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THE PERFORMANCE OF MUNICIPAL SOLID WASTE RECYCLING PROGRAM IN DEPOK, INDONESIA

Gabriel Andari Kristanto[1*], Irma Gusniani[1], Aristiati Ratna[1]

[1]*Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Kampus UI Depok 16424, Indonesia*

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ABSTRACT
In various official terms in Indonesia, waste is often defined as residual material that its function and benefit has decreased to the minimum level. Meanwhile, growing demand of raw materials drives higher cost of supply due to increasing extraction cost and limited supply. This situation encourages industries to be more innovative to reuse and recycle used materials. This research aims to analyze economic and environmental potential of municipal solid waste as a source of raw materials for industrial sector, especially in recycling industries. A recycling case study is conducted at a waste treatment unit in Depok, Indonesia where recyclable materials are highly variable in types and amount. One of key finding to increase percent of recyclable materials is to encourage waste separation at source either encouraging it by economic incentives or increasing environmental awareness among the households. Thus, this would simultaneously increasing amount and quality of wastes being recycled and at the end their price.

Keywords: Economic benefit; Recovery factor; Recycling; Solid waste

1. INTRODUCTION
1.1. Overview
Rising global population, urbanization, and rapid industrialization cause increasing demand for raw materials. These key global concerns trigger initiative to find alternative materials which economically effective and supportive to sustainable development for greener and cleaner environment. One particular method that can be applied is developing integrated solid waste management which emphasizes principle of reduce, reuse, and recycle. By applying this principles, not only secondary raw materials can be supplied to industry, but also employment is generated, littering is reduced, the lifespan of the local landfill is prolonged, resources and energy are conserved, pollution is abated, aesthetic value is maintained, and the overall flow of waste is reduced (Pasang et al., 2007; Paul et al., 2012; Ezeah et al., 2013).

Nowadays, Indonesia has about 500 landfills which almost all of them are open dumping. Emerging middle class due to relatively high economic growth drives increasing consumption level which causes significant increase in volume of waste from year to year. This does not only cause environmental issues such as surface and ground water contamination, and air pollution but also causes shortage of new locations for landfill.

One of the program in solid waste management in Indonesia is to promote recycling. This strategy includes activities such as composting, waste separation and micro-business project.

* Corresponding author's email: gakristanto@gmail.com, Tel. +62-21-7270029, Fax. +62-21-7270028
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Similar strategy has been adapted by many cities in Indonesia, however due to lack of community awareness, poor ongoing commitment of the executing agency to overcome problems that arise from the project, such inadequate trucking system to collect waste already separated by households, poor coordination with other urban systems, lack of economic incentives, and absent of a regulatory system and its enforcement.

In some Indonesia formal definitions, solid waste is still viewed as trash that can not be used with no value. For example *Kamus Umum Bahasa Indonesia* (the Indonesian General Dictionary), solid waste is defined as goods that are no longer used or could also mean dirt. Also, in the Indonesian National Standard, SNI 19-2454-1993, solid waste is characterized waste in solid form consists of organic and inorganic substances which have no longer been used.

The definitions of solid waste as mentioned above should be redefined. Scarcity of raw material causing natural resources become more expensive and difficult to find therefore industries are encouraged to optimize recycled materials. Roland Berger Strategy Consultant Report stated that global market for environmental technology (include products and services) is about $1,370 million in 2008; and it is projected to be $2,740 million in 2020. Around $41 million in 2008 and $63 million in 2020 are money that comes from waste management and recycling (Visvanathan, 2011).

Like many other developing countries such as India, China, and Egypt, informal recycling in Indonesia is carried out by poor, disadvantaged, vulnerable and/or marginalized social groups or by informal sector: scavengers to shanties (Sembiring & Nittivatannanon, 2010; Katusiimeh et al., 2013). Through recycling program from municipal solid wastes, it is expected that meaningful amount of recyclable materials can be recovered from waste flow to help reduce amount of residual waste to be disposed to a landfill. Recycling of different types of waste will not only bring products that have quality as good as those from raw material, but it also help problems of raw materials scarcity, reduce municipal waste generation, and create jobs and financial incentives for recycling industry.

