Analysis of potential RDF resources from MSW landfills in Indonesia

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Research

Analysis of potential RDF resources from MSW landfills in Indonesia

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Abstract

An analysis of the potential to synthesize refused-derived fuel (RDF) from municipal solid waste (MSW) has been carried out. This research was conducted to know the MSW potential of 3 landfills (Bantargebang, Sumur Batu, and Cipayung) as a renewable fuel and minimize greenhouse gas (GHG) emissions. Prior to processing, characterization of MSW is carried out because each landfill has a particular MSW composition. The physical parameters of a type of waste turned into RDF considerably determine the time, cost, and technology utilized in converting waste into RDF. This is because there are quality standards that the waste must meet before being used as fuel. The potential resources of RDF based on combustible solid waste in this study include waste, plastic, rubber, paper, wood, and textiles. The results showed that the total energy value that could be acquired from RDF resources of Bantargebang, Sumur Batu, and Cipayung landfills were 2742.14, 2741.24, and 2671.32 kcal/kg, respectively.

***Keywords**: calorific value; energy; landfill mining material; MSW; RDF*

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1. Introduction

In recent years, municipal solid waste (MSW) management at the landfills in the area of the cement industry has been described as a procedure that tries to collect and dispose of solid waste in a landfill without treatment (Tozlu et al., 2016). The open dumping method at the landfill has negative environmental, economic, and social impacts (Aye and Widjaya, 2006). Meanwhile, greenhouse gas (GHG) emissions associated with MSW management have become an environmental concern regarding global warming and climate change (Weitz et al., 2002).

According to the waste management hierarchy, open dumping systems such as landfills should be the last option for waste management under 3R (reduce, reuse, and recycle) and waste-to-energy (WtE) technology (Samsudin and Mat Don, 2013). At least five waste management strategies are preferred over open dumping: Recovery, Recycle, Reuse, Reduce, and Prevention (Kurniawan et al., 2021). Waste-to-Energy (WtE), which includes waste combustion and Refuse Derived Fuel (RDF), is a form of the material recovery system that involves the conversion of waste that can be used as fuel (Rigamonti et al., 2012).

The composition of the waste in the Cipayung and Sumur Batu landfills has the potential to be utilized as an alternative fuel for RDF, according to earlier studies (Suryawan et al., 2022; Widyarsana and Tambunan, 2022), but the high water content necessitates a pre-treatment process before to its usage as RDF raw material (Zamli et al., 2020). High water content makes it difficult to burn RDF and increases the energy required to do so.

Regarding this, Table 1 lists the standard RDF parameters for calorific value, moisture content, ash content, sulfur, and chlorine that are utilized in different countries.

Table 1. RDF quality standards in many countries

Parameter	Finland	Italy	UK
Calorific Value (MJ/kg)	13-16	15	18.7
Water Content (%)	25-35	Maksimum 25	7-28
Ash Content (%)	5-10	20	12
Sulphur (%)	0.1-0.2	0.6	0.1-0.5
Chlorine (%)	0.3-1.0	0.9	0.3-1.2

Source: Nithikul (2007)

This waste can be used as a renewable energy source in the cement industry. In 2010, the European Commission identified the cement industry as a sector with a particularly high need for fuel (Habert et al., 2010). Cembureau (1999) reported that energy procurement accounts for 40% of a cement plant's overall operating expenditures. The rise in worldwide CO_2 emissions suggests that more fossil fuels are being consumed. Moreover, regarding this, with a clinker factor of 80%, approximately 0.83 tons of CO_2 will be created to produce 1 ton of cement. The CO_2 emissions comprised 0.45 tonnes of calcium, 0.28 tonnes of coal combustion, and 0.1 tonnes of operating electricity generation (Martínez-Martínez et al., 2020). Consequently, emissions are the primary environmental issue linked with cement production.

