

# Conversion of Hand Phone Case Waste into Liquid Fuels in a Microwave Reactor

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# Conversion of Hand Phone Case Waste into Liquid Fuels in a Microwave Reactor

**Abstract.** Hand phone case waste as one of the highest e-waste contributors can cause severe problems to human and environment. It should be processed or converted to obtain more useful products. The purpose of this study is to investigate liquid fuels production from hand phone case waste through pyrolysis and distillation processes under microwave irradiation. In each experiment, about 150 g of hand phone case with a size of 1-2 cm<sup>2</sup> were pyrolyzed at 450°C for 1.5 hours. In order to improve pyrolysis process, the sample was mixed with carbon materials as absorber at a weight ratio of 2:1. The produced liquid fuel was then distilled to obtain gasoline, kerosene, and diesel fractions. The result showed that the average yield of liquid fuel from pyrolysis of hand phone case waste was 57 % by mass. After liquid fuel distillation process, the average yields of each fuels fraction were 21.2 vol.% gasoline, 25.2 vol.% kerosene, 26.1 vol.% diesel, and 27.5 vol.% heavy fuel and residue.

## 1. Introduction

At present, the high demand of the products along with socio-economic growth has an impact on the increase of production capacity of electrical and electronic equipment in the world. This is also due to the shorter duration of the use of electronic products in the world, including Indonesia, which is one of the largest electronic equipment consumers. The Indonesian Cellular Telephone Association reported that there were around 340 million mobile phone users in Indonesia in 2015, which clearly contributed to the high volume of electrical and electronic wastes (e-waste). Based on the e-Marketer report, smartphone active users in Indonesia grew from 55 million users in 2015 to more than 100 million users in 2018. With that amount, Indonesia will become the fourth largest smartphone active users' country in the world after China, India, and America.

Electronic plastic waste becomes one of the highest volume of solid waste. Globally, the amount of e-waste was 44.7 million tons by 2016 and is projected to grow to 49.8 million tons by 2018, with an annual growth rate of 4-5%. In Asia, around 18.2 million tons by 2016 of the e-waste was generated whereas in the European continent, including Russia, generated an amount of e-waste of 12.3 million tons. This fact shows that the high amount of e-waste not only occurs in developed countries, but also in developing countries including Indonesia. This can also cause severe problems to human and environment. Previous study reported that plastics from e-waste generally contain toxic and fire resistant halogens components such as polybrominated dibenzo dioxins/furans that can cause a serious environmental problem in e-waste recycling sites.

Although e-waste is harmful to the environment and health, e-waste contains various precious metals and a number of hydrocarbons such as plastics and rubber that can be processed into other valuable products. For this purpose, some literatures indicated that e-waste can be converted into liquid-oil through pyrolysis process. In this research, microwave-assisted pyrolysis is implemented for treating the e-waste. The rapid heating process of materials using this technology can overcome the limitations of conventional technology leading to improvement of products yield. It has been reported in a recent study that pyrolysis temperature and type of e-waste affect yield of liquid oil in which hand phone case sample provided the highest liquid oil yield of 56.2 wt.% at 450°C compared to computer case and electrical cable samples.

Different with previous research, this paper is more emphasized on the processing of plastic materials obtained from hand phone case waste and then the obtained pyrolytic liquid oils are further processed through microwave-assisted distillation to obtain fuels fractions. Therefore, this research is objected to investigate liquid fuels production from hand phone case waste through pyrolysis and distillation processes under microwave irradiation.

## **2. Materials and Methods**

### *2.1. Materials*

E-wastes from hand phone case collected from several local landfills were used in this work. After separated from the metal components, the plastic parts of the e-waste were then shredded into small pieces with an average size of about 1-2 cm<sup>2</sup>. Commercial activated carbon powder was also used as an absorber material to absorb and convert microwave energy into heat. Nitrogen gas with 99.99% purity was used to ensure inert environment and to sweep the vapor product into the condenser.

### *2.2. Experimental apparatus*

Figure 1 shows the schematic representation of the pyrolysis experimental setup. It consists of three main units: microwave reactor, cooler, and controller units. Detailed descriptions can be obtained in a previous study.

Figure 2 represents the schematic diagram of the distillation experimental setup that also mainly consists of microwave reactor, cooler, and controller units. Microwave reactor includes a modified microwave oven and a Pyrex reactor. The modified microwave oven has a frequency of 2,450 MHz and a maximum output power of 900 W. The Pyrex reactor contains a K-type thermocouple at the center of the reactor and activated carbon. Cooler consists of a double pipe glass condenser, a liquid collector of 500 mL glass bottle, a water bath and a pump for water circulation.

### *2.3. Pyrolysis Experiments*

During each experiments, pure nitrogen gas was supplied at 0.3 l/min to ensure inert environment within the reactor and other equipment, and to sweep the pyrolysis vapor product from the reactor into the condenser. The amount of e-waste and activated carbon in the reactor was kept constant at 150 g and 75 g, respectively.

Pyrolysis processes were carried out at a temperature of 450°C based on the optimum condition reported in the previous study. After each experiments, the amount of liquid-oil was weighed to obtain the yields. Three samples were taken to obtain the average. The liquid-oil was then subjected for analyzing the oil compounds using a gas chromatography–mass spectrometry (GC–MS) analyzer combined with NIST MS 2.0 software.

### *2.4. Distillation Experiments*

The liquid-oils produced from pyrolysis of e-waste were further processed through distillation to obtain fuels fraction. The distillation process used is a standard single stage distillation.

