Optimizing Waste Reduction Rate at The Integrated Waste Processing Facility in Ngipik Landfill, Gresik

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Abstract. The average weight of municipal solid waste disposed of at the Ngipik Landfill was 212.2 tons per day, with 94.8% directly deposited in the landfill. Based on field observation, there was existing reduction carried out by Integrated Waste Processing Facility (*Tempat Pengolahan Sampah Terpadu,* TPST) before the waste was deposited in the landfill. However, the exact amount of waste that could be reduced at the TPST is unknown. Further research was needed on the amount of waste that can be reduced at TPST. This data could serve as additional information in the waste material flow of Ngipik Landfill. The objectives of this study were to assess the implementation of waste reduction by TPST operational activities, then to do the calculation of waste potential weight and composition that could be reduced by TPST. The weight and composition were measured using direct measurement methods. The potential reduction of the TPST was 7.74 tons per day. The results of the TPST optimization were an increase in the amount of waste entering to 18.8 tons per day with working hours from 7:00 a.m. until 4:00 p.m., the addition of 31 people in the sorting operation, and the expansion of land to 2,521.8 m^2.

1 Introduction

Municipal Solid waste issues is a problem faced by almost all cities in Indonesia. One of these issues is the municipal solid waste problem faced by Gresik Regency. The increase in population and number of industries in Gresik Regency has resulted in a significant increase in municipal solid waste generation. Based on the data obtained from the National Waste Management Information System (*Sistem Informasi Pengelolaan Sampah Nasional,* SIPSN), Gresik Regency produced 402.23 tons of municipal solid waste per day in 2024 [1]. This amount has increased by 22.72% or 74.46 tons per day from the amount of waste generated in 2020 [1].

The increasing amount of municipal solid waste produced per day is not followed by efforts to reduce waste from the source. Currently, most cities in Indonesia still adhere to old paradigm of collect, transport, and dispose. With this paradigm, the level of reduction at the source is very low, resulting in a huge burden for landfills. If this condition continues, it will cause the landfill to overload rapidly and must be closed.

A total of 212.2 tons of municipal solid waste is sent to Ngipik Landfill every day, or around 52.7% of the total daily municipal solid waste generated by Gresik Regency [1]. This data is also supported by research conducted by Rosariawari et al., which states that the average amount of municipal solid waste entering the Ngipik landfill is 210 tons per day [2]. The disposal method implemented at the Ngipik landfill is planned to be a sanitary landfill, with solid waste covered using soil by heavy equipment every day. However, this has not been implemented due to several constraints, one of which is the operational factors of vehicles and heavy equipment at the landfill [3]. Based on field observations on December 5, 2023, the municipal solid waste disposal system at the Ngipik landfill uses a controlled landfill. A total of 199 tons or 94.8% of the solid waste entering the Ngipik landfill is directly disposed of in the landfill. Currently, the amount of solid waste at the Ngipik landfill has exceeded its capacity [4]. If solid waste is not processed before being buried in the landfill, it is estimated that the Ngipik landfill will no longer be able to accommodate municipal solid waste from Gresik Regency in the next few years.

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Considering that the reduction rate at the source is very low, there are several actions that can be taken to reduce the amount of solid waste entering landfills. One action that can be taken is to conduct preliminary processing at the landfill before the solid waste is buried in the landfill zone. It is estimated that this preliminary processing will reduce the amount of waste buried in the landfill zone, thus extending the life of the landfill. One facility that can be applied for preliminary treatment by using Integrated Municipal Solid Waste Processing Facility or we called it TPST (*Tempat Pengolahan Sampah Terpadu*). From the study that conducted by Setyaningsih and Caroline in 2016 it obtained the results that TPST has potential to reduce almost 70% MSW entering the landfill [5].

