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Liquid Smoke Fractionation from Dry Distillation of Styrofoam Board Waste to Produces Liquid Fuel

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Abstract

Styrofoam waste is difficult to be decomposed by bacteria or microorganisms. Therefore it takes a long time to be decomposed naturally. Styrofoam waste, in general, is a big problem for the survival of living things on earth because there are quite a lot of them. So, if not handled properly can cause environmental pollution. Styrofoam waste is inorganic waste composed of polymers derived from chemicals. Additives from styrofoam are harmful to humans because they are carcinogenic. This study aims to utilize Styrofoam board waste into liquid fuel. Liquid fuel from styrofoam waste has been made successfully through dry distillation and fractionation methods. The result of fractional distillation is 42.00% liquid fuel. Based on the physical properties tests that have already been carried out, including the density test, viscosity, flash point, boiling point, calorific value, and octane number, it turns out that the liquid has characteristics close to the standard gasoline fuel. The MS spectra and the GC chromatogram show that the liquid fuel consists of a mixture of hydrocarbon compounds, namely acetone 0.23%, acetic acid 0.40%, benzene 2.82%, toluene 3.56%, heptane 1.04%, 1-octene 0.26%, butyl ester 4.92%, 2,4-dimethyl-1-heptane 0.32%, p-xylene 13%, the compound with the highest composition was styrene 73.45%.

Keywords: Styrofoam, board, liquid smoke, distillation, fractionation, gasoline

INTRODUCTION

Data from the Manado City Environmental Service noted that the volume of waste in Manado City has reached 828,812 cubic meters, or has continued to increase significantly since 2012. And then from that data, the plastic waste composition is 20.03%. For plastic waste such as pampers and styrofoam by 10.50%, plastic bag crackle 8.60%, other types of plastic 7.30%, and plastic bottles packaging mineral drinks 4.00%. The data shown that the plastic waste processed in Manado City, only 7% of the plastic waste was recycled, 12% burned, the remaining 81% end up in landfills and waterways such as rivers that empty into the sea (Buol, Gedoan, Senduk, Lariwu, & Kambey, 2019).

Styrofoam waste is a waste that is difficult to be decomposed by bacteria or microorganisms. Therefore it takes a long time, even hundreds of years decompose naturally. This plastic waste is a big problem for the survival of the living creatures on the earth because the number is increasing and not well handled yet (Mukminah, 2019). Styrofoam waste is inorganic waste composed of polymers derived from chemical additives. Additives from Styrofoam are carcinogenic. Generally, styrofoam use as a protector of electronic devices (Sulchan & Nur W, 2007). Excessive use of polymer products has caused severe environmental problems, can threaten the survival of creatures on earth, and its waste has to be handled with appropriate cyclical methods (Lu, Xiao, & Chen, 2021). Styrofoam is made from polystyrene which is a synthetic polymer material and its chemical structure is shown in Figure 1.

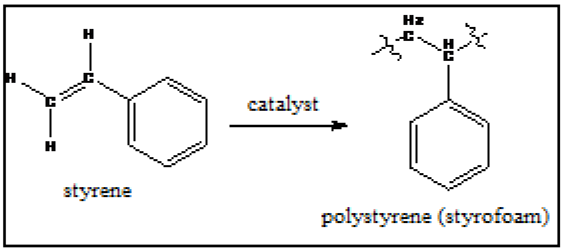

Figure 1. Chemical Structure of Styrofoam

The main source of styrene is from nature, namely petroleum. Styrene is a clear, colorless liquid similar to petroleum with an odor like benzene. Styrofoam is very light, stiff, and translucent. The chemicals used in the styrofoam manufacturing process are styrene, zinc, chlorofluorocarbons (CFCs), and butadiene compounds. To produce the flexible styrofoam product, plasticizers were added, namely dioctyl phthalate (DOP) and butylhydroxytoluene (BHT).