Separation of the fuel fraction is carried out based on the boiling temperature range of each hydrocarbon components which is 230-305°C for diesel oil fractions, 180-230°C for kerosene and paraffin fractions, 30-180°C for gasoline and naphtha fractions, and the remainder are heavy fuels and residues fractions. Three samples were taken to obtain the average. The percentage of each fractions (X) is calculated using the following equation:

where V is the volume fraction (ml) and subscript y can be replaced by G for gasoline, K for kerosene, D for Diesel, and R for residue and heavy fuel, while V<sub>B</sub> is the volume of liquid-oil (ml).

## **3. Results and Discussion**

### *3.1. E-Waste Pyrolysis*

The samples used in this study were plastics material from e-waste that were separated from the metal parts. Plastic is the result of polymerization that is a combination of monomers to form long chains. The types of plastics are very diverse including plastic from e-waste. It was reported that hand phone case samples contain high amount of carbon and hydrogen elements, without nitrogen content, indicates that the samples are composed of polymeric materials such as polycarbonate. Plastics from hand phone case contain more than 90% volatile organic matter, reflecting a high potential to be converted into liquid oil and gas fuels.

Figure 3 shows the average yield of fuel products from thermal decomposition of hand phone case at a temperature of 450°C. As indicated in the figure, high yield of liquid oil product of about 57 wt.% was obtained. This result is in line with previous studies. The liquid oils obtained in the pyrolysis process were a complex mixture of organic compounds. Study by Hall and William reported that the largest component of the liquid oil from mixed WEEE plastic was phenol, 4-isopropylphenol and styrene. The high concentration of phenol and phenol derivatives in liquid oil might be came from polycarbonate as the main constituent of hand phone case.

### 3.2. Pyrolytic Oil Composition

Chemical compounds contained within liquid oil were analyzed by using a gas chromatography–mass spectrometry (GC-MS). GC-MS is a combination of gas-liquid chromatography and mass spectrometry analysis methods to identify different substances in a liquid sample. The aim is to separate chemical elements in certain compounds and identify their molecular levels by heating the mixture to separate its elements.

Figure 4 shows the GC-MS chromatogram of the liquid oil produced at 450°C. The characteristic peaks identification were done by applying NIST MS 2.0 library software on their spectra. It can be observed from the figure that there are 11 peaks compounds identified. Among them, three main peaks were obtained at retention time of 5.98 min, 11.61 min, and 18.41 min. The molecular compounds identified in this liquid oil are also listed in Table 1 to get an idea about the fuel's composition. As it is observed from Table 1, fuel's composition are predominantly composed of ethylbenzene, styrene, phenol and phenol derivatives.

The general liquid oil product components based on carbon atom number can also be seen in Table 1. The hand phone case pyrolysis oils are complex mixtures of organic compounds. The compound components have been obtained from C<sub>6</sub> to C<sub>9</sub> structures. It indicates that the liquid oils are mainly composed of lighter hydrocarbon components. This indicates that a great amount of liquid oil has the characteristics of gasoline and diesel fuels with carbon atom structures of C<sub>6</sub> to C<sub>9</sub> and C<sub>10</sub> to C<sub>15</sub>, respectively.

### 3.3. Pyrolytic Oil Distillation

The liquid oils produced from previous pyrolysis process of hand phone case waste were further processed through distillation to obtain the fuel fractions. The distillation process was carried out by using a microwave assisted distillation reactor. The result of the distillation process is shown in Figure 5.

The result of the distillation showed that from a total of 1515 ml of liquid oil produced 321 ml of gasoline fraction, 382 ml of kerosene fraction, 396 ml of diesel fraction, and 416 ml of heavy fuel and residue fractions. The results indicated that gasoline fuel fraction was the lowest while the heavy fuel and residue fraction was the highest. Based on percentage of the yields, the average fraction of gasoline was 21.2%, kerosene was 25.2%, diesel was 26.1%, and heavy fuel and residue was 27.5%. The yield of the fuel fractions is consistent with the results of the liquid oil composition (except for heavy fuels and residues) where the liquid oil content is more dominated by styrene, phenol, and phenol derivatives with an area of 17%, 24%, and 32%, respectively. Phenol is a hydrocarbon compound which is classified as kerosene fraction while styrene is classified as gasoline fraction.

Figure 6 shows a photograph of liquid oil, gasoline, kerosene, and diesel fractions. The figure shows that liquid oil from hand phone case produced through pyrolysis process has a dark black color. The color of the fuels tends to be brighter after liquid oil distillation process. The lower the distillation

temperature, the lighter the color of the fuel. The gasoline fuel fraction has a clear yellowish color, whereas kerosene fraction has a brownish yellow color and the diesel fraction has a dark brown color. The color of the fuel indicates the amount of carbon content and the ability of the fuel to flow. Light-colored fuels tend to have short carbon chains and are thinner, whereas dark-colored fuels tend to have long carbon chains and are difficult to flow.

#### **4. Conclusions**

Plastics from hand phone case waste were successfully pyrolyzed and distilled by using a microwave reactor to produce liquid fuels. The average yield of products obtained from decomposition of the samples was dominated by liquid oil product of about 57 wt.%, while gas and solid products were only about 30 wt.% and 13 wt.%, respectively. The relatively high liquid oil product illustrates that hand phone case waste has the potential as source of hydrocarbon fuels. This is evidenced by the results of GC-MS analysis where the liquid oils are mainly composed of lighter hydrocarbon components with carbon atom structures of  $C_6$  to  $C_{16}$ . The liquid oil distillation process showed that more than 70 vol.% of the products were light hydrocarbon fuels consisting of 21.2 vol.% gasoline fraction, 25.2 vol.% kerosene fraction, and 26.1 vol.% diesel fraction. Improvement of fuel quality and performance test of the obtained fuel fractions for internal combustion engines application are important topics for further investigation.

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