GEOMATICS AND ENVIRONMENTAL ENGINEERING • Volume 18 • Number 5 • 2024

https://doi.org/10.7494/geom.2024.18.5.27

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Potential Use of Municipal Solid Waste Pile in Segawe Landfill (Tulungagung Regency, Indonesia) as Raw Material for Refuse Derived Fuel

Abstract: The Segawe municipal solid waste (SW) landfill in Tulungagung Regency, Indonesia, has currently exceeded its capacity. This study aimed to determine the potential use of dumped SW at the landfill as raw material for the production of refuse derived fuel (RDF). Buried SW samples were collected at a passive zone of the landfill in six locations. The samples were sieved using 10 and 30 mm mesh sieves. A composition analysis was conducted following the ASTM D5231-92 method to sample fractions of greater than 30 mm size. The density was measured according to the weight and volume. The moisture and volatile matter contents were analyzed using the ASTM D2216-10 and D3175-07 methods, respectively. The calorific value was measured using a Parr C3000 bomb calorimeter following the ASTM D5865 method.

The buried SW composition was dominated by a fraction size that was greater than 30 mm (79.4%). This fraction was dominantly composed of plastics (71.2%) and had average volatile matter and calorific values which met RDF criteria as a fuel. However, the ash and moisture contents exceeded the standards and, therefore, required appropriate treatments before their applications.

Keywords: calorific value, composition, landfill mining, RDF

Received: June 29, 2023; accepted: August 21, 2024

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1. Introduction

The generation rate of solid waste (SW) is increasing along with the increasing rate of the world's population. In addition, the increase in the industrial sector has also affected household income and caused impacts on people's consumption patterns. These facts have resulted in changes in not only the SW-generation rate but also the compositions and characteristics of SW from time to time [1].

Tulungagung Regency, which is located in East Java Province, had a population of 1.09 million in 2020. This regency has a municipal SW landfill in Segawe District that is 6 ha in size. Based on National Solid Waste Management Information System data, the SW generation rate in Tulungagung Regency was 544.89 t/day in 2020; this increased from 519.51 t/day in 2019 [2]. The SW is generally collected from residential areas and other sources by handcarts and brought to transfer facilities; then, it is transported to the Segawe landfill by SW transport trucks. The current condition of the landfill shows that it has exceeded its capacity [3]. The purpose of this study is to seek the possibility of reusing the landfill as a raw material source for refuse derived fuel (RDF) due to limited land availability. Landfill mining is an engineering process for extracting excavated materials or other solid natural resources from waste materials that have been disposed of and are buried in a landfill [4]. Landfill mining is applied not only for extending landfill capacity but also for valorizing the excavated materials [5–7]. Due to the diminishing availability of coal resources for cement industries and coal-fired steam power plants, the national demand of an energy substitute is urgently needed. Moreover, the use of SW as an alternative fuel in Indonesia has become prioritized since the enactment of Presidential Decree No. 35 Year 2018 concerning the Acceleration of the Construction of Solid Waste Processing Installations into Electrical Energy Based on Environmentally Friendly Technology [8].

Actually, the landfill-mining concept was regulated by the Minister of Public Works Decree No. 03/PRT/M/2013 concerning the Implementation of Infrastructure and Facilities for the Handling of Household Solid Waste and Household Solid Waste Alike (Indonesia Ministry of Public Works, 2013) [9]. Yet, the first landfill-mining project was only implemented in Indonesia in 2020 in the Bantargebang landfill in Jakarta Province [10]. Therefore, this study aimed to determine the potential use of dumped municipal SW at the Segawe landfill as raw material for RDF production. RDF is one of the SW-processing products for energy sources that hold high economical values [11, 12]. This research was implemented due the high demand of using fossil fuels for cement industries and coal-fired electricity power plants in Indonesia.

2. Methods

This research was conducted from March through June 2023. Sample analyses were conducted at the Laboratory of Solid Waste and Hazardous Waste Management, Department of Environmental Engineering of ITS in Surabaya City. The following were the stages of the research work.

2.1. Sample Collection

Six sample locations were selected based on the landfilling time periods of 2012, 2015, and 2018 (Fig. 1). The selections of the sampling locations were also based on practical considerations for conducting the sampling procedures. Buried SW samples were collected during the month of March 2023 by manual excavation at the passive zone in the Segawe landfill. The buried SW was excavated from SW pile surfaces of a 0.6 m × 1.0 m × 0.6 m size. The excavations were done in order to determine the densities of the waste heaps. The excavation depth was 1 m [11, 12] under the cover soil. The cover soil was separated from the SW and not mixed with the excavated SW samples. Based on the pre-survey data, the area of the passive zone at the Segawe MSW landfill was ca. 4 ha. Figure 1 shows the sampling locations.

