihood of garbage dumping in open areas and road sides along the journey [25].

Calculation of the needs of the garbage transport fleet can be calculated by dividing the volume of waste generation by the capacity of the garbage transport fleet multiplied by compaction and irritation

factors. The fleet used is a dump truck with a capacity of 6 m³ and the number of irritations is 2-4 times [5]. The results of the calculations are in Table 3.

Table 3. Projection of waste garbage fleets in Ponorogo regency for 2017-2026.

Year	Waste generation (m ³ /day)	Number of fleets (unit)
2017	665.745	24
2018	636.215	23
2019	607.994	22
2020	581.025	21
2021	555.252	20
2022	530.623	19
2023	507.086	18
2024	484.593	17
2025	463.098	17
2026	442.556	17

Based on the results of calculations in Table 3 there is a decrease in the number of dump trucks due to the promotion of community empowerment programs in waste management. At this step, the efficiency of collection and transportation can be improved but must be increased through increased coverage of the collection area, effective transportation costs by using vehicles and scheduled transportation systems [26]. This can reduce the amount of littering.

3.2.3 Temporary landfills

The availability of waste facility supply significantly influences waste disposal options [25]. One of the facilities needed is a temporary disposal site. This temporary disposal site aims to reduce the transport distance of collection trucks, thereby reducing transportation costs [21]. In general the place can be a large steel container, a concrete trash can or an open space [5]. In Ponorogo regency, the capacity of temporary landfills is an average of 6 m³, so the projected number of polling stations is projected as listed in Table 4.

Table 4. Projection of temporary landfills in Ponorogo regency for 2017-2026.

Year	Waste generation (m ³ /day)	Number of temporary landfills (unit)
2017	665.745	111
2018	636.215	107
2019	607.994	102
2020	581.025	97
2021	555.252	93
2022	530.623	89
2023	507.086	85
2024	484.593	81
2025	463.098	78
2026	442.556	71

In Table 4, the projection of the number of temporary landfills tends to decrease due to the commitment of Ponorogo regency which is promoting the recycling program to the community to reduce the amount of waste produced. This program needs to involve government cooperation with other parties such as companies or industries for environmental empowerment such as green and clean programs, waste banks or others as an effort to limit the amount of solid waste that is thrown into landfills [27]. This is due to the limited funds owned by the government in waste management [28].

3.2.4 Final landfills

Globally, waste dumped in landfills is around 71% [29]. Waste contains various hazardous substances including batteries, paints, mercury-containing waste, drugs, vehicle care products, and many other products [30]. On the other hand, more than 53% of landfill waste consists of hard paper boards, yard waste, paper and food that can be biodegradable by anaerobic bacteria [31].

Most of the garbage is disposed of in landfills without undergoing sorting first. This causes insufficient landfill capacity, causing negative impacts on the environment. Therefore, Ponorogo regency needs a sustainable waste management management strategy to minimize these negative impacts. Landfill was chosen as the best alternative for final disposal since the option that residues should be disposed of in landfills [32]. This technology was chosen because it is considered cheaper than other waste treatment technologies [21][33].

The final disposal site in the town of Ponorogo regency is located in Mrican, located in the district of Jenang. Mrican's land area is 17,772 m² with a garbage storage capacity of 1,964,941 m³. The waste management operation in the Mrican landfill uses a controlled landfill system. A controlled landfill is a coating system in a landfill and is covered with a layer of soil every day or the end of a certain period. This system is enough to help reduce the effects arising from landfill waste [32]. This method is suitable for landfills that cannot yet fully implement the sanitary landfill system. Sanitary landfill is a final level of waste management system recommended for developing countries (Republic of Indonesia Minister of Public Works Regulation No. 21/PRT/M/2006, because of its lower operational costs compared to other waste management techniques [33]).

Calculating the capacity of landfills can use formula (7) and formula (8) as in the previous section. Based on the data from Ponorogo Regency Environmental Agency for 2014 was obtained $T_r = 3$ m while the projected waste in 2026 is 442,556 m³/day (Table 5). Based on formula 8 the landfill capacity (K_{2026}) is obtained 5.4 hectares. Based on the calculation above, it is known that the capacity of the Mrican landfill in 2026 is 5.4 hectares while the existing condition has only 2.5 hectares. In order to reduce the burden of landfills to accommodate the amount of waste, it is necessary to reduce waste from the source. Examples are through a system of reduce, reuse, and recycle [34][35]. Therefore community participation is needed to contribute to the empowerment echoes of waste management [36].

3.2.5 Infrastructure recommendations

The results of the technical review of waste management operations in Ponorogo regency in the previous section were the basis for improving waste management in the region. The description of the strategy is in Table 5.

Table 5. Recommendations for waste management infrastructure in Ponorogo regency.

Infrastructure	Existing conditions	Projection	Strategy
Collecting equipment	197 unit	246 unit	– Addition of equipment – Addition of ritation
Carrier fleet	10 unit	16 unit	– Addition of equipment – Addition of ritation
Container in temporary landfill	34 unit	71 unit	– Addition of equipment – Addition of ritation
Landfill capacity	2.5 Ha	5.4 Ha	– Land expansion – Improved reuse, reduce, and recycle concepts from the community level

4. Conclusion

Based on the results of the analysis and discussion above, conclusions can be drawn in this study are as follows: (1) the projected population in Ponorogo regency in 2026 is 147,519 people with a projected volume of waste generation of 442,556 m³/day; (2) prediction of infrastructure needs in Ponorogo regency in 2026 is 246 units of garbage collection equipment, 16 units of garbage transport fleet, 71 units of containers in the transfer station, and expansion of landfill for Mrican to 5.4 hectares.

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