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Research Article

Analysis of Potential RDF Resources from MSW Landfills in Major Cities of Indonesia

Andre Susilo[1]*, Djoko M. Hartono[1], Dwica Wulandari[1], Muhammad Angga Kusuma[2]
[1] Master Program of Environmental Engineering, Faculty of Engineering, Universitas Indonesia, Depok, 16436, Indonesia
[2] Perusahaan Indocement Tunggal Prakarsa, Bogor, 16810, Indonesia
*Corresponding Author, email: andre.susilo@ui.ac.id

Abstract
Many Indonesian landfills include the waste that has the potential to be used as an alternative fuel in the cement industry. It is converted into RDF to enable cement manufacturers to use waste. The research was conducted to know the Municipal Solid Waste (MSW) potential of 3 landfills (Bantargebang, Sumur Batu, and Cipayung) as a renewable fuel. Before processing, MSW is characterised because there are quality standards that the waste must meet before being used as fuel. That is a quantitative study combining a literature review and laboratory test methods. The parameters that have been measured from the three sample sites were water content, ash content, volatile level, and calorific value. The results showed that the total energy value acquired from Refuse Derived Fuel (RDF) resources of Bantargebang, Sumur Batu, and Cipayung landfills was 2742.14, 2741.24, and 2671.32 kcal/kg, respectively. In addition, based on the water content at the three sample locations, only rubber samples qualified for RDF processing. In contrast, rubber was the sole component that did not match the processing conditions to become RDF based on ash content. Furthermore, the volatile level of the three research sites meets the RDF standard.

Keywords: Calorific value; energy; landfill mining material; MSW; RDF

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 (Sajjadi, 2017). Meanwhile, greenhouse gas (GHG) emissions associated with MSW management have become an environmental concern regarding global warming and climate change (Friedrich and Trois, 2016).

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, recycling, Reuse, Reducing, 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 is 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 challenging to burn RDF and increases the energy required.

Several countries have defined RDF standards for calorific value, water content, and ash content. For example, the calorific values determined by Finland, Italy, and Switzerland standards are 13-16, 15 and 25.1-31.4 MJ/kg, respectively. Meanwhile, the water content for RDF quality standards in Finland, Italy, and Switzerland are 25-35, 25, and 10%, respectively. Furthermore, the ash content for RDF quality standards in the three countries is 5-10, 20 and 0.6-0.8%, respectively (Gallardo et al., 2014).

Waste from landfills can be used as a renewable energy source in the cement industry. In 2013, the European Commission identified the cement industry as a sector with an exceptionally high need for fuel (Supina et al., 2016). Energy procurement accounts for 40% of a cement plant's overall operating expenditures (Zhou et al., 2016). The rise in worldwide CO2 emissions suggests that more fossil fuels are being consumed. Moreover, with a clinker factor of 80%, approximately 0.83 tons of CO2 will be created to produce 1 ton of cement. The CO2 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.

Due to cultural differences and the degree of separation from other sources and processing, domestic waste composition in many cities in Indonesia varies substantially. For waste to be utilized by cement manufacturers, it is processed into RDF. The cement industry has used ISO 14001 in Cirebon to reduce emissions and mitigate environmental impacts produced by the cement production process since 2002 (Anasstasia et al., 2020). This study aims to analyze 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. The investigation results determined RDF production's impact on cement manufacturing. Density, water content, ash content, FMSW composition, and laboratory test results were recorded in this investigation. Six-month side process till laboratory tests are conducted (November 2021-May 2022).

