

# Production of Fuels From HDPE and LDPE Plastic Waste via Pyrolysis Methods

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**Abstract.** This study to calculate and composition of fuels from polyethylene waste production per litre. Production method with pyrolysis at 450-621°C without catalyst, and quantitative method with GC-MS. The results product of 5 kg pyrolysis HDPE are 3.25 litres of naphtha; 0.85 litre of gasoline; 0.325 litre of diesel fuel; and 18.06 grams of residues. Then The product of 5 kg pyrolysis LDPE are 0.5 litres of naphtha; 2.9 litre of gasoline; 0.1 litre of diesel fuel; and 19 grams of residues. The conclusions in this study were product of 5 kg pyrolysis HDPE are 3.25 litres of naphtha; 0.85 litre of gasoline; 0.325 litre of diesel fuel; and 18.06 grams of residues. Then The product of 5 kg pyrolysis LDPE are 2.9 litre of gasoline, 0.1 litre of diesel fuel, and 19 grams of residues. Composition of fuels from *polyethylene* (HDPE and LDPE) pyrolysis are naphtha, gasoline, and residues.

Keywords: **Fuels; HDPE; LDPE; GC-MS; Pyrolysis.**

## 1 Introduction

The topic of production fuels from plastic waste has been widely analyzed by many researchers. A number of studies have examined the production fuels from HDPE and LDPE waste. Indonesia is one of the great producer number 2 plastic waste in the world 3,22 million metrics tonne per year and 0,48-1,29 million metrics tonne per year of plastic waste in ocean [1]. So, productions energy from plastic waste is one of methods to managed plastic waste in the world especially in Indonesia.

Biofuel industry was employed 1,724 million labours in the world, especially in Indonesia have been 154.300 labours worked at biofuel industry from palm oil [2]. This is indicated to develop biofuel industry from plastic waste was prospective too.

The relationship between production of fuels from HDPE and LDPE plastic waste via pyrolysis methods has been an active research area will explain at Theory and Methodology.

This study discusses to calculate and composition of fuels from polyethylene waste production per litre. The process used pyrolysis methods at 450-621°C without catalyst until 3 hours for LDPE and 4 hours for HDPE. The products was analyzed with kuantitative and qualitative analysis. Qualitative analysis this products with GC-MS method.

The results of this study can be used as the foundation of policy making especially in the energy and environment field, and development of industrial fuels (biofuel and biodiesel) from plastics waste in Indonesia.

## 2 Theory

Pyrolysis was the process of degradation of a material with high temperature without oxygen (thermochemical process), in degrading plastic material it takes a temperature between 300-500°C to become gas then condensed, then distilled to produced oil and the pulp in the form of char [3].

Several studies related to the production of biodiesel from plastic HDPE and LDPE have been carried out by both domestic and foreign researchers. Pyrolysis plastic oil increased efficiency by 15-20% in 100 cc bajaj motors compared to using gasoline, increased thermal efficiency gasoline engine, pyrolysis oil from HDPE has the same density as gasoline and pyrolysis oil from LDPE has the same density as diesel fuel, and pyrolysis process at a fairly low temperature required a catalyst to be efficient in combustion [4].

Pyrolysis oil from LDPE has a content similar to diesel fuel, although in viscosity and the calorific value was still a little low; the advantage of pyrolysis oil has lower carbon residue and sulfur so it was more environmentally friendly; in economic, for each pyrolysis oil production from LDPE waste ranging from 14-18 rupees it is much cheaper than the price of diesel fuel which reaches 40 rupees per litre [5].

Processing of LDPE plastic waste with microwave pyrolysis method, from this method showed that microwave pyrolysis method produced plastic biodiesel

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for 60 minutes to obtain 23.65% liquid, 30.41% CH<sub>4</sub> gas, and solid 4.67% at 500°C [6].

The best efficiency decomposition results in decomposing plastic waste occur at 420°C with a operating time of 60 minutes, and pyrolysis oil from plastic waste (HDPE and LDPE) has characteristics were not much different from the characteristics of diesel oil [7].

Production of biodiesel from plastic HDPE using the pyrolysis method heated 330-490°C resulted quality of fuel oil (biodiesel) better than diesel oil [8].

### 3 Methodology

Based on previous research data, this study was conducted using the pyrolysis method with a temperature of 450-621°C without using a catalyst, and quantitative analysis. Quantitative analysis used the GC-MS method.

### 4 Research Model

#### 4.1 Research Material

HDPE and LDPE plastics that have been chopped and obtained from plastic collectors in Semarang City. Fuel using 5.5 kg LPG from PT. Pertamina (Persero).