In addition to styrofoam used as food wrappers, styrofoam is also used as a protective material and vibration barrier for perishable items such as electronic goods such as televisions, refrigerators, DVDs, or used as a protective material for fragile items such as plates, glasses, and glass. Styrofoam waste harms human health and the environment because Styrofoam waste cannot be decomposed by microbes in nature. The CFC compounds in Styrofoam can have a global warming impact or have a greenhouse effect. According to Wirahadi (2017), the dangers of styrene monomer to health in the long term, among others, can cause disturbances in the central nervous system, can lead to the risk of leukemia, can cause cancer in humans, and can contaminate breast milk (Wirahadi, 2017). If styrene and other substances in Styrofoam enter the food, they become toxic and will cause disturbances in the endocrine system and reproductive systems. This causes the use of Styrofoam as a food or beverage container to be limited due to its carcinogenic properties (Mukminah, 2019).

Handling styrofoam waste by hoarding still burdens nature as an environmental pollutant. When Styrofoam waste is burned, the smoke also pollutes the environment for humans and animals (Fitidarini & Damanhuri, 2011). Therefore, styrofoam waste treatment activities need to find the right solution and the results can be beneficial for human life and the environment.

Based on the styrofoam waste problem that has been described, the solution given to reduce Styrofoam waste pollution is to convert it into fuel using pyrolysis techniques. The pyrolysis method is a method of decomposition of chemical compounds in Styrofoam or polymer decomposition into new smaller compounds and the system works at high temperatures without involving oxygen or oxygen to a minimum. If the styrofoam waste that is large enough could be converted into liquid fuel, then this method could be the solution to reduce environmental pollution from the type of styrofoam waste.

METHODOLOGY

Materials and Instruments

The instruments used are dry distillation or pyrolysis equipment, fractional distillation equipment, glassware, analytical balance, Erlenmeyer, boiler point meter, Fenske viscometer Oswald, smoke point tester, pycnometer, flash point meter, freezer point tester, and a combination of KG-SM, Bomb Calorimeter and OKTVIC-2thermometer.

The material used is styrofoam board waste, used as wreath board (SP) which was taken from the final waste disposal site (TPA) in Sumompo Village, Manado City. The dry SP styrofoam waste was cut into pieces of about 2 - 3 cm in size.

Methods

The research steps for Styrofoam SP waste distillation follow the distillation method carried out by (Rekathakusuma, Suwandi, & Suhendi, 2016; Anom & Lombok, 2020) as follows: The distillation method used is destructive distillation or dry distillation and is commonly called pyrolysis. The distillation method applies the evaporation and cooling process. This method is a chemical process to decompose raw materials in this case styrofoam waste and heated at high temperatures. At a certain temperature, styrofoam melts and then evaporates, forming gas, so that long hydrocarbon chains will be broken into shorter chains. Furthermore, the cooling process on the gas so that it will be condensed and turned into a liquid. The liquid obtained is then fractionated to obtain the gasoline fraction.

A total of 200 g of SP styrofoam board waste was distilled. The distillation apparatus is tightly closed and ensured that there are no leaks. The distillation apparatus is turned on, and the styrofoam sample distillation process begins. Record changes in distillation temperature and physical changes that occur from heating to liquid or distillate. The liquid is stored in an Erlenmeyer container until the styrofoam distillation process is stopped. The distillate obtained is a liquid which is a mixture of hydrocarbons. The liquid is weighed and the percentage calculated. The SP styrofoam board dry distillation apparatus is shown in Figure 2.

Figure 2. Dry Distillation Apparatus (1. Electric heater, 2. Distillation flask, 3. Thermometer, 4. Condenser, 5. Liquid holding flask, 6. Gas storage flask, 7. Measuring cup for holding water)

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The liquid from the dry distillation of SP styrofoam board waste is treated by fractional distillation to separate the gasoline fraction at temperatures below 200 °C. Determination of fractionation temperature based on the fractional distillation of petroleum by (Koesoemadinata, 1980). Furthermore, the gasoline fraction was characterized by physical and chemical properties, namely: GC-MS analysis, viscosity, boiling point, density, flash point, the heat of combustion, octane number.