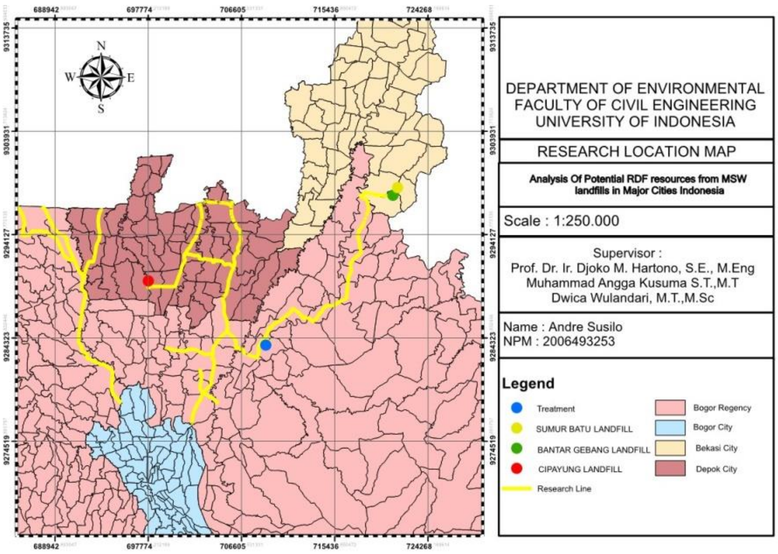

Figure 1. Research sites

2.1. Sampling of Waste Composition from the Landfills

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). A cart collected ±100 kg of waste samples from each research site. The waste was 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.

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

Meanwhile, in order to estimate the waste composition for each component, the following formula was used.

$$\text{Composition (\%)} = \frac{\text{component weight (kg)}}{\text{total generated waste component (kg)}} \text{x}100\% \quad (2)$$

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.

$$\text{M} = \left(\frac{\text{w}-\text{d}}{\text{w}}\right) \text{x}100\% \quad (3)$$

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 being weighed.

$$\text{Ash} = \left(\frac{\text{e}-\text{f}}{\text{w}}\right) \text{x}100\% \quad (4)$$

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.

$$\text{V} = \left(\frac{\text{d}-\text{e}}{\text{w}}\right) \text{x}100\% \quad (5)$$

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) (6)

$$\text{Calorific Value} = \frac{\text{potential calorific value (MJ/week)}}{\text{waste generation (kg/week)}} \text{x}100\% \quad (7)$$

Meanwhile, the traditional model based on proximate analysis (Liu et al., 1996) was used to calculate the comparative analysis of the calorific value of all types of waste in each landfill.

Hn = 45B-6W (8)

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. Waste composition is measured using the SNI 19-3964-1994 method for collecting and analyzing waste generation and composition samples.

3.1.1. Composition of Waste in 3 Research Sites

Over five days, ±500 kg of waste was collected from each landfill, accumulating ±1.5 tonnes for the three research sites. After measuring the waste's density was separated according to its components after measuring the waste's thickness. Table 1 shows the composition of the sorted waste from the three research sites.

Table 1. 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
	Polyethylene terephthalate (PET)	0.50	0.50	0.60	0.6	0.75	0.75
	Polypropylene (PP)	0.70	0.70	0.80	0.70	0.60	0.60
	Polystyrene (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 Wast (Electronics, batteries, etc.)	1.20	1.20	1.00	1.00	1.00	1.00
k.	Fines < 10 mm	1.00	0.10	1.00	0.10	1.00	1.00

Table 1 shows that each landfill has a different waste composition. Cipayung landfill has a more significant proportion of organic waste in dry and rainy conditions (62.90% for both conditions) than the other two landfills. Furthermore, the Cipayung landfill has more plastic waste (26.86% for dry and rainy conditions) than the other two research sites. However, the Bantargebang landfill has a higher percentage of paper and cardboard waste than other research sites, with 7.10 and 7.20% for dry and rainy conditions, respectively. For different types of waste, the difference is not as considerable. These differences may be related to disparities in the local population's socioeconomic status, comprising merchants, labourers, 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. A study conducted by Filho et al. (2021) supports this phenonema. The research reported that consumers usually wanted long-lasting food products and changed their shopping habits by purchasing more online or ordering food. Approximately 50% of respondents observed increased packed, fresh, and delivered foods. As a result, waste output was increased, particularly in terms of plastic packaging and food waste.