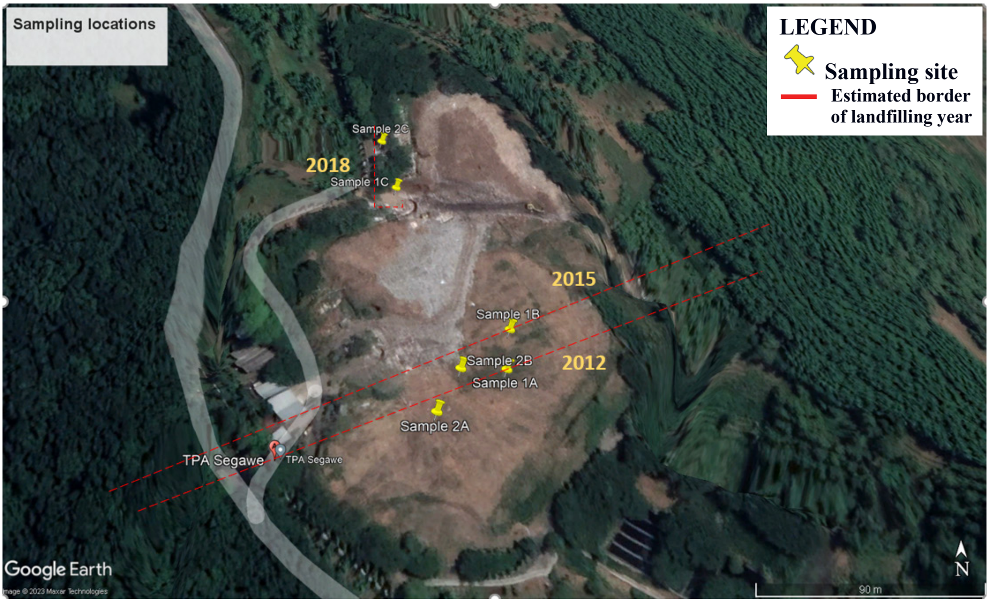

Fig. 1. Sampling locations

Table 1 shows the sampling location coordinates and landfill ages.

Table 1. Coordinates and SW dumping age of each sampling location

Year of landfill	Sampling location	Latitude	Longitude	Age of dumped SW [years]
2012	1A	8° 0′ 47.15″ S	111° 49′ 49.64″ E	ca. 12
	2A	8° 0′ 47.93″ S	111° 49′ 48.65″ E	
2015	1B	8° 0′ 46.45″ S	111° 49′ 49.70″ E	ca. 9
	2B	8° 0′ 47.16″ S	111° 49′ 48.97″ E	
2018	1C	8° 0′ 43.83″ S	111° 49′ 47.88″ E	ca. 5
	2C	8° 0′ 42.91″ S	111° 49′ 47.60″ E	

2.2. Composition and Density Measurements

The composition analyses of the SW samples were performed in two stages: the first was a composition analysis that was based on particle size, and the second was a composition analysis that was based on the SW component types of the large particles.

In the first stage, a not-less-than-100-kg sample was sieved from each site by using 10 and 30 mm mesh sieves. Each fraction was weighed, and the particle size composition was calculated based on the percentage of the wet weight. The second stage was performed for analyzing the SW composition with fractions that were greater than 30 mm in size; these were considered to become RDF raw material. The composition analysis was done according to ASTM D5231-92 [13]. The samples were manually separated into several components such as food waste, garden waste, plastic, wood, textile, rubber and leather, metal, glass, diapers, hazardous waste, and others. Each sorted component was weighed for determining the material compositions in wet weight percentages.

2.3. Density Measurement

The density of the excavated material was measured by weighing the samples from each site hole of a size of 0.6 m × 1.0 m × 0.6 m (Section 2.1). The density of the SW was calculated by using Equation (1):

$$d = \frac{w}{v} \tag{1}$$

where:

d – density of SW material,
w – weight of excavated SW material,
v – hole volume.