This study aims to assess performance of municipal solid waste recycling program in a single facility waste treatment unit Located in Depok, Indonesia. Depok is selected as a case study because the city grows fast as Jakarta's suburban that produces high volume of wastes. Through this study, economic value and recovery factors are calculated, and several challenges and opportunities are discussed as research suggestions.

1.2. Waste Management in Depok

Rapid economic growth in Indonesia has created a significant increase consumption level, which leads to an increased number of municipal waste generations per capita. For instance in 2008, Depok City (located in West Java, Indonesia) generated waste of 3,900 m^3/day and keep rising to 4,200 m^3/day in 2014 (BPS, 2014). With 1.7 million inhabitants with population growth of 4%, waste generation rate will increase steadily as the economic growth continues in Depok.

Due to the high productions of wastes, the Depok City Government launched a new management of municipal solid waste paradigm, from *"Collect–Transport-Dispose"*, to *"Collect–Process-Benefits"* (Pemerintah Daerah Kota Depok, 2008). This new paradigm is supported by the construction of 30 waste treatment units (WTUs) that have 3R-P activities (*Reduce–Reuse–Recycle-Community Participation*). These WTUs help reduce amount of waste going to the main Cipayung Landfill. In many aspects, the activities at WTUs are very similar to MBT (mechanical and biological treatment) as part of solid waste management in developed

countries; however the processes in WTUs include collection, transportation, separation, and treatment of solid waste, mostly conducted manually.

2. METHODOLOGY

2.1. Sample and Research Site Selection

The selected research site is Kampung Sasak WTU in Depok that has applied the 3R-P program daily (Depok Local Government, 2008). This WTU is located at District Limo Depok, West Java and was built in 2008 and started its operation in 2009. The WTU is situated in village area directly adjacent to a sparsely populated space with middle and lower economic level to the south and east border, while the north and further east are middle-class housing. The distance of the WTU to the Cipayung Landfill is about 5 kilometers.

The Kampung Sasak WTU serves about 2000 houses. Total amount of waste varies each day, but wastes generated every Monday and Saturday are more than the rest of the week because the WTU is closed on Sunday. Waste separation method in this WTU is mainly performed manually.

2.2. Sampling Protocol

Sample collection and measurement protocol of waste generation and composition are conducted in line with the Indonesian National Standard *SNI 19-3964-1994, Method of Collecting and Measurement of Samples and Composition of Urban Wastes*. Based on this method, waste generation and composition are measured in eight days period. They are separated into 11 primary and 18 secondary waste compositions. Several local terms are used in this study such as *bodong* and *emberan* to maintain the terminologies used by local scavengers. Both terms are used for certain types of plastic used in this study to get real picture in the field. From different sources such as schools, households and small traditional markets, solid wastes are collected and transported to WTU by using hand carts. Amount of solid wastes generated each day were calculated by the number and volume of hand carts entering the WTU.

2.3. Data Analysis

a. Calculation of waste generation

Waste generation is calculated through load count analysis method, which calculates the total of waste collection every day.

$$\begin{aligned} &total\ waste\ generation\ each\ day = \\ &number\ \ of\ hand\ carts\ entering\ the\ WTU\ \ per\ day \times volume\ of\ hand\ carts\ \ \times solid\ waste\ density \end{aligned} \quad (1)$$

b. Calculation of waste density

Waste density was measured by placing the wastes in one m^3 box dropping the boxes three times, weighted, measured the volume again, and calculated:

$$waste\ density = \frac{waste\ weight\ (kg)}{waste\ volume\ (m^3)} \quad (2)$$

c. Calculation of the composition of waste components

Waste samples are weighted and sorted based on pre-defined components. Each component is also weighted afterwards.