RESULTS AND DISCUSSION

Dry distillation of 200 g of SP styrofoam board waste, for 30 minutes at a temperature of 98-110 °C there was a physical change of styrofoam waste from solid to melt. After the distillation process lasted longer than 30 minutes and at a temperature of 120-135 °C thick white smoke was formed in the distillation flask and at the same time, the SP styrofoam board sample began to melt. A few minutes later the white smoke began to decrease until it was no longer visible, by which time all the Styrofoam samples had melted and boiled. Evaporation begins to occur and the hot steam is condensed so that soon dew points have formed on the walls of the condenser. At 60 minutes and the dry distillation temperature at 60-170 °C, it can be observed that the liquid begins to drip and is collected in the distillate flask. The velocity of the dripping liquid or distillate begins to stabilize at a temperature of 180-190 °C. After the dry distillation of SP, styrofoam board waste lasted approximately 3.5 hours and at that time the final distillation temperature reached 350 °C, and the dry distillation process was stopped.

From 200 g of dry distillation of SP styrofoam board waste obtained as much as 140 g of liquid. Dry distillation of SP styrofoam board waste was repeated five times, and each repetition used a sample weighing 200 g so that the total sample of SP styrofoam board waste used was 1000 g. From 1000 g sample of SP styrofoam board waste which was distilled, 674 g of light brown liquid was obtained or 67.40 percent of the western sample of 1000 g. Furthermore, 674 g of the liquid obtained is fractionated distillation to obtain the gasoline fuel fraction at a boiling point less than 200 °C (Koesoemadinata, 1980). After being treated by fractional distillation, a clear liquid of 420 g (42.00%) of gasoline fraction was obtained. The color change of liquid smoke from the dry distillation of SP styrofoam waste from light brown to clear is because the two liquids have different physical and chemical properties. The boiling point, density, viscosity, and composition of the chemical compounds in the two liquids must be different. The data on the physical and chemical properties of the gasoline fractionated liquid obtained, then compared with the physical and chemical properties of the gasoline quality standard recommended by the Indonesian National Standard (INS) are shown in Table 1.

Table 1. Physical and Chemical Properties of Liquid Gasoline Fraction

Properties	Sample Data Results	Gasoline Fuel (INS)
Density (g/mL)	0.79	0.71-0.77
Viscosity (cP)	0.80	0.70
Boiling Point (ºC)	138.10	40-180
Flash Point (ºC)	26.10	-
Heat value (cal/g)	10,107	11,414.453
Octane Number (RON)	97	86 – 94
Total compound (GC-MS)	10	-

Density

The density value of gasoline fraction fuel oil is 0.79 g/mL. The density value of the gasoline fraction is greater than or above the gasoline quality standard set by INS and also higher than the results of research conducted by Anom and Lombok (2020) which is 0.76 g/mL (Anom & Lombok, 2020). The density of gasoline fuel oil is between the density of kerosene which is 0.78–0.81 g/mL (Adoe, Bunganaen, Krisnawi, & Soekwanto, 2016). The high-density value of SP fuel oil can be caused by the influence of organic compounds which have a chain number of carbon atoms greater than 5 carbon atoms. Based on the density value of the gasoline fraction obtained, it cannot be classified as gasoline fuel but it is more appropriate to be recommended as kerosene fuel. The high density of fuel oil will be able to increase engine thirst, causing damage to the engine (Rachim, Raya, & Zakir, 2017; Setiawati & Edwar, 2012).