#### 4.2 Pyrolysis Process

Cleaned and chopped HDPE and LDPE plastic samples of 5 kg each were put into the reactor. The plastic is heated using the pyrolysis method with a temperature of 450-621°C without catalyst for 4 hours for HDPE and 3 hours for LDPE. The gas produced from the reactor were condensed into a liquid phase using a condenser. The product conversion calculation produced is used as follows:

$$\text{Liquid Products (\%)} = \left( \frac{\text{Litre of product}}{\text{Litre of product total}} \right) \times 100\% \quad (1)$$

$$\text{Solid products or Residues (Kg/Kg \%)} = \left( \frac{\text{Kg of product}}{\text{Mass of raw material}} \right) \times 100\% \quad (2)$$

$$\text{Gas Products} = 100\% - \text{Liquid Products (\%)} \quad (3)$$

Products from plastic pyrolysis in the form of naphtha, gasoline, and diesel fuel and produced residues were analyzed by GC-MS at the Diponegoro University Integrated Laboratory.

## 5 Result

### 5.1 Pyrolysis of HDPE Plastics Waste

HDPE plastic pyrolysis carried out for 4 hours using 5.5 kg LPG without catalyst. The process produced 3.25 L in the form of naphtha; oil fraction 1 (F1) as much as 1 L; oil fraction 2 (F2) as much as 0.25 L; and residues as much as 18.06 grams. Processing 1 kg of plastic waste equal to 1 litre of fuel[9]. If the results are included in the formula it will be produced as follows: Naphtha :  $\left( \frac{3.25 \text{ L}}{5 \text{ L}} \right) \times 100\% = 65\%$

$$\text{F1 : } \left( \frac{0.325 \text{ L}}{5 \text{ L}} \right) \times 100\% = 6,5\%$$

$$\text{F2 : } \left( \frac{0.85 \text{ L}}{5 \text{ L}} \right) \times 100\% = 17\%$$

$$\text{Residues : } \left( \frac{0.01806 \text{ Kg}}{5 \text{ Kg}} \right) \times 100\% = 0.3612\% \approx 0,36\%$$

Gas :  $100\% - (65\% + 6.5\% + 17\%) = 11.5\%$ . Overall the products produced during the pyrolysis process of HDPE plastics are 88.86% non-gas and 11.5% gas.

### 5.2 Pyrolysis of LDPE Plastics Waste

LDPE plastic pyrolysis carried out for 3 hours using 5.5 kg LPG without catalyst. The process produced oil fraction 1 (F1) as much as 0.1 L; oil fraction 2 (F2) as much as 2.9 L; and residues as much as 19 grams. Processing 1 kg of plastic waste equal to 1 litre of fuel[9]. If the results are included in the formula it will be produced as follows:

$$\text{F1 : } \left( \frac{0.1 \text{ L}}{5 \text{ L}} \right) \times 100\% = 2\%$$

$$\text{F2 : } \left( \frac{2.9 \text{ L}}{5 \text{ L}} \right) \times 100\% = 58\%$$

$$\text{Residues : } \left( \frac{0.019 \text{ Kg}}{5 \text{ Kg}} \right) \times 100\% = 0.38\%$$

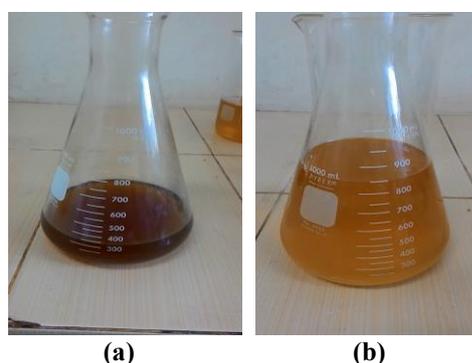
$$\text{Gas : } 100\% - (2\% + 58\%) = 40\%$$

Overall the products produced during the pyrolysis process of LDPE plastics are 60% non-gas and 40% gas.

**Table 1.** Pyrolysis of HDPE and LDPE Plastics Waste

	LDPE	HDPE	Unit
Naphtha	0	65	%
Diesel Oil (F1)	2	6.5	%
Gasoline (F2)	58	17	%
Residues	0.38	0.36	%
Gas	40	11.5	%