d. Calculation of waste percentage composition

To determine the percentage composition of the waste component is calculated using the following equation.

$$\%\ component = \frac{component\ weight}{total\ waste\ weight} \times 100\% \quad (3)$$

e. Calculation of economic value

Waste generation is calculated through load count analysis method, which calculates the total of waste collection every day.

$$economic\ value = total\ waste\ (kg) \times sale\ price\ per\ kg \quad (4)$$

f. Theoretical and Actual Recovery Factor

Theoretical recovery factor is calculated based on the following equation:

$$Theoretical\ recovery\ factor\ = \frac{total\ weight\ of\ waste\ that\ are\ potentialy\ recyled\ (organic\ and\ inorganic)(kg)}{solid\ waste\ weight\ (kg)} \times 100\% \quad (5)$$

Meanwhile, the value of the actual recovery factor based on waste that is successfully sold or recycled each month are as follows:

$$Actual\ recovery\ factor\ = \frac{total\ weigt\ of\ wastes\ that\ have\ been\ recyled\ \ (organic\ and\ inorganic)(kg)}{solid\ waste\ weight\ (kg)} \times 100\% \quad (6)$$

3. RESULTS AND DISCUSSION

3.1. Waste Composition

Total waste generated at the Kampung Sasak WTU is 2.3 tons/day or 70 tons/month with detailed of primary compositions show in figure 1 and the detail secondary compositions presented in Table 1.

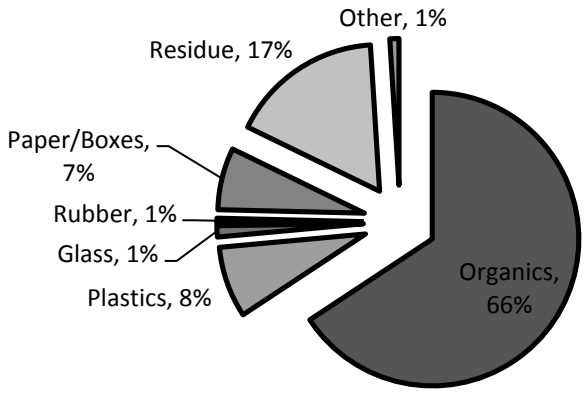

Figure 1 Waste composition in Kampung Sasak WTU

About 19% of the total inorganic waste is comprised of potentially recyclable materials such as, glass, plastics, metals, rubbers, papers and boxes and others (Figure 2). Prior to selling, the recyclable materials are collected and stored until reaching certain amount of weight. Usually the buyers will come, buy, separate the wastes in detail, store the wastes again, and sell them to shanties offering the best price. Several factors influence the price of the recyclable materials such as rarity of the materials, seasons (dry or rainy), and abundant supplies of waste around religious holidays especially in Eid al-Fitr, main Moslem holiday, that causes price of the waste to drop or fluctuate significantly.

Table 1 Recovery Factor of waste from Kampung Sasak WTU

Primary Waste Composition	Secondary Waste Composition	Total Waste Generation (kg/day)	Total Waste Generation (kg/month)	Amount of Waste Sold (kg/ month)	Total Recovery Factor (%)
Organics	-	1533.3	4,5997.5	15,000.0	32.6
Plastics	*Bodong*	7.3	218.4	42.0	19.2
	Plastics cups	3.5	105.0	10.0	9.5
	Emberan	20.8	623.1	192.0	30.8
	Plastic bags	88.9	2,667.3	1,416.0	53.1
	Thick white plastics	60.8	1,823.1	209.0	11.5
	Other	1.4	41.4	0	0
Metal	Iron	3.7	111.3	7.0	6.3
	Other	0.9	25.8	0.0	0.0
Rubber	Rubber slippers	4.0	119.1	13.0	10.9
	Other	9.7	291.6	0	0
Glass	Glass bottles	29.0	869.7	500.0	57.5
Electronics		4.9	146.7	0	0
Paper/Boxes	Duplex	69.2	2,077.2	282.0	13.6
	White paper	13.8	412.5	10.0	2.4
	Cardboard box	11.8	353.1	32.0	9.1
	Newspaper	52.9	1,588.2	6.0	0.4
	Packaging box	11.7	350.1	70.0	20.0
Tin		6.0	178.5	75.0	42.0
Aluminum	Aluminum beverage can	0.2	4.8	0	0
Bone	Bone	4.5	134.4	5.0	3.7
Residu		391.9	11,755.5	0	0