2.4. Characterization of Mined SW Material as RDF Raw Material

The physical-chemical characterizations of the >30 mm-sized fractions were performed for determining the moisture, volatile matter, ash, and calorific values. The samples were placed in a cool box during transport to the laboratory and kept in a refrigerator prior to our analyses.

Moisture

A moisture analysis was performed according to ASTM D2216-10 [14]. The moisture content was calculated by using Equation (2):

$$moisture\ content\ [\%] = \frac{b-c}{b-a} \cdot 100\% \tag{2}$$

where:

a – weight of dried empty crucible [g],
b – weight of crucible and fresh sample [g],
c – weight of crucible and sample after drying [g].

Volatile Matter

A volatile matter analysis was carried out based on the dry weight of each sample (following ASTM D3175-07) [15]. The samples were heated in a furnace at 550°C for one hour. The volatile matter was calculated by using Equation (3):

$$volatile\ matter\ [\%] = \frac{a-b}{a} \cdot 100\% \tag{3}$$

where:

a – dry weight of sample [g],
b – weight of sample after heated in furnace [g].

Ash Content

The ash content was measured based on the dry weight of each sample by using Equation (4):

$$ash\ content\ [\%] = \frac{b-c}{a} \cdot 100\% \tag{4}$$

where:

a – dry weight of sample [g],
b – weight of sample after heated in furnace [g],
c – weight of empty crucible [g].

Calorific Value

The calorific value was determined as a high heating value according to ASTM D5865 [16] using a Parr C3000 bomb calorimeter.

The results of the SW characterization were compared to the RDF quality standards (Table 2).

Table 2. RDF quality standards

Parameter	Quality standards
Calorific value [MJ/kg]	10.0–35.0
Moisture content [%]	7.0–35.0
Volatile matter [%]	65.9–68.0
Ash content [%]	5.0–25.0

Source: [10, 17, 18]

3. Results and Discussion

3.1. Composition of Excavated SW Material

The composition of the excavated SW samples based on particle size is shown in Figure 2. The main component of the mined SW was the fraction of the >30 mm size (79.4%). The fraction of the 10–30 mm size (10.8%) comprised uncountable components such as soil, plastic, twigs, and glass. The SW fraction of the <10 mm size (9.8%) was soil-like material that consisted of biodegradable organic waste and other small particles (which were difficult to separate).

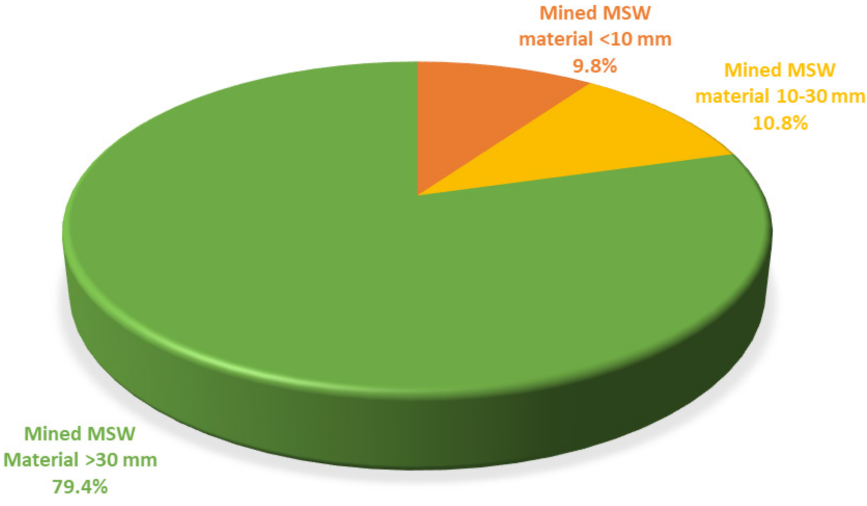

Fig. 2. Composition of mined SW material based on particle size

The mined SW material of the >30 mm size consisted of plastics (71.2%), textiles (6.9%), diapers (5.0%), wood (3.9%), garden waste (3.4%), rubber (1.8%), glass (1.1%), metals (0.2%), undecomposed food waste (0.1%), hazardous waste (0.1%), and others (6.3%) (Fig. 3). The undecomposed garden waste was comprised of coir and coconut shells, whereas the food waste consisted of bones and hard fruit rinds. The metal-waste component was composed of beverage cans, spoons, and small metal pieces. The SW component that contained hazardous material consisted of electric wires and batteries. The SW component category of "others" was comprised of inseparable small particles such as stones, tiny organic matter, and dirt.