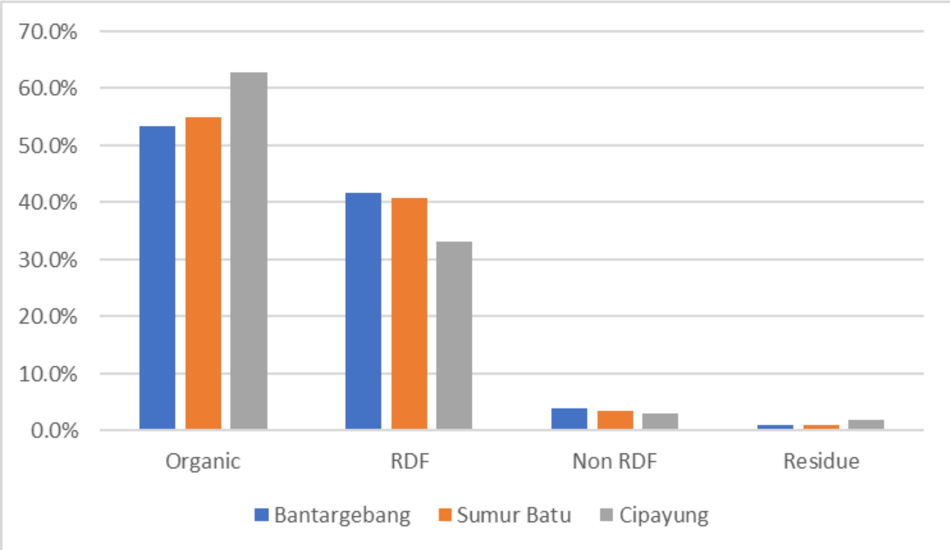

Figure 2. Waste composition at the research sites (dry season)

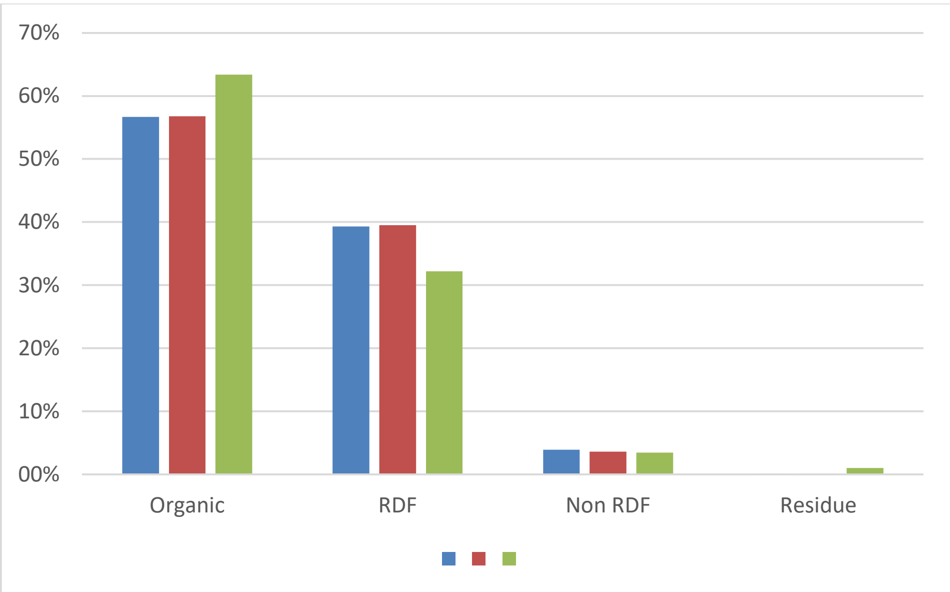

Figure 3. Waste composition at the research sites (rainy season)

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, aluminium, and electronic items are examples of non-RDF waste, which cannot be used as raw material in RDF production. The residue is the non-recyclable waste 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.