Based on that reference, the Ngipik landfill management has make several efforts to reduce the amount of solid waste entering the landfill. Currently, there are processing efforts carried out by the informal sector, Integrated Waste Management Facilities (TPST), and composting houses. However, there is no data available on the amount of waste reduced by these sectors. From the waste processing data at the TPST, it will be possible to estimate the amount of solid waste reduction before it enters the landfill and the lifespan of the landfill. This will enable recommendations to be made on measures that can be taken to optimize solid waste reduction activities before it enters the landfill and efforts to extend the lifespan of the landfill. The research was conducted by examining solid waste reduction implementation at the Ngipik landfill from TPST operational activities, calculating the weight and composition of solid waste reduced by the TPST, and analyzing the material flow of solid waste at the Ngipik landfill. The expected outcome of this research is that the data produced can be used as a reference for landfill managers to calculate the lifespan of the landfill more accurately and evaluate existing activities at the Ngipik landfill.

2 Research method

2.1 Primary Data Collection

Primary data was obtained through direct observation, surveys, field calculations, and interviews with respondents at the research site. The data obtained in this study is as follows:

1. Data on the volume, density, and composition of daily solid waste entering the landfill.
   Volume data was obtained to determine the amount of solid waste entering the landfill per day. The data collection method used was weight volume analysis for 8 consecutive days by recording the weight of each truck entering and leaving the landfill at the weighbridge. The weight of the solid waste in the truck was obtained from the weight of the truck entering the landfill minus the weight of the truck leaving the landfill. In addition to the weight of the truck, the type of vehicle, vehicle license plate number, time of entry and exit of the truck, and the destination of the truck, whether directly to the landfill or to the TPST, were also recorded. The density was obtained by dividing the weight of the solid waste in the truck by the volume of the truck container. The composition of the solid waste is measured by taking 100 kg of waste that has just been unloaded from the truck, which is then sorted and weighed according to its composition.
2. Data on the weight and composition of waste reduced at the TPST.
   Data on TPST reduction was collected using direct measurement methods over a period of 4 days. The measurement of solid waste generation and composition was carried out in accordance with Indonesian National Standard (*Standar Nasional Indonesia,* SNI) number 19-3964-1994 concerning Methods for Collecting and Measuring Samples of Urban Waste Generation and Composition [6].
3. Data on the capacity of processing machines and the area of the TPST.
   The method of collecting data on machine capacity and TPST area was through interviews with TPST officers and direct calculations. Data from interviews with landfill and TPST management personnel included operating hours, the solid waste processing and management flow at the landfill and TPST.

2.2 Secondary Data Collection

In conducting this research, secondary data is needed to support the data analysis as follows:

1. Recapitulation of solid waste data entering the landfill.
2. Organizational structure and operational system at the TPST.

2.3 Data Analysis

Data processing and discussion were carried out on the primary and secondary data that had been collected. Research data analysis to determine reduction results, assessment of TPST operational activities, and material flow of solid waste at TPST was carried out in several ways, as follows:

1. Analysis of waste reduction from TPST operational activities at the Ngipik landfill.
   Analysis was carried out based on interviews with TPST officers and landfill management officers. Next, a descriptive analysis was conducted related to the operational system and organizational structure of the TPST, coordination between TPA and TPST activities, and the operating hours of the TPA and TPST. The existing conditions at the TPST were compared with the recovery factors of other TPSTs in order to optimize the recovery factor to match the ideal reduction. Then, the land area requirements per facility were calculated.
2. The analysis of TPST reduction results was carried out using direct measurement methods.
   The calculation of the average daily reduction of TPST from the processing results included the sorting of recyclable waste, plastic chips, compost, and briquettes.

3 Result and Discussion

3.1 Weight and Composition of Solid Waste Entering the Ngipik Landfill

Based on sampling conducted over 8 days, the average amount of waste entering the Ngipik Landfill was 234,262 kg per day or 234.2 tons per day. The largest amount of waste entered on Friday, amounting to 307 tons, and the smallest amount entered on Sunday, amounting to 160 tons. This occurred because the number of non-environmental agency trucks that disposed of waste on Monday-Friday was higher than on Saturday-Sunday, resulting in a significant decrease. Meanwhile, trucks from the Gresik environmental agency routinely disposed of waste every day. A summary of the weight of waste entering the landfill can be seen in Figure 1.