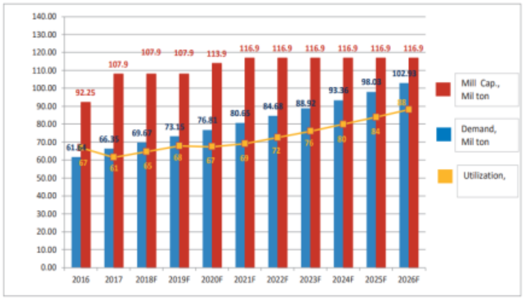

Figure 1. Projection of capacity and cement demand (ASI, 2017)

Due to cultural differences and the degree of separation from other sources and processing, domestic waste composition in many cities in Indonesia varies substantially. In order for waste to be utilized by cement manufacturers, it is processed into RDF. The cement industry has utilized ISO 14001 in Cirebon to reduce emissions and mitigate environmental impacts produced by the cement production process since 2002 (Anasstasia et al., 2020). This article describes the possibility of MSW processing into RDF at three locations: Bantargebang, Sumur Batu, and Cipayung landfills.

2. Methods

This study is a type of quantitative research employing literature review and laboratory test methods. This research aims to determine the generation and composition of waste used as RDF material in the Bantargebang, Sumur Batu, and Cipayung landfills based on four RDF manufacturing systems. The investigation results will be utilized to determine the impact of RDF production on cement manufacturing. Density, water content, ash content, solid waste composition, and laboratory test results were recorded in this investigation. Six-month side process till laboratory tests are conducted (November 2021-May 2022).

2.1 Sampling of Waste Composition from the Landfills

Assessment of the composition and relative density of waste in the landfills is governed by SNI 19-3964-1994, which outlines the procedure for collecting and analyzing samples of the generation and composition of urban waste (Hartono et al., 2015). The landfill waste was sampled using a 100-kilogram cart. The garbage was then placed in a wooden box, and its volume and density were determined by measuring and weighing it. In addition, the trash was separated based on its characteristics. The following equation is utilized to calculate the density of waste.

$$\text{Density} = \frac{\text{solid waste weight (kg)}}{\text{solid waste volume (m}^3\text{)}} \quad (1)$$

2.2 Water Content Measurement

This water content measurement was conducted following SNI 03-1971-1990 (Hamdi and Imran, 2019). Approximately ±10 g of weighted sample was collected and then placed in a porcelain dish. The sample was then heated for three hours at 105 °C. The sample was then placed in a desiccator for 30 minutes before being weighed until the weight remained constant.

$$M = \left(\frac{w-d}{w}\right) x100\% \quad (2)$$

where M is the water content (%); w is the initial weight (kg); and d is the weight after drying in the oven at a temperature of 105 °C (kg).

2.3 Ash Content Measurement

The process for measuring ash content was carried out following ASTM E 830-87 (Irfan et al., 2020). The remaining samples that had been heated to 575 ± 25 °C were reheated in the furnace for 7 minutes at a temperature of 950 °C. The sample was then placed in a desiccator until it reached room temperature, after which it was weighed.

$$\text{Ash} = \left(\frac{e-f}{w}\right) x100\% \quad (3)$$

where Ash is the ash content (%); e is the weight after being heated in the furnace at 600 °C (kg); f is the weight after being heated in the furnace at a temperature of 950°C (kg); and w is the initial weight (kg).

2.4 Volatile Level Calculation

The determination of volatile levels is based on the following formula, which is calculated using a proxymate analysis approach.

$$V = \left(\frac{d-e}{w}\right) x100\% \quad (4)$$

Where V is the volatile content (%), w is the initial weight (g), d is the weight after drying in an oven at 105 °C, and e is the weight after being heated in a furnace at 950 °C.

2.5 Calorific Value Measurement

The calorific value was measured using a bomb calorimeter in this study. Calculating the calorific value based on the potential calorific value is as follows.