The composition of this waste differed from that reported by Budihardjo et al. (2019) in many landfills in Semarang, Indonesia. The percentage of organic waste in Semarang landfills was only 48.41%. Meanwhile, in Surabaya landfills, the rate of organic waste is significantly higher than the percentage reported in this study, which is 72,4% (Dhokhikah and Trihadiningrum, 2012). 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 colour of this type of waste and the possibility that it is mixed with organic waste, the percentage of wood and rubber waste in the three research locations is deficient.

3.1.2. Waste Generation

The waste composition data acquired from the three locations is presented in Table 2.

Table 2. 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 most significant waste generated in Bantargebang and the smallest amount in Cipayung. Based on data from Bali's landfills, weekly waste generation is approximately +10,020 tonnes (Widyarsana et al., 2019). 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 (Mihai, 2018).

3.2. Waste Parameters at the Research Sites

The water content of waste significantly impacts the time required to heat the waste before its conversion into RDF. The ash content is measured to assess how much ash is left over from combustion.

3.2.1. Water Content

That is since wet organic waste comprises food, vegetable, and fruit waste, containing 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 less water than 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 Italy RDF quality standard with a water and an ash content of 25% and 20%, respectively. The Italy standard was chosen because of its comparatively minimal standards, which allowed for its easy adaptation to the waste conditions at the research site. Furthermore, as a cement plant partner in this study, PT Indocement agreed to use this standard for RDF potential analysis.

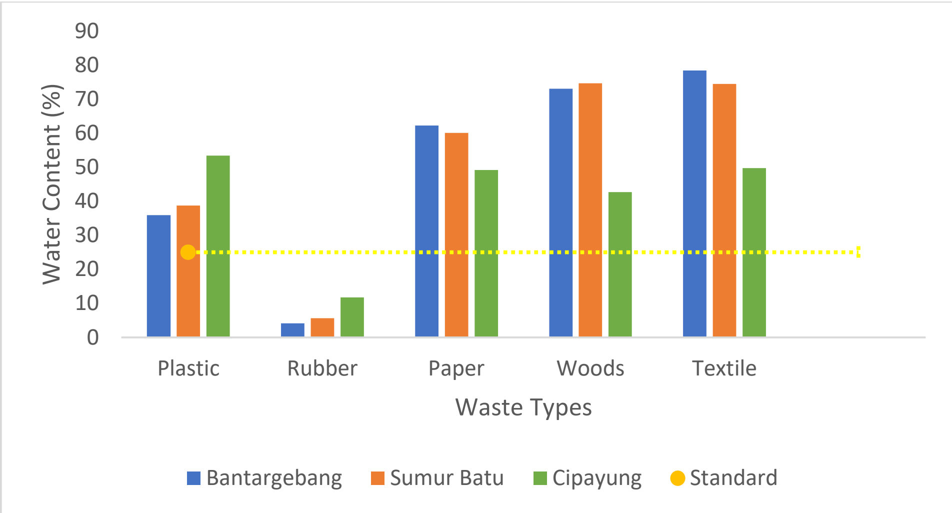

Figure 4. Comparison of wastewater content at the research sites

Figure 4 compares the water content of each form of plastic, rubber, paper, wood, and textile wastes, with RDF standards. Based on Figure 4, practically all forms of waste from the three research sites did not meet the RDF standards. Paper, wood, and textile waste from the Cipayung landfill show a lower water content than waste from the other two research sites. That is likely because the effect of moisture transfer in soil between heat source temperature and initial soil water content is different based on location (Gao et al., 2020). 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. 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 fulfil the standards. According to the obtained results, the Cipayung landfill is the research site where all types of waste meet the criteria for ash content. That means that waste from this landfill can be processed directly into RDF without the need for ash reduction. That was because the rubber sample was still mixed with noncombustible materials during testing, resulting in significant ash content.