a. Poly Ethylene Plastics

b. High Density Plastics

c. Light Bulbs

d. Computer Panels

e. Bottles

f. Cans

Figure 2 Some of materials that can be recycled

To find buyer with the highest price, recycled materials from WTU are commonly sold to various shanties because usually every shanty has their own specialty or preference. For instance, the Kampung Sasak WTU sells materials for recycling to nine different shanties to maximize profits.

Flow of recycled materials is not always conducted from smaller to larger shanties because the materials can be sold to other more specialized small shanties and then to larger ones. Size of shanties is defined by its capital, waste separation process, and recycled materials distribution. In smaller shanties, recycled materials received from WTU often are not sorted in detail. As an example newspapers are intentionally mixed with white paper. On the other hand, in larger shanty the same waste material package went through more detail separation due to request of recycling industry that sets certain standards on "purity" of recycled material. These recycled materials which have been sorted in more detail have a higher selling price. Lack of capital in smaller shanties to sort material in more detail is a constraint causing the chain of sales increasingly long hence reducing their profits. It is very common that the small shanties that do not have conveyance systems selling their waste to another nearest shanty, large or small, and accept the only offering price resulting in fewer profit margins.

Data on total sold wastes per month were collected and used to calculate the actual and total total recovery factors (Table 1). Several solid wastes have zero total recovery factors. Zero value indicates that minimum amount of saleable recycled wastes were not reached during observation period. As a result, the shanty must keep the potential recycling materials until they reach certain saleable amount of weight. This condition also reduces profit margin of the shanties because larger storage area needs to be rented.

The Table 1 shows that glass bottles have the highest recovery factor at 57.6% because the glass bottles can be sold at any condition either intact or broken. Other material with high recovery factor is plastic bags at 53%. Large amount of plastic bags used in daily life finally end up as waste and easily collected at the WTU. The minimum weights of those waste plastic bags are easily reached for selling. Composting is viable end product of organic wastes, however the recovery factor is relatively small (32.6%) because most of them are mixed with residues and decomposed easily during collection and transportation process.

3.2. Recycling System

Total shanties in the area are around 30 and located in a radius of 15 kms from the Kampung Sasak WTU. In average each shanty employs 5–10 people. Their duties include collecting wastes directly from household or other source waste bins, sorting, washing, and storing the wastes in the shanty area. Most of them are young to middle age men who previously worked as farm labors without own lands to cultivate. Since they are usually family related, it is much easier for them to borrow money from the shanty's owner. Most of their earnings are sent to their wives and children when one of them visits his families back in the village.

3.3. Economic Benefits

Economic benefit is calculated by multiplying total weight of recyclable materials by average unit price per kg offered by shanties in the area (Table 2).

The value of recycling waste per day in the Kampung Sasak WTU is about 550 thousand rupiahs (USD 47), consist of Rp 180 thousand from from compost and Rp 370 thousand from inorganic waste. Total collected value is about Rp 16.5 million (USD 1,400) or about USD 17,000 per year. Since the minimum wages in Depok were approximately USD 185 in 2014, the money collected from selling the recyclable wastes can be used for hiring around 6 workers as part of solid waste management team.