Potential calorific value = waste generation (kg/week) x calorific value reference (MJ/kg) (5)

$$\text{Calorific Value} = \frac{\text{potential calorific value (MJ/week)}}{\text{waste generation (kg/week)}} \quad (6)$$

Meanwhile, the traditional model was used to calculate the comparative analysis of the calorific value of all types of waste in each landfill (7).

$$Hn = 45B-6W \quad (7)$$

Where Hn represents energy (kcal/kg), B represents combustible volatile matter (total volatile content in %), and W represents water content (%).

3. Result and Discussion

3.1 Analysis of RDF Composition and Waste Generation

Not all waste entering the landfills is utilized in RDF production as a raw material. Only some wastes, such as plastic, rubber, paper, wood, and textile, are included in the RDF type of waste, as it is more combustible and has a higher calorific value than other waste types, such as organic, metal, electronic, and residues. Measurement of waste composition utilizing the SNI 19-3964-1994 method for collecting and analyzing samples of waste generation and composition.

3.1.1 Composition of waste in 3 research sites

Over five days, 578.7 kg of waste was collected from three research sites: Bantargebang, Sumur Batu, and Cipayung landfills. After measuring the waste's density, it was separated according to its components. Table 2 shows the composition of the sorted waste from the three research sites.

Table 2. Composition of Fresh Municipal Solid Waste at the research sites (dry and rainy seasons)

	Waste Type Classification	Percentage (%)					
		Bantargebang		Sumur Batu		Cipayung	
		Dry	Rainy	Dry	Rainy	Dry	Rainy
a.	Organics	**53.40**	**56.70**	**54.90**	**56.8**	**62.90**	**62.90**
	Garden	14.20	13.60	15.10	14.1	14.40	14.40
	Kitchen	39.20	43.10	39.80	42.7	48.50	48.50
	Compost Lime	0.00	0.00	0.00	0.0	0.00	0.00
b.	All Plastic	**20.20**	**18.60**	**21.20**	**19.1**	**26.86**	**26.86**
	Plastic Film	13.50	13.20	14.60	14.3	18.10	18.10
	PVC	0.10	0.10	0.10	0.1	0.10	0.10
	HDPE	0.10	0.10	0.10	0.1	0.10	0.10
	PET	0.50	0.50	0.60	0.6	0.75	0.75
	PP	0.70	0.70	0.80	0.70	0.60	0.60
	PS	0.10	0.10	0.10	0.10	0.15	0.15
	Plastic Mix	5.10	4.00	4.90	3.90	7.06	7.06
c.	Paper and Cardboard	**7.10**	**7.20**	**6.20**	**6.80**	**4.60**	**4.60**
	Paper	5.00	5.00	4.10	4.30	2.50	2.50
	Cardboard	2.10	2.20	2.10	2.50	2.10	2.10
d.	Nappies	**1.00**	**7.70**	**0.90**	**7.00**	**1.30**	**1.30**
e.	Textile	**8.10**	**4.00**	**7.10**	**4.00**	**0.57**	**0.57**
f.	Woods	**4.10**	**1.80**	**4.10**	**1.90**	**0.57**	**0.57**
g.	Rubber	**2.10**	**0.60**	**2.10**	**0.60**	**0.50**	**0.50**
h.	Metals	**0.60**	**0.30**	**0.60**	**0.20**	**0.14**	**0.14**
	Alumunium	0.30	0.30	0.20	0.40	0.00	0.00
	Iron	0.30	1.10	0.40	1.10	0.14	0.14
i.	Inert (Glass, Stone, etc.)	**1.10**	**1.10**	**0.90**	**0.90**	**0.56**	**0.56**
j.	Toxic and Hazardous Waste (Electronics, batteries, etc.)	**1.20**	**1.20**	**1.00**	**1.00**	**1.00**	**1.00**
k.	Fines <10mm	**1.00**	**0.10**	**1.00**	**0.10**	**1.00**	**1.00**

Table 2 shows that each landfill has a different waste composition. This may be related to disparities in the local population's socioeconomic status, which comprises merchants, laborers, and farmers. In addition, the increase in plastic waste in each waste can be attributed to changes in people's lifestyles, where practically all activities, including work, school, and the purchase of daily requirements, are conducted online. This increases online shopping. According to data provided by the Indonesian E-commerce Association (idEA) and We Are Social 2020, internet shopping has increased by 25-30%, increasing the amount of plastic waste generated at each landfill. Figures 2 and 3 depict the waste composition at the three landfills.