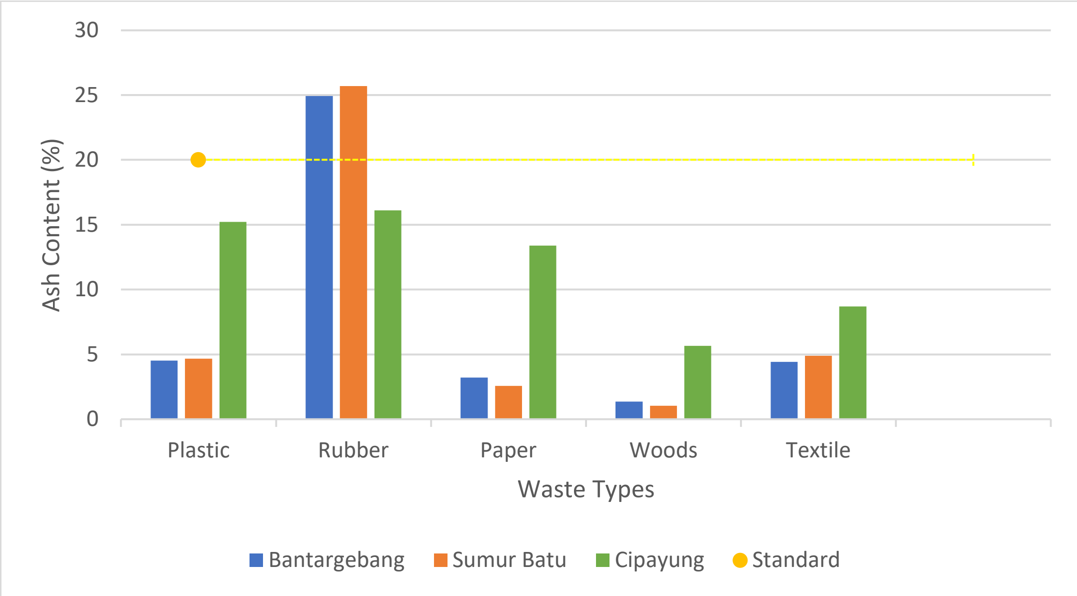

Figure 5. Comparison of ash contents from at the research sites

3.2.3. Volatile Levels

Table 3 shows the results of the calculations of volatile levels in waste samples from the three research locations.

Table 3. Volatile levels of waste in each landfill

Waste Types	Volatile Levels (%)		
	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 combustible material from all forms of waste and the total dry weight, yielding flammable contents of 61.71, 61.68, and 59.26% for Bantargebang, Sumur Batu, and Cipayung, respectively. This finding is similar to several previous studies conducted in Indonesian landfills. In Bali's dumps, for example, the volatile level was at 67.86% (Widyarsana et al., 2021). Furthermore, the Bandung landfill's explosive level was 78.72% (Hadinata et al., 2018). The waste samples at the three research sites could be directly processed into RDF using the combustible method since this study's volatile level was 50-70%.

3.3. Waste Calorific Value

The three research sites determined the calorific value of waste components such as plastic, rubber, paper, wood, and textiles—the higher the calorific value, the quicker the combustion process. Meanwhile, selecting 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

Based on the calorific value measurement findings that have been obtained. Because their calorific values (5035, 4879, and 5498 kcal/kg, or 21, 20, and 23 MJ/kg, respectively) met the Italian RDF quality criteria of more than 15 MJ/kg, plastic samples from the three research sites were considered feasible as raw materials for RDF production. Similarly, the conversion value of calorific value for rubber waste in MJ/kg is 21, 24, and 29 MJ/kg. Meanwhile, paper waste has a calorific value below the RDF Italy quality standard, with discounts of 10, 9.8, and 10 MJ/kg for the three research sites. As a result, the third paper sample cannot be used as a raw material for RDF. That indicates the third paper sample is inadequate for raw material for RDF production and must be pre-processed. Furthermore, the calorific values of the waste woods at the three research sites are 13, 13, and 12.8 MJ/kg, respectively, none of which met the RDF quality standards. Similarly, the calorific value of textile waste did not meet the RDF quality standards in this study, which were 12, 11, and 10.9 MJ/kg.