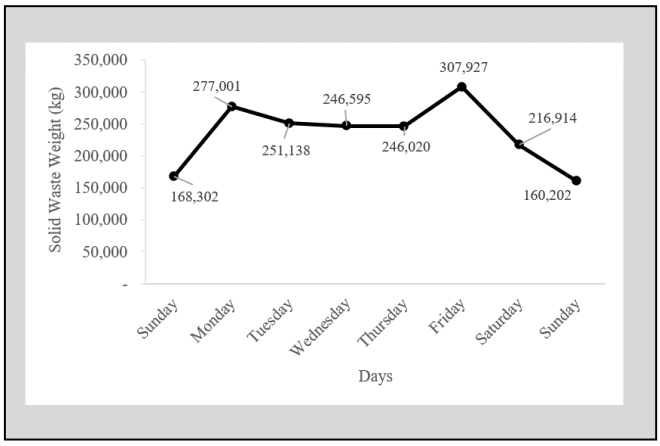


Fig. 1. Graph of Total Solid Waste Entering the Ngipik Landfill per Day

The composition of solid waste at the Ngipik Landfill is sorted based on SNI 19-3964-1994. The largest composition of municipal solid waste is food waste at 71.6%, while the smallest composition is other waste at 0.02% that mostly consist of sacks waste. The percentage composition of waste can be seen in Figure 2. Food waste and yard waste have high moisture content, which affects the weight of the waste and causes the percentage composition of these two types of waste to be the largest. Both types of waste have the potential for biological treatment because they can degrade naturally. The type of plastic waste with the highest percentage (47%) is Low Density Polyethylene (LDPE), which consists of disposable plastic bags, frozen food bags, bubble wrap, and food packaging plastic. This shows that LDPE plastic is still widely used by the community, especially for packaging. Other plastic compositions consist of multilayer plastics (19%), Polivinyl Chloride/PVC (12%), Polyethylene Terephthalate/PET (11%), Polypropylene/PP (5%), Polystyrene/PS (3.3%), and High Density Polyethylene/HDPE (2.3%). Residual waste consisting of diapers,

menstrual pads, tissues, and other items are the third largest composition of waste entering the Ngipik landfill, with a percentage of 6.2%.

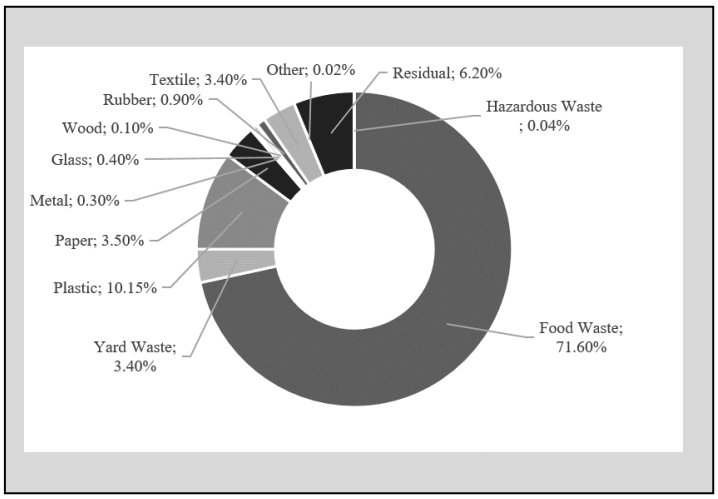
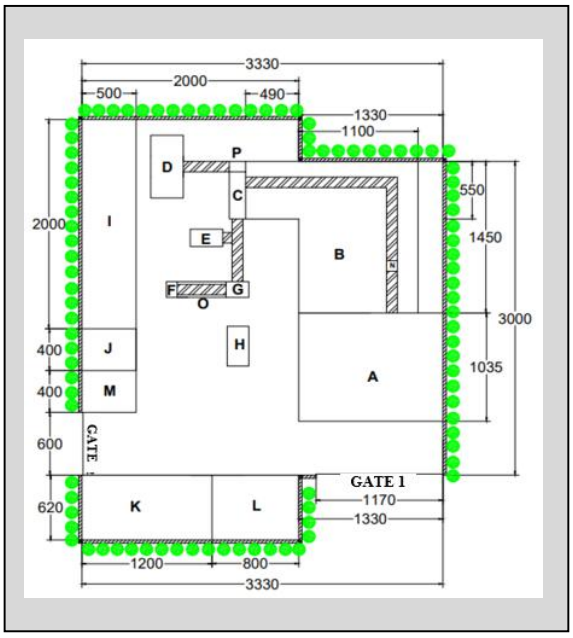


