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Processing of plastic waste from Klotok Landfill Kediri City with thermal cracking method

N Citrasari¹, A I Agusningtyas¹, S Hariyanto² and A F Maidi¹

¹ Environmental Science and Technology, Department of Biology, Faculty of Science and Technology, Universitas Airlangga, Indonesia

² Biology, Department of Biology, Faculty of Science and Technology, Universitas Airlangga, Indonesia

Email: nita-c@fst.unair.ac.id

Abstract. This study aimed to determine the characteristics of raw materials and plastic waste thermal cracking solid products at Klotok Landfill Kediri City, through proximate values (water content, volatile matter, and ash content) and the values of heat; liquid, solid, and gas products as an alternative energy source; molecular quality of liquid hydrocarbon products; and the availability of plastic waste as the raw material of the product in meeting the required fuel amount for operating landfill machinery. The raw materials came from the highest types of plastic waste generations in Klotok Kediri Landfill, namely other plastics: HDPE: PP with the variation A, B, and C ratios of 75: 12.5 : 12.5; 12.5 : 75 : 12.5; and 12.5 : 12.5 : 75. This research used the thermal cracking method with Tripod 4M reactor of 1 kilogram capacity with the combustion temperature of 300-400°C for 45 minutes. The proximate and raw material calorific values, as well as products of variations A, B, and C met the standards of Turkey RDF, lignite coal, European Standard, market fuel, and solid products have better quality than the Thailand RDF, making it a potential candidate for use as fuel. The highest percentage of liquid product was produced in variation C with 78.422%, and the highest solid and gas product yields was produced by composition A with 28.578% and 46.690%. The molecular quality of the liquid hydrocarbons in each variation has an aromatic content of 1.04% and the distribution of C atoms of > 50%, indicating its feasibility to be used as a gasoline fuel to meet the total energy consumption for the landfill operating machines. The minimum amount of plastic waste in the landfill to meet the total energy consumption is 20,087.14 kg/day.

1. Introduction

Processing is still a problem in Indonesia. The Local Environment Status (SLHD) Indonesia ranks second in the category of countries with the largest plastic waste in the sea after China, which dumps 0.48-1.29 MMT/year [1]. The average Indonesian resident produces 0.8 kg of garbage/person or as much as 189,000 tons/day collectively. Based on that amount, 15% or 28,400 ton is plastic waste. In fact, plastic waste is a material that is difficult to degrade [2], impacting on the difficulty of finding land for landfill use.

Plastic is a polymer compound with the main elements of carbon and hydrogen, while the thermoplastic group melts if heated to a certain temperature, which is potential to be recycled into oil fuel (BBM) [3]. Research on plastic waste processing at Klotok Landfill Kediri City aimed to determine the potential of alternative energy sources that can be generated and utilize the mining of



passive zone to be reusable as a new landfill.

2. Research Methods

The research was conducted in March-August 2017 with sampling locations at Klotok I and II Landfills Kediri City. The sampling used an observational and integrated method, while the sampling point determination used purposive sampling technique. The analysis of raw materials and products are in the form of moisture content, ash content, volatile matter, calorific value, and GCMS. The method used was thermal cracking with 4M Tripod 4M reactor with a capacity of 1 kg at a temperature of 300-400°C for 45 minutes. The raw material used is the ratios of polypropylene (PP) plastic: High Density Polyethylene (HDPE): Other divided into variation A (75%: 12.5%: 12.5%), variation B (12.5%: 75%: 12.5%), and variation C (12.5%: 12.5%: 75%) with a total sample per composition of 3000 g.

3. Result and Discussion

3.1. Formula and equation

The test parameters in this study include proximate analysis (moisture content, ash content, volatile matter), calorific value, GC-MS, Mass Balance, and engine fuel consumption. The formula used such as water content (ASTM D 3137), ash content (ASTM E 830-87), volatile matter (Standard Method 2540 E), calorific value (ASTM D 5865-03), mass balance analysis, and engine fuel consumption.

3.2. Figures and tables

3.2.1. Composition and characteristics of plastic waste of Klotok Landfill Kediri City as a raw material for thermal cracking.

The composition of the selected plastic waste as the raw material for thermal cracking can be seen in Table 1 and the proximate characteristics and calorific value can be seen in Table 2. The composition was chosen because the availability of plastic waste in the landfill met the needs of raw materials, so as to maintain the sustainability of the production process and the quality of thermal cracking products [5].

Table 1. The composition and generation of plastic waste at Klotok Landfill Kediri City chosen as the raw material for thermal cracking

High to Low Value	Klotok I Landfill Kediri City			Klotok II Landfill Kota Kediri			Klotok Landfill		
	Plastic Type	Plastic Generation (Kg)	Plastic Generation (%)	Plastic Type	Plastic Generation (Kg)	Generation Plastic (%)	Plastic Type	Plastic Generation (Kg)	Generation Plastic (%)
1	Other	43.07	92.13	HDPE	623.9	43.59	HDPE	624,500	42.26
2	LDPE	2.03	4.34	PP	326.2	22.79	PP	326,980	22.12
3	PP	0.78	1.67	Other	173.2	12.10	Other	216.270	14.63

Table 2. Proximate and calorific value characteristics of thermal cracking material [6]