These results were similar to the compositions of the excavated SW from the other landfills; for example, the plastic component amounted to 35–51% from the Nonthaburi landfill, followed by fine particles (19–30%) [19], and plastics and fine particles of sizes that were less than 20 mm were the main components from Finland's Kuopio landfill [20].

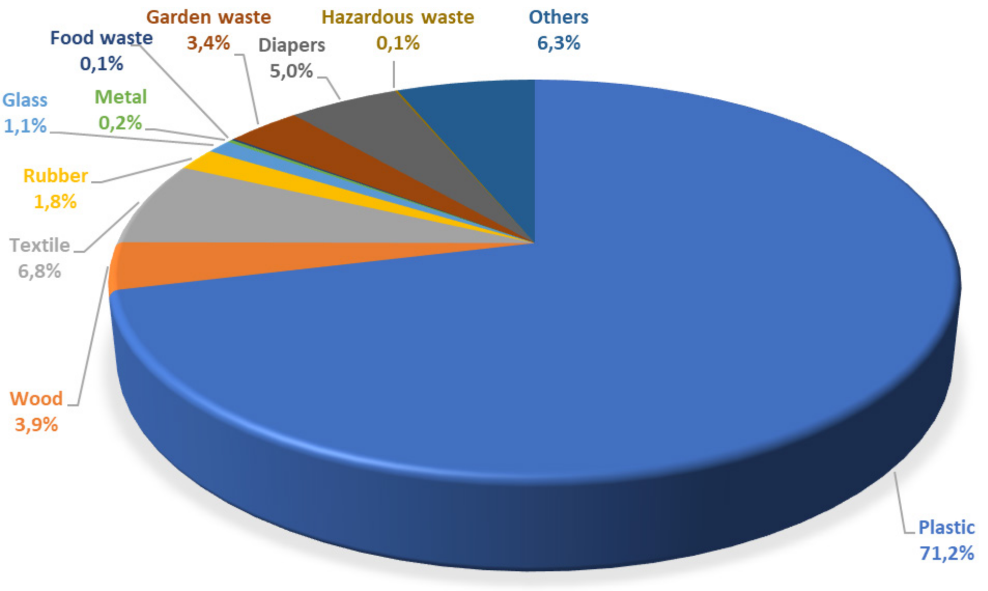

Fig. 3. Composition of excavated SW material of >30 mm size

3.2. Density

The average densities of the excavated SW material samples varied between 245.41 and 356.74 kg/m^3, with an overall average of 298.82 kg/m^3 (Table 3).

Table 3. Weight, volume, and estimated density of mined material in each sampling location with different year of landfilling

Starting year of landfill	Sampling location	Volume [m^3]	Weight of each sample [kg]	Density [kg/m^3]	Average density [kg/m^3]
2012	1A	0.49	101.24	206.60	245.41 ±54.89
	2A	0.36	102.32	284.22	
2015	1B	0.36	146.17	406.03	356.74 ±69.71
	2B	0.36	110.68	307.44	
2018	1C	0.34	96.63	285.89	294.30 ±11.90
	2C	0.34	102.32	302.72	
Overall average [kg/m^3]				298.82 ±63.98	

The density of the excavated material was affected by the composition of the SW [19]. If the excavated material was dominated by soil-like material, the density was higher. As shown in Table 3, the average density of the excavated material was 298.82 kg/m^3; this density data was lower than that from previous studies (approximately 400 kg/m^3) [19, 20]. This large difference could have been caused by the differences in the SW compositions. A high content of soil cover material could have increased the SW's density, while high amount of plastics could have reduced the density. As shown earlier, the most dominant SW component was plastics. In addition, the cover soil of the landfill had been separated, so it was not counted as part of the excavated material; therefore, the excavated SW material density from the Segawe landfill was lower than those from the other landfills. Previous investigators concluded that the moisture content, the SW composition, the presence of cover soil, and compaction during the landfill's operation affected the bulk density of the excavated materials [19–21]

The bulk density data can be used estimate the quantity of RDF raw material from a landfill; however, precise estimations of RDF quantities in landfills require technical specifications as are outlined in the design plans of each landfill as well as its operation practices in order to obtain the buried SW spatial dimensions.

3.3. Potential of Excavated SW as Raw Material for RDF

The potential of mined SW for RDF was evaluated by placing some physical-chemical characteristics into consideration; namely, the moisture, volatile matter, ash content, and calorific values.

