



CONVERSION OF MEDICAL PLASTIC COVERS MADE UP OF LDPE INTO LIQUID HYDROCARBONS USING BIOGAS AS A SOURCE OF HEAT

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Abstract

Food waste and the plastic covers used for packing medical items are big sources of land pollution. In this study food waste has been converted into biogas. This biogas is used as a heating agent to crack the non-recyclable waste plastic covers, made up of LDPE, into liquid hydrocarbons in a reactor using lignite fly ash as catalyst. The cat/pol ratio used in this work is 0.1. This cracked vapour is condensed in air and water cooled condensers to separate high and low boiling liquid hydrocarbons. In this work, 25 kg of food waste is converted into 4.5m³ of biogas. This biogas is used as fuel for cracking 0.5 kg of plastic made of LDPE using 50 g catalyst. The conversion of waste plastic into hydrocarbons is 100%. The amount of biogas consumed was 2.5m³. The waste plastic oil (WPO) obtained after the cracking was 266 g (53.2%). The amount of gasses hydrocarbon is 234 g (46.8%). The amounts of low and high boiling fractions were 24.8% and 28.4%, respectively. The physical and chemical properties of these fractions have been determined. The properties of high boiling fraction are comparable to those of diesel and the properties of low boiling fraction are comparable to those of petrol. Comparison of EDX spectra and SEM images of the fly ash before and after the pyrolysis proves the involvement of the catalyst in the cracking. ¹H NMR spectra have been recorded for both the fractions. The ¹H NMR spectra suggest that high boiling fractions contains largely higher alkenes whereas the low boiling fraction contains largely lower alkenes. ¹H NMR spectra also suggest that both fractions contain very little aromatic compounds IR spectra also have been recorded for both fractions. These spectra also suggest that high

boiling fraction contains largely higher alkenes are low boiling fraction contains lower alkenes.

Keywords : Food waste, Waste plastics LDPE, Biogas, Degradation, Waste plastic extraction oil, Catalytic cracking

INTRODUCTION

Nowadays plastics are widely used. It has an outstanding character so that none of the metal can compete with plastics. The popularity and usability of plastic is getting increased year by year due to its low cost, easy availability, attractive colors, less weight, corrosion resistance, electrical insulations and strength.

Non degradable nature is the one and only drawback of plastics. Due to this property the plastics get accumulated in huge amounts. These accumulated plastics create problems to the human community. So, they started touring, junk pilling and water flashing the waste plastics. This creates a very big environmental damage. A lot of research is being done to save environment from waste plastics.

Food waste and waste plastic are two major causes of land pollution. Food waste largely contains carbohydrates, proteins and fats. Most of the waste plastics are made up of hydrocarbons such as HDPE (high density polyethylene), LDPE (low density polyethylene) and PP (Polypropene).

The ingredients in food waste are bio degradable. These can be converted into simple molecules by anaerobic digestion. Anaerobic digestion is a complex process in which micro organisms break down biodegradable organic matter. Anaerobic digestion of food waste produces biogas which is largely a mixture of methane and carbon dioxide. The slurry left after the evolution of biogas can be used as fertilizer for plants. Biogas can be used as a fuel. Several studies [1-6] have been made on the production of biogas using food waste.

Design of biogas generation plant from food waste has been reported [1-6]. It has been estimated [1] that a biogas plant of 1m³ capacity is equivalent to 65% of a LPG cylinder per month. The effect of pH on the yield of biogas has been studied. It has been found [4] that the yield of biogas is high when

the pH of the sub stock is around [7].

Polyalkenes can be degraded into simple hydrocarbons using thermal cracking. Several such studies [7- 24] have been made. Several catalysts have been used in such degradations. Degradation of conventional waste plastics has been reviewed [25]. Uddin et al. [7] have studied the degradation of HDPE using silica-alumina (a mixture of SiO_2 and Al_2O_3) catalysts. Different catalysts were made by using different compositions of SiO_2 and Al_2O_3 . Ding et al. [8] have used TiCl_3 (titanium chloride) and HZSMZ-5 as catalysts for the degradation of HDPE. Catalyst HZSMZ-5 contains Al_2O_3 and SiO_2 with a Si/Al ratio of 3.5.

Aguado et al. [9] have studied the degradation of HDPE and LDPE using different samples of zeolite beta. Walendziewski and Steinunger [10] have studied the degradation of polyethylene by using Ni/W (an alloy of nickel and tungsten) and 10% Hy-Zeolite as catalysts Walendziewskia [11] has studied the degradation of polyethylene and polypropene using ZnO as catalysts. Karagoz et al. [12] have studied the degradation of HDPE using M/A (M stands for metal and Ac stands for active carbon) catalyst. They have used cobalt, molybdenum and nickel as metals. They have also used alloys of these metals. Gob in and Manos [13] have used zeolite based and clay-based catalysts for the degradation of LDPE.