Viscosity

The viscosity or viscosity of the liquid fuel liquid gasoline fraction has a value of 0.8 cP, greater than the INS viscosity value of 0.7 cP. Viscosity is strongly influenced by density, where the heavier the density of the liquid, the greater the viscosity, meaning that the more particles contained in it hinder the fluid flow because the particles rub against each other (Adoe et al., 2016), and affect the work of the engine (Juwono, Triyono, Sutarno, & Wahyuni, 2013; Juwono et al., 2017; Musta, Haetami, & Salmawati, 2017; Sutapa, Rosmawaty, & Samual, 2013). When viewed from the value of gasoline viscosity (INS) is 0.70 cP, then SP

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liquid fuel cannot be classified into permitted gasoline fuel.

Boiling Point

It is found that the boiling point of the liquid fuel of the gasoline fraction has a value of 138.10 °C. Based on INS 06-3506-1994 the final boiling point for fuel is set at 205 °C (Juwono et al., 2017). The boiling point of liquid fuel in the gasoline fraction shows the number 138.10 °C. Based on the boiling point value, the liquid fuel of the gasoline fraction can be classified as a substitute for gasoline.

Flashpoint

It is found that the results of the flashpoint test on the liquid fuel of the gasoline fraction have a value of 26.10 °C. The flashpoint of comercial gasoline is 57 °C. The flashpoint value of liquid fuel is below the flashpoint of gasoline on the market. The flashpoint of fuel indicates a safe limit against fire hazards during storage. The more the composition of short-chain hydrocarbon compounds, the smaller the flashpoint and the higher the boiling point (Juwono, Sujadmiko, Fauziah, & Ayyun, 2019).

Heat Value

The calorific value of the liquid fuel gasoline fraction is 10,107 cal./g. The calorific value obtained does not meet the standard calorific value of gasoline if it is based on data from Pertamina which states that the calorific value of gasoline is at least 10,160 cal/g and a maximum of 11,000 cal/g. The gasoline fraction with a low calorific value shows the composition of the short-chain hydrocarbon fraction is small (Juwono et al. 2019).

Octane Number

Table 1 shows that the octane number of liquid fuel in the gasoline fraction is 97 RON. According to the standards and quality of gasoline circulating in the market, a minimum of 90 RON (Directorate General of Oil and Gas, 2017). Premium gasoline is said to have an octane number of 90 meaning that it has the same knock characteristics in the ASTM standard CFT test engine test with a knock characteristic of a mixture of 90% volume iso-octane in a mixture with n-heptane. Based on the octane number obtained, the liquid fuel of the gasoline fraction meets the requirements to be classified as gasoline.

GC-MS Data Analysis

Based on the GC analysis, the liquid fuel chromatogram of the gasoline fraction can be seen in Figure 3. The GC chromatogram showed that the liquid fuel gasoline fraction consisted of 10 compound peaks with a large percentage of compounds. From the MS spectra data and area data on the GC chromatogram, it turns out that the liquid fuel of the gasoline fraction consists of a mixture of hydrocarbon compounds, namely acetone (0.23%), acetic acid (0.40%), benzene (2.82%), toluene (3.56%), heptane (1.04%), 1-octene (0.26%), butyl ester (4.92%), 2,4-dimethyl-1-heptane (0.32%), p-xylene (13%) and the compound with the highest composition was styrene (73.45%).

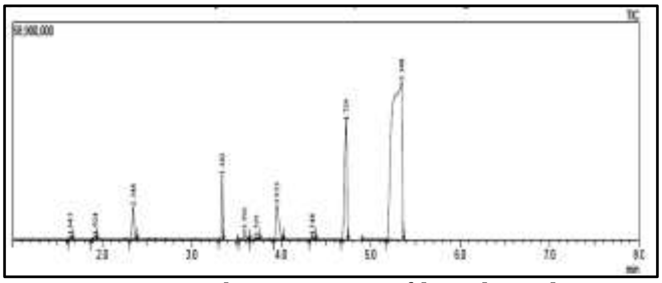

Figure 3. GC chromatogram of liquid gasoline

According to the results of research conducted by Maryudi, Salamah, & Aktawan (2018), pyrolysis of styrofoam using alumina-silica catalyst produces styrene (59.22%), isopropyl benzene (4.06%), di-phenyl compounds (11.49%), other compounds benzene (0.65%), ketones (0.28%) and carboxylic acids (17.92%). Park, Jeong, Guzelciftci, & Kim (2020) also researched that the pyrolysis of polystyrene or styrofoam produces good benzene, toluene, ethylbenzene, and xylene and has the potential to be used as a substitute for gasoline or diesel fuel when mixed with oil with low aromatic content.