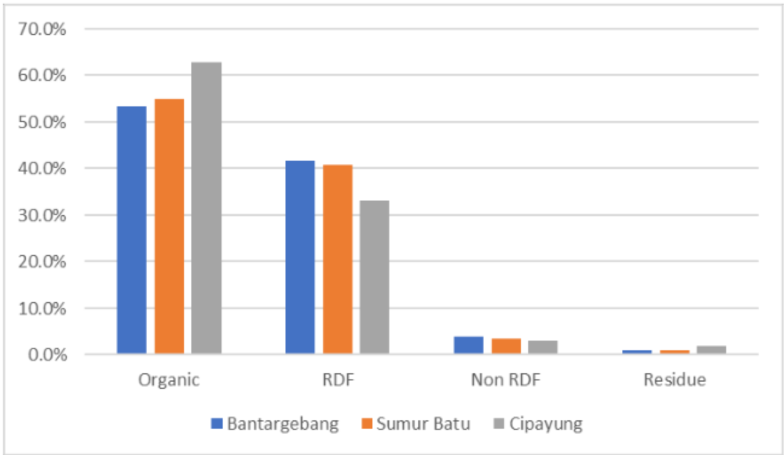

Figure 2. Graph of waste composition at the research sites (Dry Season)

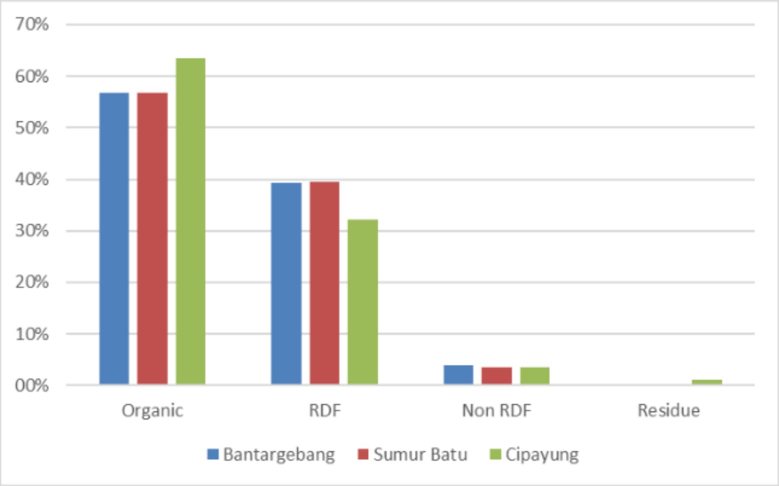

Figure 3. Waste composition at the research sites (Rainy Season)

The graph categorizes the waste from the three research sites into four categories: organic, RDF, non-RDF, and residue. RDF waste consists of plastic, wood, rubber, textile, and paper waste utilized as raw materials for RDF. Glass, iron, aluminum, and electronic items are examples of non-RDF waste, which cannot be used as raw material in RDF production. The residue is non-recyclable waste that is disposed of in a landfill with a particle size of 15 mm. Nevertheless, the leftover waste has the potential to be utilized as RDF of lower quality. In contrast, organic trash includes food leftovers, waste from traditional markets, and garden trash.

This classification determines how much waste will be reduced if the research site's waste is processed into RDF. In terms of waste composition, the three research sites are comparable to fresh MSW in that the proportion of organic waste is still above 50%.

According to Table 2, most RDF is composed of plastic waste. Due to the small size and light color of this type of waste, as well as the possibility that it is mixed with organic waste, the percentage of wood and rubber waste in the three research locations is extremely low.