Moisture

The average moisture contents of the samples varied between 32.62 and 46.62%, which mostly exceeded the quality standards for RDF (7–35%) (Table 4).

Table 4. Moisture contents in all samples

Year of landfilling	Sampling location	Moisture content [%]		
		Fraction >30 mm	Average	RDF quality standards [10, 17, 18]
2012	1A	49.51	46.62 ±4.08	7–35
	2A	43.74		
2015	1B	37.82	32.62 ±7.35	
	2B	27.42		
2018	1C	49.12	43.18 ±8.40	
	2C	37.24		

Only the average moisture of the SW samples from the 2015 zone met the quality standards; however, this moisture data was lower than those from the Sukawinatan (68.39–69.23%) [12] and Bantargebang (48.73%) landfills [22]. The sample from Site 1A had the highest moisture content of all of the locations; this was due to the rain at the site the night before the samples were collected. This fact was confirmed by former researchers who stated that high moisture contents could be caused by rainfall [22]. A high moisture content in RDF will affect its combustion efficiency and calorific value; therefore, it is necessary to conduct an additional drying stage for reducing the moisture content. One of these options is sun drying; however, this method can only be done during the dry season. During the rainy season, mechanical drying is required; however, mechanical drying requires an energy source, which increases fuel consumption and emits air pollutants. Therefore, the application of moisture-control technology for RDF processing should consider energy efficiency, the minimization of pollutant emissions, and the maintenance of operational reliability.

Volatile Matter

All of the samples showed high volatile matter contents of 70.67–70.92%, which were higher than the RDF quality standards (65–68%) (Table 5). The volatile matter contents of the samples in the study area were much higher than those from the Sukawinatan landfill (47.45–59.06%) [12]. The higher volatile matter content could have meant that the easier the material is to burn and ignite, the faster the combustion rate [23].

Table 5. Volatile matter contents in all samples

Year of landfilling	Sampling location	Volatile matter content [% dry weight]		
		Fraction >30 mm	Average	RDF quality standards [10, 17, 18]
2012	1A	71.78	70.92 ±1.21	65–68
	2A	70.06		
2015	1B	71.04	70.67 ±0.53	
	2B	70.30		
2018	1C	71.34	70.88 ±0.65	
	2C	70.42		

Ash Content

The ash contents of the excavated samples were 29.08–29.33%, which slightly exceeded the maximum quality standards for RDF (25%); this is shown in Table 6. The ash contents of the SW samples indicated the amounts of solid residue after combustion [23, 24]. This residue could have originated from the soil cover of the landfill, which was mixed with the excavated matter.

Table 6. Ash contents in all samples

Year of landfilling	Sampling location	Ash content [% dry weight]		
		Fraction >30 mm	Average	RDF quality standards [10, 17, 18]
2012	1A	28.22	29.08 ±1.21	5–25
	2A	29.94		
2015	1B	28.96	29.33 ±0.53	
	2B	29.70		
2018	1C	28.66	29.12 ±0.65	
	2C	29.58		

However, this ash content data was much lower than that from the Sukawinatan landfill (40.93–55.55%) [12]. These lower values of the ash contents in the samples in the study area might have been caused by the removal of the landfill cover soil prior to the analyses.

Calorific Value

The average calorific values of the samples from all of the dumping ages varied between 10.35 and 15.62 MJ/kg (Table 7). These calorific values generally met the RDF quality standards (10–35 MJ/kg).

Table 7. Calorific values of excavated material

Year of landfilling	Sampling location	Calorific value		RDF quality standards [MJ/kg] [10, 17, 18]
		Each location [MJ/kg]	Average [MJ/kg]	
2012	1A	8.17	10.35 ±3.09	10–35
	2A	12.54		
2015	1B	18.37	15.62 ±3.89	
	2B	12.87		
2018	1C	10.00	11.98 ±2.81	
	2C	13.97		

The calorific values of the mined SW in this research were comparable to those of the Sukawinatan (9.69–15.61 MJ/kg) [12] and Bantargebang (13.72–15.14 MJ/kg) landfills [10, 25, 26].

Overall, the results of this research showed that excavated material of a >30 mm size from the Segawe landfill had the potential to be used as raw material for RDF production. The high ash and moisture contents seemed to be typical for the excavated matter from the landfills [10]. The removal of the cover soil is required for reducing the ash content during the implementation of any excavation practices. Additionally, the drying stage of the excavated material is important to be performed in order to meet the moisture standards for RDF.