Imani Moqadam, Mirdrikvand, Roozbehani, Kharaghani, & Shishesaz, (2014) researched the pyrolysis of polystyrene using a silica-alumina catalyst and also produced a liquid with a high percentage of styrene monomer (80%), making it possible to use it directly for polymer production. The difference in chemical compounds obtained from the researchers can be caused by the influence of the use of catalysts, analytical equipment, and the conditions of the pyrolysis equipment used.

CONCLUSION

Fractionation of the liquid smoke from the dry distillation of SP styrofoam board waste produces liquid fuel with a gasoline fraction of 42.00%. Based on the physical properties test that has been carried out, namely the boiling point test, viscosity, density, flash point, calorific value, octane number, the liquid fuel of the gasoline fraction has characteristics close to gasoline fuel based on the INS 06-3506-1994 standard. Based on the MS spectra data and area data on the GC chromatogram, it turns out that the liquid fuel of the gasoline fraction consists of a mixture of hydrocarbon compounds, namely acetone (0.23%), acetic acid (0.40%), benzene (2.82%), toluene (3.56%), heptane (1.04%), 1-octene (0.26%), butyl ester (4.92%), 2,4-dimethyl-1-heptane (0.32%), p-xylene (13%) and the compound with the highest composition was styrene (73.45%).

REFERENCES

Adoe, D. G. H., Bunganaen, W., Krisnawi, I. F., & Soekwanto, F. A. (2016). Pirolisis Sampah Plastik PP (Polyprophylene) menjadi Minyak Pirolisis sebagai Bahan Bakar Primer. *LONTAR Jurnal Teknik Mesin Undana (LJTMU)*, *3*(1), 17–26. https://doi.org/10.1234/ljtmu.v3i1.455

Anom, I D. K., & Lombok, J. Z. (2020). Karakterisasi Asap Cair Hasil Pirolisis Sampah Kantong Plastik sebagai Bahan Bakar Bensin. *Fullerene Journal of Chemistry*, *5*(2), 96–101. https://doi.org/10.37033/fjc.v5i2.206

Fitidarini, N. L., & Damanhuri, E. (2011). Timbulan Sampah Styrofoam Di Kota Bandung. *Jurnal Teknik Lingkungan*, *17*(2), 87–97. https://doi.org/10.5614/jtl.2011. 17.2.9

Imani Moqadam, S., Mirdrikvand, M., Roozbehani, B., Kharaghani, A., & Shishesaz, M. (2014). Polystyrene Pyrolysis Using Silica-Alumina Catalyst in Fluidized Bed Reactor. *Clean Technologies and Environmental Policy*. https://doi.org/10.1007/s10098-015-0899-8

Juwono, H., Sujadmiko, M. A. T., Fauziah, L., & Ayyun, I. Q. (2019). Catalytic Conversion From Plastic Waste by Silica-Alumina-Ceramic Catalyst to Produce an Alternative Fuel Hydrocarbon Fraction. *Jurnal ILMU DASAR*, *20*(2), 83–88. https://doi.org/10.19184/jid.v20i2.8829

Juwono, H., Triyono, T., Sutarno, S., & Wahyuni, E. T. (2013). The Influence of Pd Impregnation into Al-MCM-41 on the Characters and Activity for Biogasoline Production by Catalytic Hydrocracking of Fames from Nyamplung Seed Oil (Calophyllum Inophyllum). *Indonesian Journal of Chemistry*, *13*(2), 171–175. https://doi.org/10.22146/ijc.21301

Juwono, H., Triyono, T., Sutarno, S., Wahyuni, E. T., Harmami, H., Ulfin, I., & Kurniawan, F. (2017). Production of Hydrocarbon (C7-C20) from Hydrocracking of Fatty Acid Methyl Esters on Pd/Al-MCM-41 Catalyst. *Bulletin of Chemical Reaction Engineering & Catalysis*, *12*(3), 337–342.