3.1.2 Waste Generation

The waste composition data acquired from the three locations is multiplied by the total waste generation entering the landfills, as detailed in Table 3.

Table 3. Data on waste generation in the three research sites

Waste Types	Waste Generation (tonnes/week)		
	Bantargebang	Sumur Batu	Cipayung
Organic	31,284.63	6842.73	6890.87
Plastic	11,834.26	2642.36	2449.60
Paper and Cardboard	41,59.57	772.77	679.23
Textile	4745.42	884.94	62.44
Woods	2402.00	511.02	62.44
Rubber	1230.29	261.74	54.78
Metals	351.51	74.78	15.34
Inert (Glass, Stone, etc.)	644.44	112.18	61.35
Toxic and Hazardous Waste (Electronics, batteries, etc.)	703.02	99.71	109.55
Fines <10 mm	585.85	124.63	109.55
Others	644.44	137.10	460.12
Total	**58,585.45**	**12,463.99**	**10,955.28**

Table 3 compares the waste generated in each landfill, with the biggest amount of waste generated in Bantargebang and the smallest amount in Cipayung. The variation in the amount of generation entering the landfills is affected by the size of the service area, the number of individuals serviced, and the socioeconomic conditions of the surrounding community.

3.2 Characteristics of Waste at the Research Sites

Water and ash content were the waste parameters examined in this study. During the dry season, measurements were conducted utilizing samples. The amount of water in the waste is determined by measuring its water content. The water content of waste significantly impacts the time required to heat the waste prior to its conversion into RDF. The ash content is measured to assess how much ash is left over from the combustion process.

3.2.1 Water Content

This is since wet organic waste comprises food, vegetable, and fruit waste, all of which contain a high degree of water. In the meantime, wood waste has the second-highest water content since wood waste is dry organic waste. In contrast, dry organic waste often has low water content. Rubber waste has the lowest water content of the three locations because of its inability to absorb water. As a result, rubber waste contains the least water compared to the other compositions.

Physical parameters of waste from each landfill that will be used as RDF raw material must be compared with standards (water and ash content), as shown in Figures 4 and 5, where the RDF standard used is the Italian RDF quality standard with a water and an ash content of 25% and 20%, respectively. The Italian standard was chosen because of its comparatively minimal standards, which allowed for its easy adaptation to the waste conditions at the research site.

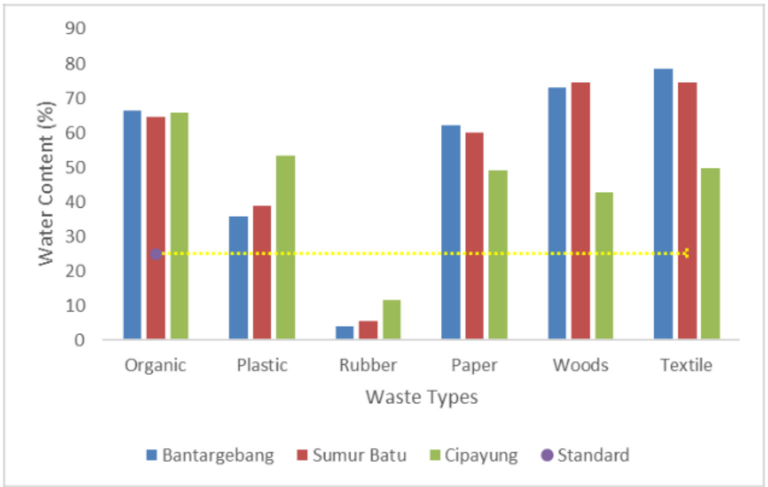

Figure 4. Comparison of wastewater content at the research sites

Figure 4 compares the water content of each form of organic waste, plastic, rubber, paper, wood, and textile, with RDF standards. Based on Figure 4, practically all forms of waste from the three research sites did not meet the RDF standards. Waste having a water content that does not match the standard must be treated first before being utilized as fuel to lower its water content by drying or re-enumeration. However, organic waste with a fairly high water content demands a longer processing time and costs, therefore, it is not included as a source material for RDF and is preferred for compost.