Table 2 Potential Economic Value of waste from Kampung Sasak WTU per day

Secondary Waste Composition	Weight (kg)	Sale Price (Rp/kg)	Economic Value (Rp)
Organic (compost)	1533,25	3,000	183,990
Bodong	7.28	4,000	29,120
Plastic cups	3.50	6,500	22,750
Emberan	20.77	2,500	51,925
Plastic bag	88.91	500	44,455
Thick plastic	60.77	700	42,539
Crystal plastic	1.38	6,000	8,280
Iron	3.71	3,000	11,130
Aluminum	0.45	20,000	9,000
Brass	0.06	27,000	1,620
Rubber slippers	3.97	500	1,985
Glass bottle	27.65	350	9,677.5
Soy sauce bottle	1.34	500*	500
CD	0.06	9,000	540
Duplex	69.24	600	41,544
Cardboard box	11.77	1,200	14,124
White paper	13.75	1,500	20,625
Magazine	0	1,500	0
Newspaper	52.93	600	31,758
General Can	5.95	2,100	12,495
Boxes	11.67	650	7,585.5
Aluminum beverage can	0.16	15,000	2,400
Bone	4.48	700	3,136
Total			551,179

Note:
In 2014 1US $ = 12,000 Rupiah (Rp)
Compost's price is calculated per 25 kg
*Soy sauce bottles' price is 500 Rupiah (Rp) each

The most dominant recycled material in overall selling value is plastic which comprised 36% of total selling value. On the industrial market, and international trading recycled plastic materials are very competitive and meet a high demand. They can be traded as clean shreds or pellets of recycled plastic (Matter, 2013).

3.4. Assessment of Waste Recovery

To assess the recycling program, the theoretical and actual recovery factors are calculated. The theoretical recovery factor is conducted by comparing the amount of waste that potentially recycled, both organic and inorganic, and the total amount of waste including residues while the actual recovery factor is based on waste that is successfully sold or recycled each month per total amount of wastes generated. While the theoretical recovery factor obtained from waste in the Kampung Sasak WTU is 83%, the actual recovery factor is 26% which mean the sale of recycled materials in the Kampung Sasak WTU is still far below its potential. In other words, it indicates that there is still a lot of waste that can be recycled but escaped in sorting stage. With 30 WTUs and solid waste collection rate in Depok is around 35%, the opportunity to recycle waste materials are greatly diminished. These unsorted wastes usually ends up in rivers and drains or simply burnt in WTU yards causing many environmental problems in air, water, and soil.

Several factors contribute to the low actual recovery factors. Limited numbers of workers compare to the high amount of waste generated, lack of proper sorting equipment and technology, as well as a high degree of difficulty to separate due to mixed waste. Many of recyclable waste materials also end up having lower quality or even damage since no separation of waste from the sources. For instance, white paper, newspaper, and plastic bags were found mixed with other waste and they became wet and dirty hence reducing their reselling value. Several approaches are suggested to increase waste separation such as economic intensive and environmental awareness (Matter et al., 2013). While economic intensive approach will improve incomes of such informal workers and strengthen their livelihoods, the environmental awareness will depend significantly on households' environmental awareness and understanding of the benefit of separation for their immediate environment. Another approach that can be adopted is integrating the informal sector into solid waste management system such as increasing the ability of the informal sector to add value to collected materials. When the value is increased, the price of materials increases hence the informal workers can improve their living condition, as well as get social acceptance from other inhabitants of the city (Sembiring & Nittivanananon, 2012).

4. CONCLUSION

In Indonesia, solid waste is generally defined as a result of the activities that have reduced function and value benefits. However, this research noted that municipal solid waste actually has remaining value as raw materials for recycling industry. As it is harder and more expensive for industries to extract raw materials from nature, allows municipal solid waste to be recovered and processed. There are some challenges using of waste as a recycled material. One of key finding to increase percent of recyclable materials is to encourage waste separation at source either encouraging it by economic incentives or increasing environmental awareness among the households. Thus, this would simultaneously increasing amount of waste being recycled, recyclable waste quality and at the end the price.

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