4. Conclusion

The excavated material in the study area generally met the quality standards as raw material for RDF production; however, two parameters (namely, the ash and moisture contents) exceeded the quality standards. For this reason, excavated material from the Segawe landfill requires careful separation from the soil cover in order to decrease the ash content. Additionally, an extra drying stage may be required for reducing the moisture content – especially during the rainy season.

Funding

Funding of the research was awarded by the Directorate of Research & Public Service of Sepuluh Nopember Institute of Technology through Scientific Research Grant No. 1725/PKS/ITS/2023.

CRediT Author Contribution

D. P. H.: field survey, data collection, laboratory analysis, and manuscript writing.

Y. T.: conceptualization, methodology, research supervision, and manuscript development.

S. A. W.: research fund acquisition.

D. R. R.: research administration and fund management.

A. Y. B.: research management.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

All data in this paper are publicly accessible.

Use of Generative AI and AI-assisted Technologies

No generative AI or AI-assisted technologies were employed in the preparation of this manuscript.

Acknowledgement

The authors gratefully acknowledge the Directorate of Research & Public Service of Sepuluh Nopember Institute of Technology for supporting this study with Scientific Research Grant No. 1725/PKS/ITS/2023 of financial year 2023.

References

[1] Apriyani A., Putri M.M., Wibowo S.Y.: *Pemanfaatan Sampah Plastik Menjadi Ecobrick*. Masyarakat Berdaya dan Inovasi, vol. 1(1), 2020, pp. 48–50.

[2] Sistem Informasi Pengelolaan Sampah Nasional (SIPSN): *Timbulan Sampah*. https://sipsn.menlhk.go.id/sipsn/public/data/timbulan [access: 21.12.2021].

[3] Choirurrozaq: *Kapasitas TPA Segawe Makin Kritis*. Radar Tulungagung, 19.10.2020, https://radartulungagung.jawapos.com/tulungagung/76787063/kapasitas-tpa-segawe-makin-kritis [access: 20.12.2022].

[4] Krook J., Svensson N., Eklund M.: *Landfill mining: A critical review of two decades of research*. Waste Management, vol. 32, 2012, pp. 513–520. https://doi.org/10.1016/j.wasman.2011.10.015.

[5] Jagodzińska K., Lopez C.G., Yang W., Jönsson P.G., Pretz T., Raulf K.: *Characterisation of excavated landfill waste fractions to evaluate the energy recovery potential using Py-GC/MS and ICP techniques*. Resources, Conservation and Recycling, vol. 168, 2021, 105446. https://doi.org/10.1016/j.resconrec.2021.105446.

[6] Jain M., Kumar A., Kumar A.: *Landfill mining: A review on material recovery and its utilization challenges*. Process Safety and Environmental Protection, vol. 169, 2023, pp. 948–958. https://doi.org/10.1016/j.psep.2022.11.049.

[7] Márquez A.J.C., Filho P.C.C, Rutkowski E.W., Isaac R.D.: *Landfill mining as a strategic tool towards global sustainable development*. Journal of Cleaner Production, vol. 226, 2019, pp. 1102–1115. https://doi.org/10.1016/j.jclepro.2019.04.057.

[8] *Presidential Regulation (Perpres) Number 35 of 2018 concerning the Acceleration of the Development of Waste Processing Installations into Electrical Energy Based on Environmentally Friendly Technology*. 12 April 2018, https://leap.unep.org/en/countries/id/national-legislation/presidential-regulation-perpres-number-35-2018-concerning.

[9] *Minister of Public Works Decree No. 03/PRT/M/2013 Concerning the Implementation of Infrastructure and Facilities for the Handling of Household Solid Waste and Household Solid Waste Alike*. 14 March 2013, https://leap.unep.org/en/countries/id/national-legislation/regulation-minister-public-works-no-03prtm2013-implementation.

[10] Prihartanto P., Trihadiningrum Y., Kholiq M.A., Bagastyo A.Y., Warmadewanthi I.D.A.A.: *Characterization of landfill-mined materials as a waste-to-energy source at integrated solid waste treatment facilities of Jakarta Province, Indonesia*. Journal of Material Cycles and Waste Management, vol. 25, 2023, pp. 3872–3884. https://doi.org/10.1007/s10163-023-01810-9.