Meanwhile, the total water content of all forms of waste in the landfills was determined to be 30.16, 29.80, and 32.15% for Bantargebang, Sumur Batu, and Cipayung, respectively.

3.2.2 Ash Content

Figure 5 compares the ash content of waste from the three research sites. According to the graph, the waste from the three landfills meets the criteria for ash content. Only rubber waste from the two sites did not fulfill the standards. This was because the rubber sample was still mixed with noncombustible materials during testing, resulting in significant ash content.

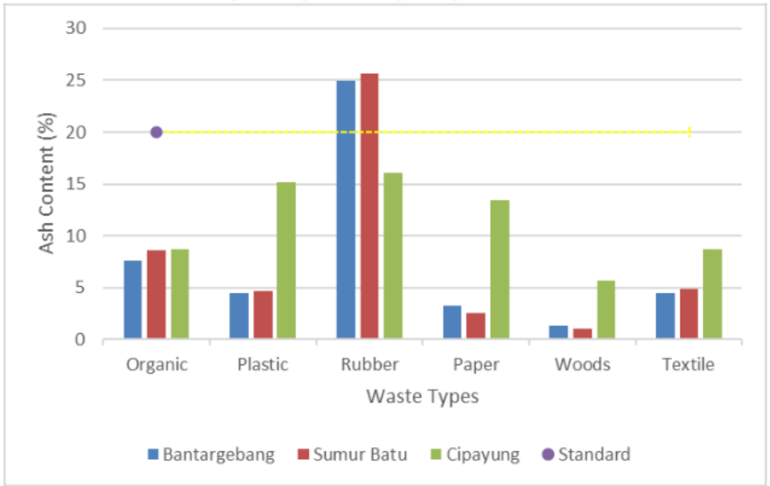

Figure 5. Comparison of ash contents from many wastes

3.2.3 Volatile Content

Table 4 shows the results of the calculations of volatile contents in waste samples from the three research locations.

Table 4. Volatile contents of waste in each landfill

Waste Types	Volatile Content (%)		
	Bantargebang	Sumur Batu	Cipayung
Plastic	61.67	59.99	56.71
Rubber	92.41	91.40	87.53
Paper	49.84	53.29	46.87
Wood	52.34	52.29	53.90
Textile	47.82	48.73	49.15

Meanwhile, the overall volatile content for each landfill was estimated using the total weight of volatile material from all forms of waste and the total dry weight, yielding volatile contents of 61.71, 61.68, and 59.26% for Bantargebang, Sumur Batu, and Cipayung, respectively.

3.3 Waste Calorific Value

The calorific value of waste components such as plastic, rubber, paper, wood, and textiles from the three research sites was determined. The higher the calorific value, the quicker the combustion process. Meanwhile, the selection of these five components is based on the likelihood that they can serve as fuel and raw materials for RDF. The organic waste component is one of the fuel-usable waste components. However, it is assumed in this study that organic waste components are utilized in the composting process and not as raw materials.

Table 4. Calorific value for each research site

Waste Types	Calorific Value (kcal/kg)		
	Bantargebang	Sumur Batu	Cipayung
Plastic	5035	4879	5498
Rubber	5147	5746	6994
Paper	2556	2345	2402
Woods	3148	3158	3068
Textile	2987	2698	2616

3.4 Potential Utilization of RDF

The energy values obtained from the RDF based on the traditional model in the three landfills, namely Bantargebang, Sumur Batu, and Cipayung are 2742.14, 2741.24, and 2671.32 kcal/kg, respectively.

4. Conclusions

The total MSW produced by Bantargebang, Sumur Batu, and Cipayung landfills were 58,585, 12,463, and 10,955 tonnes/week, respectively. The energy values generated from RDF in the Bantargebang, Sumur Batu, and Cipayung landfills were 2742.14, 2741.24, and 2671.32 kcal/kg, respectively.

5. Acknowledgement

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