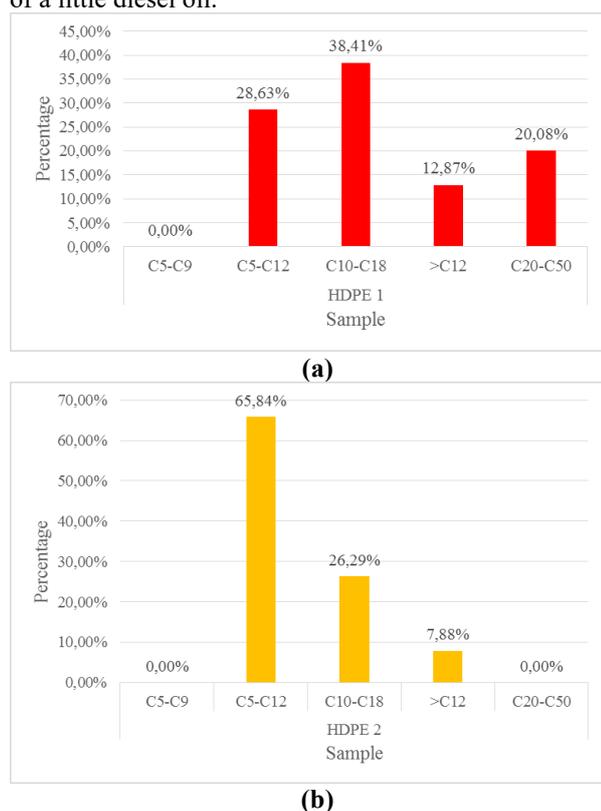
### 5.3 GC-MS of HDPE Plastics Waste



**Fig. 1.** Pyrolysis oil of HDPE plastics waste (a) Fraction 1 and (b) Fraction 2

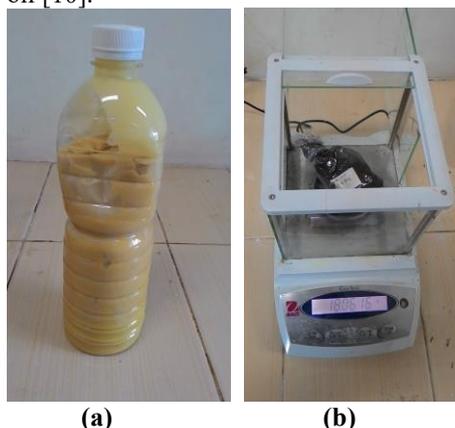
In Figure 1a, pyrolysis oil of HDPE plastics waste saw dark brown. Most likely the oil content in it includes the C chain which was quite long to very long. Physically similar to diesel oil, kerosene, and heavy oil. In Figure 1b, pyrolysis oil of HDPE plastics waste saw yellowish-brown. It is likely that the oil content in it includes the C chain, which was quite short to quite long. Physically

similar to gasoline, kerosene, and there is the possibility of a little diesel oil.



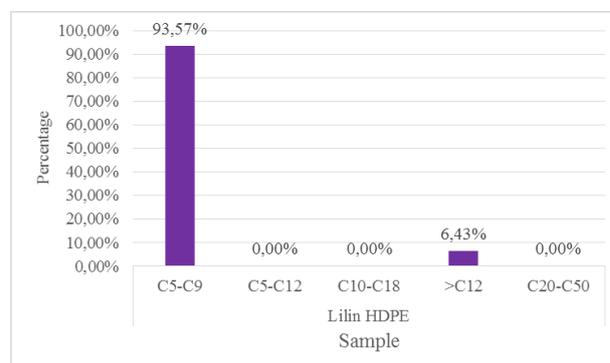
**Fig. 2.** GC-MS results from pyrolysis of HDPE plastic waste (a) Fraction 1 and (b) Fraction 2

In figure 2a, the content of the fraction 1 from the pyrolysis of HDPE plastic waste was proven to be dominated by kerosene (C10-C18) as much as 38.41%, gasoline (C5-C12) as much as 28.63%, heavy oil (C20-C50) as much 20.08%, and diesel oil (> C12) as much as 12.87%. In Figure 2b, the content of the fraction 2 from the pyrolysis of HDPE plastic waste was proven to be dominated by gasoline (C5-C12) as much as 65,84%, kerosene (C10-C18) as much as 26.29%, and diesel oil (> C12) as much 7.88%. The C5-C12 chain is classified as gasoline, C10-C18 is classified as kerosene, > C12 is classified as diesel oil, and C20-C50 is classified as oil [10].



**Fig. 3.** Solid phase from pyrolysis oil of HDPE plastics waste (a) Like Naphtha and (b) Residues

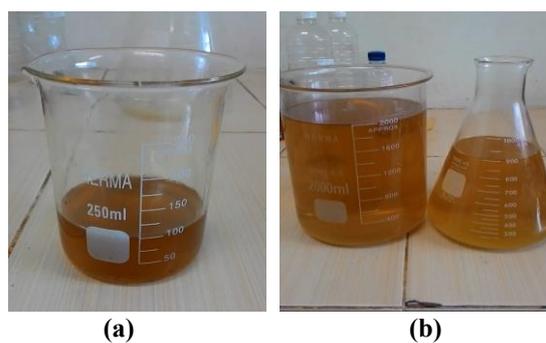
In Figure 3a, it appears that the results were solids resulting from the pyrolysis of HDPE plastic waste in the form of a type of naphtha and colored slightly brown. Most likely other than naphtha there is another ingredient in the naphtha. In Figure 3b, the results of pyrolysis of HDPE plastic waste also produced black residues. The activated carbon produced in the pyrolysis is 18.06 grams.