[11] Mahmudin I., Trihadiningrum Y.: *Potensi Ekonomi Timbunan Sampah di TPA Ngipik Kabupaten Gresik*. [in:] *Prosiding Seminar Nasional Manajemen Teknologi XIX: Program Studi MMT-ITS, Surabaya, 2 November 2013*, pp. D-2-1–D-2-7.

[12] Wahyono S., Sahwan F.L., Suryanto F., Febriyanto I., Nugroho R., Hanif M.: *Studi Karakterisasi Sampah Landfill dan Potensi Pemanfaatannya (Studi Kasus di TPA Sukawinatan dan Bantargebang)*. Jurnal Teknologi Lingkungan, vol. 20(2), 2019, pp. 179–188.

[13] *Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste*. ASTM D5231-92, Society for Testing and Materials International, West Conshohocken 2016.

[14] *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*. ASTM D2216-10, American Society for Testing and Materials International, West Conshohocken 2014.

[15] *Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke*. ASTM D3175-07, American Society for Testing and Materials International, West Conshohocken 2007.

[16] *Standard Test Method for Gross Calorific Value of Coal and Coke*. ASTM D5865-03, American Society for Testing and Materials International, West Conshohocken 2003.

[17] Chaerul M., Wardhani A.K.: *Refuse Derived Fuel (RDF) dari Sampah Perkotaan dengan Proses Biodrying: Review*. Jurnal Presipitasi, vol. 17(1), 2020, pp. 62–74.

[18] Almaulidy N.: *Kajian Optimalisasi Produksi Refuse Derived Fuel (RDF) Menggunakan Bioaktivator EM4 Pada Proses Biodrying Di TPST RDF Jeruklegi Cilacap*. Institut Teknologi Sepuluh Nopember, Surabaya 2023 [undergraduate thesis].

[19] Prechthai T., Padmasri M., Visvanathan C.: *Quality assessment of mined MSW from an open dumpsite for recycling potential*. Resources, Conservation, and Recycling, vol. 53(1–2), 2008, pp. 70–78. https://doi.org/10.1016/j.resconrec.2008.09.002.

[20] Kaartinen T., Sormunen K., Rintala J.: *Case study on sampling, processing, and characterization of landfilled municipal solid waste in the view of landfill mining*. Journal of Cleaner Production, vol. 55, 2013, pp. 55–66. https://doi.org/10.1016/j.jclepro.2013.02.036.

[21] Chiemchaisri C., Charnnok B., Visvanathan C.: *Recovery of plastic wastes from dumpsite as refuse-derived fuel and its utilization in small gasification system*. Bioresource Technology, vol. 101(5), 2010, pp. 1522–1527. https://doi.org/10.1016/j.biortech.2009.08.061.

[22] Prihartanto, Putri, V.M., Trihadiningrum Y., Kholiq M.A., Bagastyo A.Y., Warmadewanthi I.D.A.A.: *Characteristics of humate soil from landfill mining in Bantargebang Integrated Solid Waste Treatment Facility, Indonesia*. IOP Conference Series: Earth and Environmental Science, vol. 1201, 2023, 012002. https://doi.org/10.1088/1755-1315/1201/1/012002.

[23] Novita D.M., Damanhuri E.: *Perhitungan Nilai Kalor Berdasarkan Komposisi Dan Karakteristik Sampah Perkotaan di Indonesia Dalam Konsep Waste to Energy*. Jurnal Teknik Lingkungan, vol. 16(2), pp. 103–114. https://doi.org/10.5614/jtl.2010.16.2.1.

[24] Izaty F.N.: *Analisis Komposisi Dan Identifikasi Potensi RDF (Refuse Derived Fuel) Pada Sampah Zona 1 TPA Piyungan Bantul Dengan Analisis Proximate Dan Nilai Kalor*. Universitas Islam Indonesia, Yogyakarta 2018. https://dspace.uii.ac.id/handle/123456789/10164.

[25] Kristanto G.A., Jansen A., Koven W.: *The potential of landfill mining in two inactive zones of the Bantar Gebang Landfill in Jakarta, Indonesia*. International Journal of Technology, vol. 11(7), 2020, pp. 1430–1441. https://doi.org/10.14716/ijtech.v11i7.4571.

[26] Putri V.M.: *Kajian Pengolahan Sampah Hasil Landfill Mining Di TPST Bantargebang.* Institut Teknologi Sepuluh Nopember, Surabaya 2022 [undergraduate thesis].