

Budihardjo_2019_IOP_Conf._Ser ._Earth_Environ._Sci._337_0120 28.pdf *by*

Submission date: 25-Feb-2021 02:46PM (UTC+0700)

Submission ID: 1517766442

File name: Budihardjo_2019_IOP_Conf._Ser._Earth_Environ._Sci._337_012028.pdf (665.03K)

Word count: 2700

Character count: 13462

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To cite this article: M A Budihardjo *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **337** 012028

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The role of waste banks in the reduction of solid waste sent to landfill in Semarang, Central Java, Indonesia

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Abstract. Approximately 1,000 tonnes of solid waste are generated in Semarang every day, only 850 tonnes of which are transferred to the Jatibarang Landfill. Solid waste that is not transferred to the landfill can trigger environmental and health problems. With the help of community groups, reduction of solid waste is achievable using 'the three Rs' of waste reduction and the implementation of waste banks. Waste banks could act as mediums for depositing waste, improve the socio-economic status of local residents, and develop community connections. Waste banks improve the volume of waste reduction and reduce landfilled waste, helping to extend the operational life of landfills. This study examined the role of waste banks in Semarang and the potential to improve waste management based on the sampling of solid waste generation and composition. This topic was investigated with a purposive sampling method. Results showed that the existing system of waste banks in Semarang is ineffective in reducing waste. However, the system could be improved by increasing waste bank usage, including for various types of valuable waste in Semarang.

1 Introduction

According to the Regional Secretary of Semarang, in 2017, 1.6 million people lived in Semarang's 16 sub-districts. Each day, approximately 1,000 tonnes of solid waste are generated in Semarang, only 850 tonnes of which are transferred to the Jatibarang Landfill. The remainder, solid wastes which are transferred to the landfill, can trigger environmental and health problems. Amid increasing amounts of solid waste generated in the city, a well-organized system of solid waste management is needed to reduce waste.

UU no. 18 of 2018, a law that administers solid waste management in Indonesia, explains the need to change from conventional to advanced waste reduction methods, focusing on minimisation and treatment of solid waste. Minimisation can be achieved by reducing, reusing, or recycling waste, commonly known as the 'three Rs' of waste reduction [1].

Certain types of waste have economical value if sold or reformed into other things, as raw materials or finished goods. If Semarang locals, as generators of solid waste in the city, are to play an important role in Semarang's solid waste management, they will require a physical location for waste management operational processes. Semarang's waste banks could act as mediums for depositing waste, improve the socio-economic status of local residents, and develop community connections in the city [2]. An effective system of waste banks may improve the city's solid waste management, increasing the amount of waste deposited into the waste banks. This system would improve the volume of waste reduction and landfilled waste in the city while extending the operational life of Semarang's landfill [3]. Moreover, if these systems function effectively, the amount of residual waste in the city will be diminished, its environment will become cleaner, and health outcomes could be improved [4].

2 Methodology

The study was conducted over four months, from September to December 2018, in Semarang, Central Java, Indonesia. Solid waste generation and composition calculation were conducted using SNI 19-3964-1992 [5] in three stages. The first stage was solid waste sampling in domestic and non-domestic areas of



Semarang over eight consecutive days. Sample points were selected from various locations around Semarang to represent the city's solid waste generation and composition.

In this stage of the study, Semarang was divided into five sections: Tugu, Tembalang, Central Semarang, Gajahmungkur, and Gayamsari. During the study, a trash bag was distributed to the city's waste sources the day before weighing of waste commenced. The next stage was solid waste weighing, which was conducted using tools such as gloves, trash bags, shovels, and weight scales. Weighing steps were conducted twice to measure the combined weight of all waste types and separate weight of each waste type to understand the city's waste composition. The last stage of this study was a purposive sampling-based questionnaire, which was targeted at waste bank developers and consumers in Semarang. The number of respondents was calculated with Slovin's formula to identify the correct value of the sample in certain populations and apply this number to a larger population

$$n = \frac{N}{N(d)^2 + 1} \quad (1)$$

Annotation:

n = number of samples

N = number of populations

d = degree of freedom (ex: 0.1, 0.05, 0.01)

The number of respondents for this study's purposive sampling questionnaire is shown in Table 1 below:

Table 1. Number of respondents.

Sub-District	Population (Houses)	Respondents (Houses)
Mijen	13.958	4
Gunungpati	21.889	6
Banyumanik	31.199	9
Gajahmungkur	11.992	3
South Semarang	13.997	4
Candisari	15.189	4
Tembalang	38.846	11
Pedurungan	40.777	12
Genuk	22.157	6
Gayamsari	15.879	5
East Semarang	14.972	4
North Semarang	23.632	7
Central Semarang	12.075	3
West Semarang	32.211	9
Tugu	6.408	2
Ngaliyan	30.769	9
Total	345.950	100

Besides the questionnaire, an interview was conducted at waste banks in Banyumanik and Pedurungan to understand the quantity and type of waste withdrawn and deposited in the waste bank each month. This interview helped the authors to review the performance of existing waste banks in several areas of Semarang.