Koesoemadinata, R. P. (1980). *Geologi Minyak dan Gasbumi Jilid 2*. ITB.

Lu, C., Xiao, H., & Chen, X. (2021). Simple Pyrolysis of Polystyrene Into Valuable Chemicals. *E-Polymers*, *21*, 428–432. https://doi.org/10.1515/epoly-2021-0037

Maryudi, Salamah, S., & Aktawan, A. (2018). Product Distribution of Pyrolysis of Polystyrene Foam Waste Using Catalyst of Natural Zeolite And Nickel/Silica. *IOP Conference Series: Earth and Environmental Science*, *175*, 012012. https://doi.org/10.1088/1755-1315/175/1/012012

Mukminah, I. A. (2019). Bahaya Wadah Styrofoam dan Alternatif Penggantinya. *Majalah Farmasetika*, *4*(2), 32–34. https://doi.org/10.24198/farmasetika.v4i2.22589

Musta, R., Haetami, A., & Salmawati, M. (2017). Biodiesel Hasil Transesterifikasi Minyak Biji Nyamplung (Calophyllum inophyllum) Dengan Metanol. *Indonesian Journal of Chemical Research*, *4*(2), 394–401. https://doi.org/10.30598//ijcr.2017.4-rus

Park, K.-B., Jeong, Y.-S., Guzelciftci, B., & Kim, J.-S. (2020). Two-Stage Pyrolysis of Polystyrene: Pyrolysis Oil as A Source Of Fuels or Benzene, Toluene, Ethylbenzene, and Xylenes. *Applied Energy*, *259*(C). Retrieved from https://ideas.repec.org/a/eee/appene/v259y2020ics0306261919319270.html

Rachim, S. A. G., Raya, I., & Zakir, M. (2017). Modifikasi Katalis CaO Untuk Produksi Biodiesel Dari Minyak Bekas. *Indonesian Journal of Chemical Research*, *5*(1), 47–52. https://doi.org/10.30598//ijcr.2017.5-sit

Rekathakusuma, I., Suwandi, S., & Suhendi, A. (2016). Karakterisasi Bahan Cair Produk Distilasi Sampah Plastik Dan Pemanfaatannya Sebagai Bahan Bakar. *eProceedings of Engineering*, *3*(3). Retrieved from https://openlibrarypublications.telkomuniversity.ac.id/index.php/engineering/article/view/3017

Setiawati, E., & Edwar, F. (2012). Teknologi Pengolahan Biodiesel Dari Minyak Goreng Bekas Dengan Teknik Mikrofiltrasi Dan Transesterifikasi Sebagai Alternatif Bahan Bakar Mesin Diesel. *Journal of Industrial Research (Jurnal Riset Industri)*, *6*(2), 1–11.

Sulchan, M., & Nur W, E. (2007). Keamanan Pangan Kemasan Plastik dan Styrofoam. *Majalah Kedokteran Indonesia*, *57*(2), 54–59.

Sutapa, I W., Rosmawaty, R., & Samual, I. (2013). Biodiesel Production from Bintanggur Oil (Callophyllum inophyllum L.) Using Calsium Oxide (CaO) Catalyst. *Indonesian Journal of Chemical Research*, *1*(1), 53–60.

Wirahadi, M. (2017). Elemen Interior Berbahan Baku Pengolahan Sampah Styrofoam dan Sampah Kulit Jeruk. *Jurnal Intra*, *5*(2), 144–153.