Fig. 2. Solid Waste Composition Entering the Ngipik Landfill

3.2 Existing Conditions of TPST

The TPST at the Ngipik landfill has a land area of 1,203 m^2 with a waste input capacity of 2.5 tons per hour. According to Minister of Public Works Regulation No. 3 of 2013, the requirement for establishing a TPST is to have a minimum building area of 20,000 m^2 [7]. In terms of land area, the TPST at the Ngipik landfill does not yet comply with the minimum building area requirement. The management office and weighbridge facilities are integrated with the Ngipik landfill. The layout of the existing TPST can be seen in Figure 3.



Description:
A Reception area
B Sorting area
C Sorting machine
D Compost shredding area
E Residue area
F Plastic shredding area
G Shredder
H Briquette production area
I Compost material storage area
J Mixed sorting output storage area
K Shredding output storage area
L Briquette output storage area
M Paper sorting output storage area
N Bag opener machine
O Plastic shredding area

Fig. 3. Existing TPST Layout

From the layout in Figure 3, there are areas for receiving, sorting, shredding, composting, and storing sorted waste, briquettes, and shredded waste. The processing machines at the TPST are a bag opener machine that tears open plastic wrappers from household waste, a plastic shredder machine that shreds plastic into small pieces, and a sorting machine that sorts compostable waste, residues, LDPE plastic, and others. The existing waste processing flow at the TPST can be seen in Figure 4.

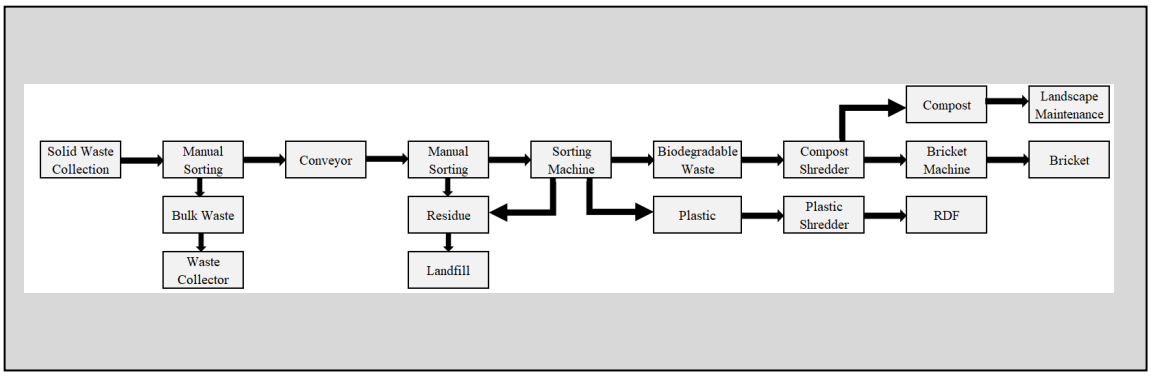


Fig. 4. Existing Waste Processing Flow at TPST

Based on an interview with the manager of the Ngipik landfill, the TPST at the Ngipik landfill began operating in July 2023. The TPST operates every Monday to Friday from 8:00 a.m. to 3:00 p.m. On average, 7-8 trucks enter the TPST every day, which are determined by the Environmental Agency. The final output of the TPST is plastic chips that will be used as Refuse Derived Fuel (RDF), as well as charcoal briquettes and compost materials that will be used for composting. At the TPST, waste that can be recycled, such as paper, cardboard, and certain types of plastic like HDPE, PET, PVC, and others, is sorted and later sold to waste collectors.