3 Results

The city's solid waste generation and composition were calculated based on the weight of waste. This calculation was used because the reduction rate could be determined by the difference between weight with and without implementation of waste banks. In addition, weight is a common unit of measurement used by Semarang's waste scavengers and collectors in their trading processes. For this reason, the use of weight in this calculation made the study easier to understand and more relevant to real-world conditions.

Table 2. Total solid waste generation in Semarang.

Domestic Facility	Number of People	Solid Waste Generation Rate (kg/day/person)	Total Solid Waste Generation (kg/day)
Housing	1,701,172	0.43	732,002.91
Sub-Total			732,002.91

Non-Domestic Facility	Number of Units	Solid Waste Generation Rate (kg/day/unit)	Total Solid Waste Generation (kg/day)
Elementary School	591	13.77	8,137.04
Junior High School	220	21.86	4,808.78
Senior High School	189	27.38	5,174.47
Shop	681	3.12	2,124.61
Restaurant	4,352	6.72	29,230.05
Health clinic	37	8.3	306.92
Hospital	26	239.33	6,222.57
Market	47	928.09	43,620
Sub-Total			99,624.43
Total Solid Waste Generation of Semarang			831,627.35

Table 2 illustrates the total solid waste generation from domestic and non-domestic facilities in Semarang. In total, 732,002.91 kilograms of solid waste were generated from homes used as domestic facilities each day. Non-domestic facilities such as schools, markets, and hospitals produced 99,624.43 kilograms of solid waste each day. Together, both types of facilities generated 831,627.35 kilograms of solid waste each day. This table shows that individual domestic facilities generated more solid waste than individual non-domestic facilities. However, domestic facilities generated less solid waste than non-domestic facilities as a group.

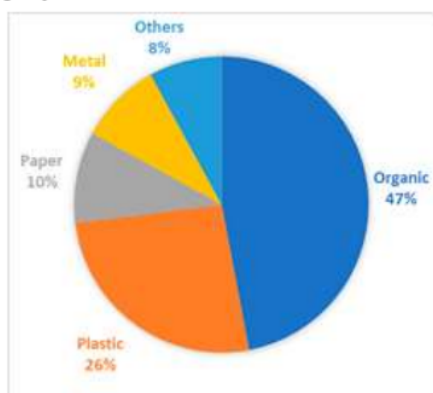


Figure 1. Solid waste composition of domestic facilities.

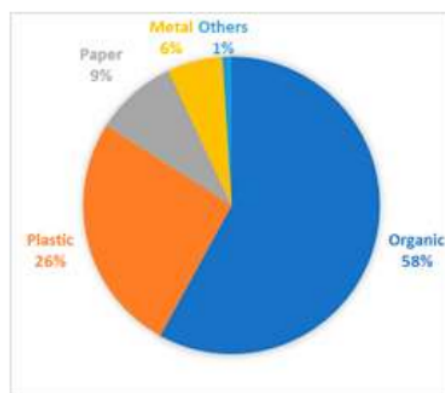


Figure 2. Solid waste composition of non-domestic facilities.

Figure 1 and 2 demonstrate the percentage of composition for each type of waste in domestic and non-domestic facilities respectively. Solid waste composition is differentiated into five different type of waste: organic, plastic, paper, metal, and others. Both domestic and non-domestic facilities produced mainly organic waste (47% and 58% respectively), followed by plastic (26% for both types of facility). Three types of waste accounted for no more than 10% of solid waste from domestic and non-domestic facilities: paper, metal, and others (including glass, rubber, or cloth).

Table 3. Solid waste generation for each type of waste.

Type of Waste	Domestic Facilities (kg/day)	Non-Domestic Facilities (kg/day)	Total (kg/day)	Percentage (%)
Plastic	1916000.69	25,636.74	216,637.43	26.05
Paper	72,000.46	8,809.03	80,809.49	9.72

Metal	68,000.82	5,884.4	73,885.22	8.88
Organic	345,000.08	57,569.31	402,569.39	48.41
Others	56,000.86	1,724.96	57,725.82	6.94
Total	732,002.91	99,624.43	831,627.35	100.00

Table 3 shows the amount of solid waste generated by each type of waste in domestic and non-domestic facilities. Organic waste accounted for 48.41%, or almost the half, the city's total waste. Plastic accounted for 26.05%, while waste types like paper (9.72%), metal (8.88%), and others (6.94%) were less significant. Overall, this table illustrates that the people of Semarang mainly consume products made from organic materials and plastics, rather than paper, metal, or other materials (such as glass, rubber, or cloth). In addition, the city's high percentage of organic waste may be caused by the enormous amount of food waste and plant matter litter in Semarang.