**Fig. 4.** The result of GC-MS is a type of naphtha (Figure 3a) resulting from the pyrolysis of HDPE plastics waste

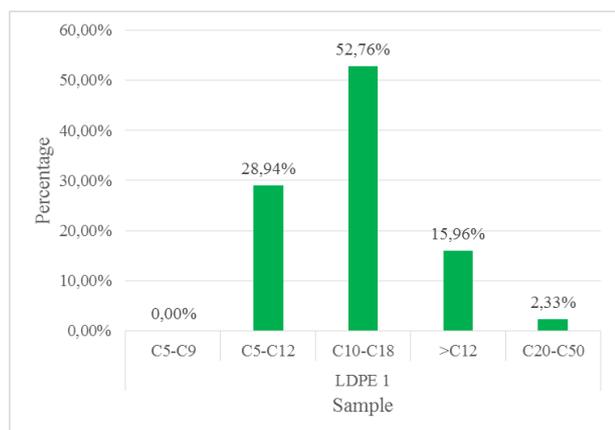
In figure 4, the content of a type of naphtha from the pyrolysis of HDPE plastics waste was proven to be dominated by naphtha (C5-C9) as much as 93.57%, and diesel oil (> C12) as much as 6.43%. This is in accordance with the physical appearance observed by the researcher.

#### 5.4 GC-MS of LDPE Plastics Waste

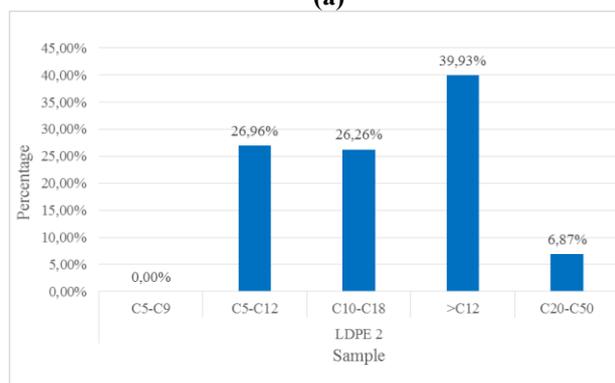


**Fig. 5.** Pyrolysis oil of LDPE plastics waste (a) Fraction 1 and (b) Fraction 2

In Figure 5a, the pyrolysis oil of LDPE plastic waste was dark brown. Most likely the oil content in it includes the C chain which is quite long to very long. Physically similar to kerosene, diesel oil, kerosene and heavy oil. In Figure 5b, the pyrolysis oil of LDPE plastic waste is dark brown. Most likely the oil content in it includes the C chain which was quite short to quite long. Physically similar to kerosene, diesel oil and the possibility of gasoline, or a little heavy oil.



(a)



(b)

**Fig. 6.** GC-MS results from pyrolysis of LDPE plastic waste (a) Fraction 1 and (b) Fraction 2

In figure 6a, the content of the 1st fraction from the pyrolysis of LDPE plastic waste was proven to be dominated by kerosene (C10-C18) as much as 52.76%, gasoline (C5-C12) as much as 28.94%, diesel oil (> C12) as much as 15.96%, and heavy oil (C20-C50) as much as 2.33%. In figure 6b, the content of the fraction 2 from the pyrolysis of LDPE plastics waste was proven to be dominated by diesel oil (> C12) as much as 39.93%, gasoline (C5-C12) as much as 26.96%, kerosene (C10-C18) as much as 26.26%, and heavy oil (C20-C50) as much as 6.87%. The C5-C12 chain is classified as gasoline, C10-C18 is classified as kerosene, > C12 is classified as diesel oil, and C20-C50 is classified as heavy oil[10].



**Fig. 7.** The results of residues from pyrolysis oil of LDPE plastics waste

In Figure 7, the results of pyrolysis of LDPE plastic waste also produced black residues. The activated carbon produced in the pyrolysis was 19 grams.

## 6 Conclusion

The product of 5 kg pyrolysis HDPE are 3.25 litres of naphtha; 0.85 litre of gasoline; 0.325 litre of diesel fuel; and 18.06 grams of residues. Then The product of 5 kg pyrolysis LDPE are 2.9 litres of gasoline, 0.1 litre of diesel fuel, and 19 grams of residues. Composition of fuels from polyethylene (HDPE and LDPE) pyrolysis were naphtha, gasoline, and residues.

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