Recapitulation of TPST input weight and reduction can be seen in Figure 5. Based on the Figure 5, the largest reduction in TPST was on Wednesday, amounting to 8,169.3 kg or 8.16 tons, while the smallest reduction was on Thursday, amounting to 6,659.4 kg or 6.65 tons. The results of TPST processing, namely plastic chips, briquettes, compost, and sorted waste, can be recycled. From the field data, the average waste reduction rate at the TPST was 20%.

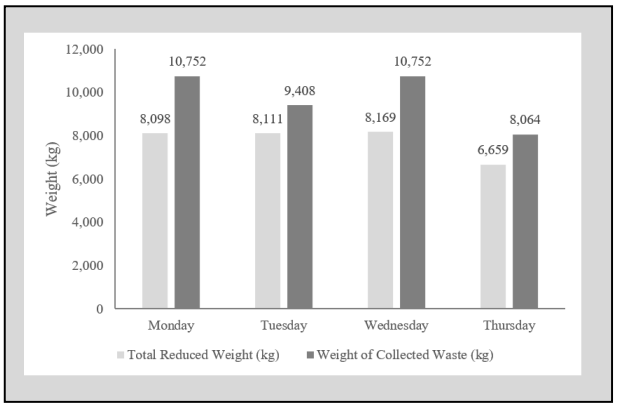


Fig. 5. Recapitulation of TPST Input Weight and Reduction

3.3 TPST Optimization

TPST optimization was carried out by increasing the weight of incoming waste from 7 trucks to 14 trucks per day with residential waste weighing a total of 18,819.5 kg. Additionally, working hours were extended from 6 hours to 8 hours in accordance with Law Number 11 of 2020 on Job Creation (Job Creation Law) [8]. The results of the calculation of the land area required for optimization can be seen in Table 1.

Table 1. Summary of Land Requirements for TPST Optimization

No.	Function	Existing Area (m^2)	Optimized Area (m^2)
1	Office	0	24
2	Receiving area	137.7	137.7
3	Sorting area	193.2	163.5
4	Plastic shredding area	11.4	27
5	Briquette production area	7.6	13
6	Residual waste handling area	4.98	10.6
7	Plastic shredding storage area	100	21
8	Mixed sorting results storage area	40	16
9	Paper sorting results storage area	40	9
10	Briquette storage area	49.6	13.8
11	Compostable waste shredding area	18	31.6
12	Composting area	100	567.8
13	Maturation area	0	197.5
14	Compost screening area	0	22.2
15	Compost storage	0	15.4
	TOTAL LAND AREA	662.4	1,270.1

From the Tabel 1, the total land area required for TPST optimization is 1,270.1 m^2. The results of the optimized building design for building 1 can be seen in Figure 6.