3.4. Potential Utilization of RDF

The energy values obtained based on proximate analysis (Liu et al., 1996) (Eq. 8) in the three landfills, Bantargebang, Sumur Batu, and Cipayung, are 2742.14, 2741.24, and 2671.32 kcal/kg, respectively.

4. Conclusions

The research has revealed several facts about the characteristics of various types of garbage from the three research locations and the feasibility and potential of generating RDF. The water content of all kinds of waste from the three research locations did not meet the quality standards of RDF Italy, so it needed to be pre-processed before being converted into RDF raw materials. Meanwhile, only rubber waste from the Bantargebang and Sumur Batu landfills did not meet the RDF quality standards regarding ash content. Meanwhile, all types of waste from the three research locations met the RDF standard on the volatile level parameter. Furthermore, because of their calorific value, plastic and rubber waste can be used as raw materials for RDF without pre-processing. Additionally, energy values for RDF in the Bantargebang, Sumur Batu, and Cipayung landfills are 2742.14, 2741.24, and 2671.32 kcal/kg, respectively.

References

Anasstasia, T.T., Lestianingrum, E., Cahyono, R.B., Azis, M.M., 2020. Life cycle assessment of refuse derived fuel (RDF) for municipal solid waste (MSW) management: case study area around cement industry, Cirebon, Indonesia. IOP Conference Series: Materials Science and Engineering 778, 012146.

Budihardjo, M.A., Wahyuningrum, I.F.S., Muhammad, F.I. and Pardede, R., 2019, November. The role of waste banks in the reduction of solid waste sent to landfill in Semarang, Central Java, Indonesia. In IOP Conference Series: Earth and Environmental Science 337(1), 012028.

Dhokhikah, Y. and Trihadiningrum, Y., 2012. Solid waste management in Asian developing countries: challenges and opportunities. Journal of Applied Environmental and Biological Sciences, 2(7), 329-335.

Friedrich, E. and Trois, C., 2016. Current and future greenhouse gas (GHG) emissions from the management of municipal solid waste in the eThekwini Municipality–South Africa. Journal of Cleaner Production, 112, 4071-4083.

Habert, G., Billard, C., Rossi, P., Chen, C., Roussel, N., 2010. Cement production technology improvement compared to factor 4 objectives. Cement and Concrete Research 40, 820–826.

Hamdi, F., Imran, H.A., 2019. Mechanical degradation of normal concrete due to seawater intrusion. IOP Conference Series: Materials Science and Engineering 674, 012015.

Hartono, D.M., Kristanto, G.A., Amin, S., 2015. potential reduction of solid waste generated from traditional and modern markets. International Journal of Technology 6, 838.

Gallardo, A., Carlos, M., Bovea, M. D., Colomer, F. J., & Albarrán, F., 2014. Analysis of refuse-derived fuel from the municipal solid waste reject fraction and its compliance with quality standards. Journal of cleaner production, 83, 118-125.

Gao, Y., Dong, S., Wang, C., Chen, Y. and Hu, W., 2020. Effect of thermal intensity and initial moisture content on heat and moisture transfer in unsaturated soil. Sustainable Cities and Society, 55, 102069.

Hadinata, F., Damanhuri, E., Rahardyan, B. and Widyarsana, I.M.W., 2018. Identification of initial settlement of municipal solid waste layers in Indonesian landfill. Waste Management & Research, 36(8), 737-743.

Irfan, M., Siddiqui, M., Bashir, F., Butt, M.T., Abbas, N., 2020. Efficient removal of hydrogen sulfide from wastewater using waste-tire-derived rubber particles. International Journal of Environmental Science and Technology 17, 3515–3524.

Kurniawan, T.A., Lo, W., Singh, D., Othman, M.H.D., Avtar, R., Hwang, G.H., Albadarin, A.B., Kern, A.O., Shirazian, S., 2021. A societal transition of MSW management in Xiamen (China) toward a circular economy through integrated waste recycling and technological digitization. Environmental Pollution 277, 116741.