Results of this study's purposive sampling via questionnaire and interview revealed that the city's waste bank customers usually deposited their waste each month. Although most deposits were organic waste, customers also deposited their inorganic waste. However, most customers collected organic waste until they accumulated a quantity large enough to be sold at the waste bank.

Table 4. Valuable waste in all sub-districts of Semarang.

Sub-District	Number of Customers (Houses)	Valuable Waste (kg/month)							Total (kg/month)
		Paper		Plastic		Metal		Other	
		Plain Paper	Card-Board	Bottle	Cup	Iron	Aluminium		
Mijen	82	49.4	54.6	20.8	13	46.8	31.2	44.2	260
Gunungpati	245	131.1	144.9	55.2	34.5	124.2	82.8	117.3	690
Banyumanik	405	157.7	174.3	66.4	41.5	149.4	99.6	141.1	830
Gajahmungkur	237	89.3	98.7	37.6	23.5	84.6	56.4	79.9	470
South Semarang	110	60.8	67.2	25.6	16	57.6	38.4	54.4	320
Candisari	92	53.2	58.8	22.4	14	50.4	33.6	47.6	280
Tembalang	256	121.6	134.4	51.2	32	115.2	76.8	108.8	640
Pedurungan	370	165.3	182.7	69.6	43.5	156.6	104.4	147.9	870
Genuk	84	49.4	54.6	20.8	13	46.8	31.2	44.2	260
Gayamsari	180	96.9	107.1	40.8	25.5	91.8	61.2	86.7	510
East Semarang	72	53.2	58.8	22.4	4	50.4	33.6	47.6	280
North Semarang	67	36.1	39.9	15.2	9.5	34.2	22.8	32.3	190
Central Semarang	320	148.2	163.8	62.4	39	140.4	93.6	132.6	780
West Semarang	423	169.1	186.9	71.2	44.5	160.2	106.8	151.3	890
Tugu	78	53.2	58.8	22.4	14	50.4	33.6	47.6	280
Ngaliyan	350	138.7	153.3	58.4	36.5	131.4	87.6	124.1	730
Total	3,371	1,573	1,738	662	414	1,490	993	1,407	8,280
Average	210.69	98.33	108.68	41.40	25.88	93.15	62.10	87.98	517.5
Percentage		19%	21%	8%	5%	18%	12%	17%	

Table 3 demonstrates the amount of valuable wastes that could be deposited in waste banks in all sub-districts of Semarang. During this study, there were 8,280 kilograms of valuable waste in total. The sub-district with the highest number of waste bank customers was West Semarang, with 423 houses. North Semarang had the lowest number, with only 67 houses. West Semarang households also produced the highest amounts of valuable waste (890 kilograms per month), with Banyumanik households in second place, producing 830 kilograms per month.

According to the Environmental Agency of Semarang (DLH), there are only 62 active waste banks in Semarang. With the city's average total deposited waste rate at 517.5 kilograms per month, approximately 1,069.5 kilograms of waste are deposited in waste banks all around Semarang each day. In addition, the current percentage of waste reduction

caused by residents depositing waste in Semarang's waste banks is shown in the following calculation:

- Solid waste generation in Semarang = 831,627.35 kilograms per day
- Existing deposited waste = 1,069.5 kilograms per day

$$\begin{aligned}
 - \text{Reduction percentage} &= (1,069.5 / 831,627.35) \text{ kilograms per day} \\
 &\times 100\% \\
 &= 0.13\%
 \end{aligned}$$

From this calculation, it is shown that only 0.13% of waste reduction in Semarang can be attributed to the implementation of waste banks. This percentage may increase if more customers use the waste banks in the upcoming year. However, this number remains far below the amount of valuable waste that could be deposited in the waste banks, as shown in the Table 3. Semarang's waste banks could reduce the amount of solid waste transported to Jatibarang Landfill significantly. However, this outcome is possible only if a greater percentage of the city's valuable waste is deposited to the waste banks so that only invaluable waste is deposited in the landfill.

4 Conclusion

At present, Semarang's waste banks are operated by community groups with the help of the city's government. In total, 1,069,5 kilograms of solid waste are deposited into the city's waste banks each day. This figure has contributed to a 0.13% reduction of solid waste generation in Semarang. This number is small compared with the amount of valuable waste produced across Semarang. If more of the city's valuable waste is deposited in waste banks, solid waste generation will be reduced significantly, along with landfilled waste. In summary, effective implementation of waste banks may reduce solid waste generation in Semarang and extend the operational life of the city's Jatibarang Landfill.

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