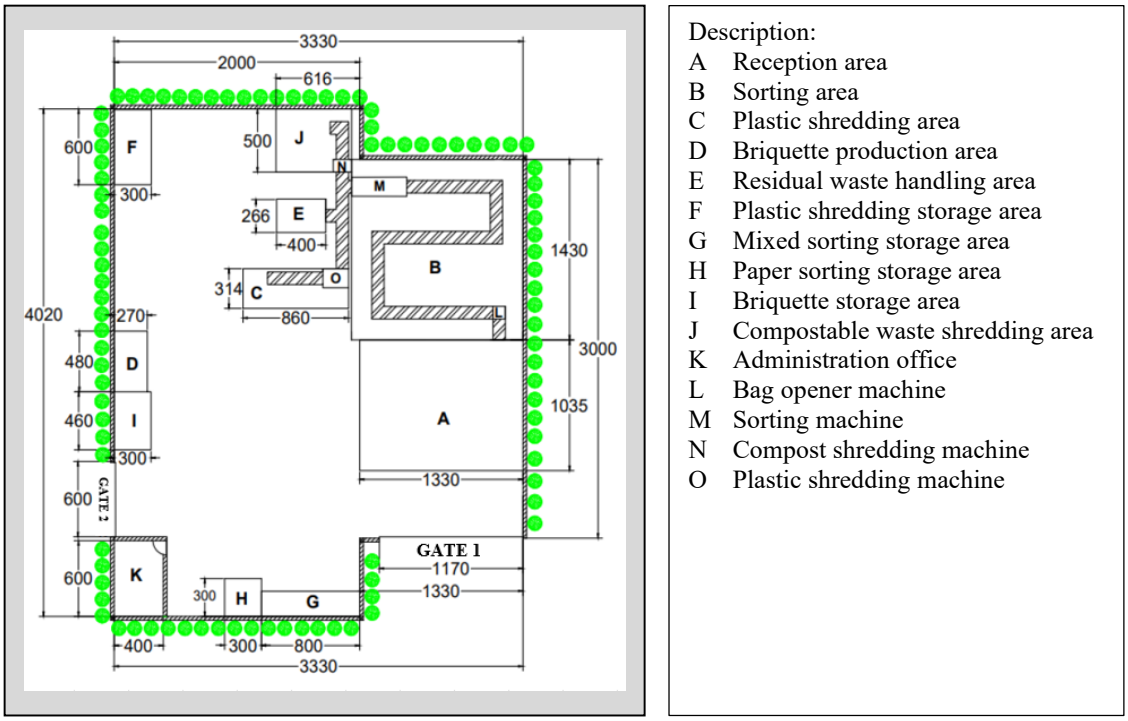
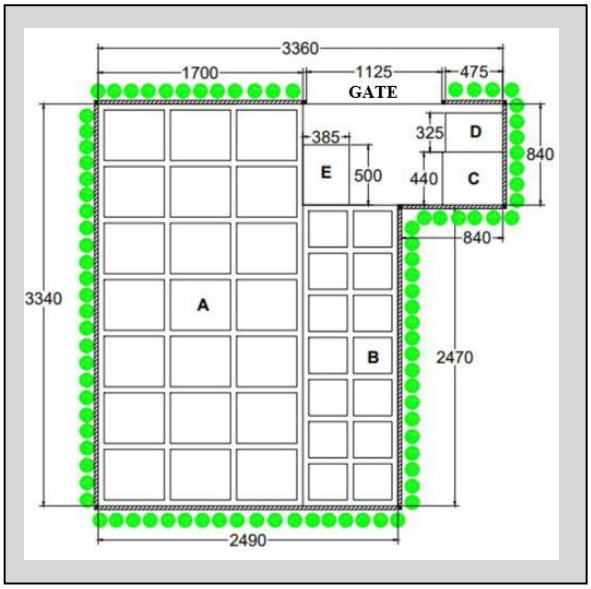


Fig. 6. Layout Optimization of Building 1 TPST

The location for the composting facility is planned on unused landfill land 110 m from the waste transfer station. The location of the planned site can be seen in Figure 7.

Fig. 7. Composting Facility Planning Location

From Figure 7, the planned location of the composting facility is in the area marked with a yellow box, covering an area of 902.22 m^2, at distance of 110 m from the existing TPST building. The reason for choosing this location is that composting cannot be carried out on the existing TPST land, so a location around the landfill must be found for the planning of the composting building. The results of the optimized TPST building 2 design planning can be seen in Figure 8.



Description:
A Composting area
B Maturation area
C Sifting area
D Compost storage area
E Compost material reception area.

Fig. 8. Optimization Layout of Building 2 TPST

4 Conclusion

The average weight of waste entering the Ngipik landfill is 234.26 tons per day. Of the 228.72 tons that go directly to the landfill, 9.74 tons go to the TPST. The TPST is estimated to reduce waste by 84.68% of the total waste entering the TPST, so that only 15.32% enters the landfill. To achieve this result, a scenario can be implemented by increasing the amount of waste entering the TPST from 7 trucks to 14 trucks per day. In addition, working hours will be increased from 6 hours to 8 hours. The processing results at the TPST include sorted recyclable waste, plastic chips, compost, and briquettes.

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