No.	Parameter	Sample Code			Standard	Reference	Suitability
		B	B	C			
1.	Water content (%)	0.038 ± 0.011	0.005 ± 0.001	0.00 ± 0.00	< 25	European Standard	In accordance
2.	Volatile Matter (%)	99.172 ± 0.151	99.290 ± 0.440	99.040 ± 0.007	≥92.3	Turkey RDF	In accordance
3.	Ash content (%)	0.129 ± 0.133	0.284 ± 0.437	0.040 ± 0.007	< 5	European Standard	In accordance
4.	Calorific Value (kcal/kg)	5,288.32 ± 29.164	5,512.67 ± 29.467	5,747.27 ± 76.89	3,585 4,830-6,330	European Standard Lignite Coal *)	In accordance In accordance

The suitability of moisture content with the European Standard indicates that plastic waste variations are highly potential for thermal cracking because the water content of < 25% speeds up the production process during combustion and minimizes air pollution to be generated [7]. The volatile

matter of thermal cracking raw material is very high compared to volatile matter required by Turkey RDF, so plastic waste variation is very potential to be used as raw material of thermal cracking. Volatile matter of $\geq 92.3\%$ can increase burning speed, so raw material will be more flammable and combustible [4].

The ash content of the raw material meets the criteria of European Standard because it has a value of $<5\%$ [8]. The suitability indicates that plastic waste variation is highly potential as a thermal cracking raw material, since ash content $<5\%$ increases the quantity of product [9]. The highest calorific value was on variation C (plastic PP 75%). This thermal cracking raw material has a high heating value of $> 5,700$ kcal/kg, which exceeds the provisions of the European Standard and the standard of lignite coal quality, so it is potentially a good source of energy [10].

3.2.2 Potential of thermal cracking product as an alternative energy source.

The thermal cracking process produces products in liquid, solid, and gaseous forms as shown in Table 3.

Table 3. Liquid, solid, and gas products resulting from the thermal cracking process

No.	Variation	Product	Liquid Volume (mL)	Liquid (%)	Solids (g)	Solids (%)	Gas (%)
1.	B	1	36.00	0.973	857.35	28.578	46.690
		2	867.00	23.759			
2.	B	1	180.00	4.864	758.70	25.290	44.423
		2	928.75	25.420			
3.	C	1	592.50	16.011	251.75	8.392	13.187
		2	2,311.50	62.411			

The composition with the highest volume of thermal cracking liquid product is variation C (75% PP plastic), which has the biodegradability to form gas and liquid at a certain temperature [11], which is at the range of $200\text{--}350^\circ\text{C}$ in this study. The composition with the highest solid product is variation A (75% Other plastic) because it is dominated by sachet packaging mostly coated in aluminum foil that is not combustible [12]. Variation B (75% HDPE plastic) produces a solid product that resembles paraffin or wax because it has a long C chain. The product can be used as raw material for candles and stamps [13].

3.2.3. Potential of thermal cracking liquid products as oil fuel.

The calorific value of liquid thermal cracking products meets the premium calorific value and quality standard of the Department of Energy and Mineral Resources (ESDM) of the Republic of Indonesia Year 2008, so the product can be purported as oil fuel and thermal cracking technology can be used for the conversion of energy made from plastic waste. Potential liquid product can be seen in Table 4[14].

Table 4. Potential liquid product of thermal cracking results compared to market oil fuel and quality standard of Department of ESDM RI

Para-Meter	Product	Sample Code			Premium*)	Quality standard**)	Suitability
		B	B	C			
Value	1	10,615	10,663	11,560.8	10,509	10,000	In accordance
Calorific value (kcal / kg)	2	10,512	10,605	11,980.5			

3.2.4. Potential of thermal cracking solid products as Refuse Derived Fuel (RDF)

The thermal cracking process produced solid product with the characteristics and comparison with Thai RDF according to Table 5.

Table 5. Thermal cracking solid product characteristics in comparison with Thailand RDF

Parameter	Units of measurement	Value			RDF Thailand *)	Description
		B	B	C		
Water content	(%)	0.10	0.13	0.05	12	Better

Volatile Matter	(%)	79.92	71.71	67.18	50-70	Better
Ash content	(%)	0.020	0.458	0.0055	12	Better
Calorific Value	(kkal/kg)	5,474	5,129	5,304.50	4,636.70	Better

The calorific value of thermal cracking solid product at each variation is higher than the Thailand RDF calorific value of 4,636.70 kcal / kg and has met the lignite class calorific value standard for coal, which is 4,830-6,360 kcal / kg [6]. These values indicate solid products that are highly potential to become a raw material for fuel and as a mixture of asphalt manufacturing as has been done in Europe [15].

3.2.5. Potential of plastic waste generation from Klotok Landfill Kediri City as raw material of thermal cracking in fuel requirement of operational machines in landfill.

The thermal liquid cracking products are known to be equivalent to gasoline, so they can be used as fuel for the landfill operational equipment such as tricycle, garbage truck, and excavator. This is based on the results of calculations from primary and secondary data using equation 9, assuming that all types of plastics are used and are producing the same fuel volume (Variation C produces 968 mL of fuel from 1 kg plastic). It is known that the amount of plastic waste disposal of Klotok Landfill of Kediri City as raw material of fuel production can fulfill the volume of fuel needed by operational machines in the landfill with total daily energy consumption of 20,087.14 kg/day.

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