Leal Filho, W., Voronova, V., Kloga, M., Paço, A., Minhas, A., Salvia, A.L., Ferreira, C.D. and Sivapalan, S., 2021. COVID-19 and waste production in households: A trend analysis. Science of the Total Environment, 777, p.145997.

Liu, J.I., Paode, R.D. and Holsen, T.M., 1996. Modeling the energy content of municipal solid waste using multiple regression analysis. Journal of the Air & Waste Management Association, 46(7), 650-656.

Mihai, F.C., 2018. Waste collection in rural communities: challenges under EU regulations. A case study of Neamt County, Romania. Journal of Material Cycles and Waste Management, 20(2), 1337-1347.

Martínez-Martínez, S., Pérez-Villarejo, L., Eliche-Quesada, D., Sánchez-Soto, P.J., Christogerou, A., Kanellopoulou, D.G., Angelopoulos, G.N., 2020. New waste-based clinkers for the preparation of low-energy cements. A step forward toward circular economy. International Journal of Applied Ceramic Technology 17, 12–21.

Rigamonti, L., Grosso, M., Biganzoli, L., 2012. environmental assessment of refuse-derived fuel co-combustion in a coal-fired power plant. Journal of Industrial Ecology 16, 748–760.

Sajjadi, S.A., Aliakbari, Z., Matlabi, M., Biglari, H. and Rasouli, S.S., 2017. Environmental impact assessment of gonabad municipal waste landfill site using Leopold Matrix. Electronic physician, 9(2), 3714.

Samsudin, M.D.M., Mat Don, M., 2013. Municipal solid waste management in Malaysia: current practices, challenges and prospects. Jurnal Teknologi 62.

SIPSN, 2020. Sistem Informasi Pengelolaan Sampah Nasional.

Supino, S., Malandrino, O., Testa, M. and Sica, D., 2016. Sustainability in the EU cement industry: the Italian and German experiences. Journal of Cleaner Production, 112, 430-442.

Suryawan, I.W.K., Septiariva, I.Y., Fauziah, E.N., Ramadan, B.S., Qonitan, F.D., Zahra, N.L., Sarwono, A., Sari, M.M., Ummatin, K.K., et al., 2022. Municipal solid waste to energy: palletization of paper and garden waste into refuse derived fuel. Journal of Ecological Engineering 23, 64–74.

Tozlu, A., Özahi, E., Abuşoğlu, A., 2016. Waste to energy technologies for municipal solid waste management in Gaziantep. Renewable and Sustainable Energy Reviews 54, 809–815.

Weitz, K.A., Thorneloe, S.A., Nishtala, S.R., Yarkosky, S., Zannes, M., 2002. The impact of municipal solid waste management on greenhouse gas emissions in the united states. Journal Air Waste Manage Assoc 52, 1000–1011.

Widyarsana, I.M.W., Damanhuri, E., Agustina, E. and Aulia, R.N., 2019. Risk assessment and rehabilitation potential of municipal solid waste landfills in Bali Province, Indonesia. GEOMATE Journal, 17(63), 164-171.

Widyarsana, I.M.W., Tambunan, S.A. and Mulyadi, A.A., 2021. Municipal solid waste characteristics: recycling potential and waste diversion rate in Bali Province, Indonesia.

Widyarsana, I.M.W., Tambunan, S.A., 2022. Analysis of potential utilization of landfill materials (case study: Sumur Batu landfill, Bekasi). IOP Conference Series: Earth and Environmental Science 999, 012021.

Zamli, A.F., Mahmood, W.M.F.W., Ghopa, W.A.W., Lim, M.T., 2020. the research on food waste pre-treatment technology for incineration in Malaysia. Journal of Environmental Treatment Techniques 9, 139–147.

Zhou, W., Jiang, D., Chen, D., Griffy-Brown, C., Jin, Y. and Zhu, B., 2016. Capturing CO2 from cement plants: A priority for reducing CO2 emissions in China. Energy, 106, 464-474.