Jan et al. [14] have studied the degradation of HDPE using MgCO_3 as catalyst. The degradation of HDPE has been studied using BaCO_3 as catalyst [15]. The degradation of HDPE has been studied [16] using CaCO_3 as catalyst. Premkumar [17-19] has degraded plastics made up of HDPE and LDPE using fly ash, obtained after burning lignite coal, as catalyst. In this process high yield of plastic oil has been obtained at lower temperatures than using other catalysts. Babln Alawa et al. [20] have studied the co-pyrolysis of HDPE and PP waste plastics. They have characterized the pyro-oil using mass spectrometry and NMR spectroscopy. Junga nishno et al. [21] have studied the cracking of LDPE, HDPE, PP and waste plastics from industries using H- gallosilicates as catalyst. The catalyst H-gallosilicate used by them had silicon

and gallium in the ratio Si/Ga=25. They have used a temperature of about 550-560°C for cracking. They have studied the degradation using various ratios of plastic/catalyst. They have obtained 55-68% of liquid products. The liquids largely contained aromatic compounds like benzene, toluene and xylenes.

Jeong-Geol Na et al. [22] have studied the degradation of LDPE using catalysts obtained by mixing fly ash with NaOH in different ratios. They have activated the catalyst by co-precipitation. They have observed that use of catalyst reduces the degradation temperature. They have found that the synthetic catalysts are comparable to commercial catalysts in catalytic activity.

Dutta et al. [23] have studied the thermal pyrolysis of HDPE and blends of HDPE and waste plastic made using HDPE. They have followed the kinetics of the pyrolysis using TGA. They have used nitrogen as carrier gas. Maximum yield of liquid was obtained at a temperature of 475°C. The liquid obtained was found to contain largely alkanes and alkenes.

Aya Soliman et al. [24] have studied the degradation of waste plastic made from LDPE using commercial catalysts bentonites, kaolin, silica gel and activated charcoal. They have also used mixtures of catalysts. They have found that the temperature at which first oil drop is formed varies from 509 °C to 567 °C depending on the catalyst used. The time required for complete pyrolysis varies from 2 h to 2 h 50 mins. The percentage of aromatic in the liquid product varied from 5.27% to 10.48% depending on the catalyst. Serrano et al. [25] have studied the degradation of LDPE using micrometer HZSM-5, noncrystalline HZSM -5 and Al-MCM-41 as catalysts. Kanduri and Seethamraju. [26] have studied the catalytic co- pyrolysis of biomass and plastics made of polyethylene (high and low density) using spent FCC catalyst. Panda et al. [27] have studied the degradation of LDPE, HDPE, PP and a mixture of three using sulphated zirconium hydroxide as catalyst.

The pyrolysis of polymers has been made using electrical heating [19] LPG [17,18] or microwave [30]. In this study bio gas is used as a source of heat.

Many workers have degraded the waste plastics using electrical, LPG & microwave heating by using synthetic and commercial catalysts.

In this study the waste plastic is degraded using biogas as a heating source and fly ash as catalyst. The biogas is obtained from bio degradation of food waste. The catalyst used is also a major pollutant from thermal power plant. During this work the biodegradable and non- biodegradable waste are converted into useful hydrocarbons. All the unusable products by human communities which create pollution to the environment are converted into useful products for human communities.

MATERIALS AND METHODS

Materials Food waste

The food waste was collected from nearby houses on a daily basis. About 25 kg of food waste was collected for 10 days. Preparation of waste food slurry. The collected food waste was crushed using a hand. Then it was mixed with an equal volume of water.

Waste plastics

Packing covers to cover the medical items like saline bottles, syringes, urinary tubes, and cotton made up of LDPE were obtained from a nearby hospital. Totally 0.5 kg of waste plastic was collected.

Catalyst

Catalyst used in this work is fly ash. This was obtained from a nearby power plant.

Methods

The sketch of the plant used for the degradation of waste plastic is shown in Fig. 1. The plant consists of two units. In one unit biogas is produced. In the other unit the waste plastic is degraded using biogas as the heating agent. Production gets increased the holder slides upward. When gas is utilized, the holder slides downward. A water sealing is provided in between the sides of the biogas plant and the gas holder to prevent the leakage of biogas. The top surface of the digester is fitted with a valve and is attached to a pipeline. The outlet slurry water is connected in the empty glass jar and a pH probe is

dipped inside to measure the pH value of this slurry using Horiba B-121 meter. The volume of biogas is measured by measuring the rise in height of the biogas holder on daily basis. This biogas is burnt in the reactor using a burner.

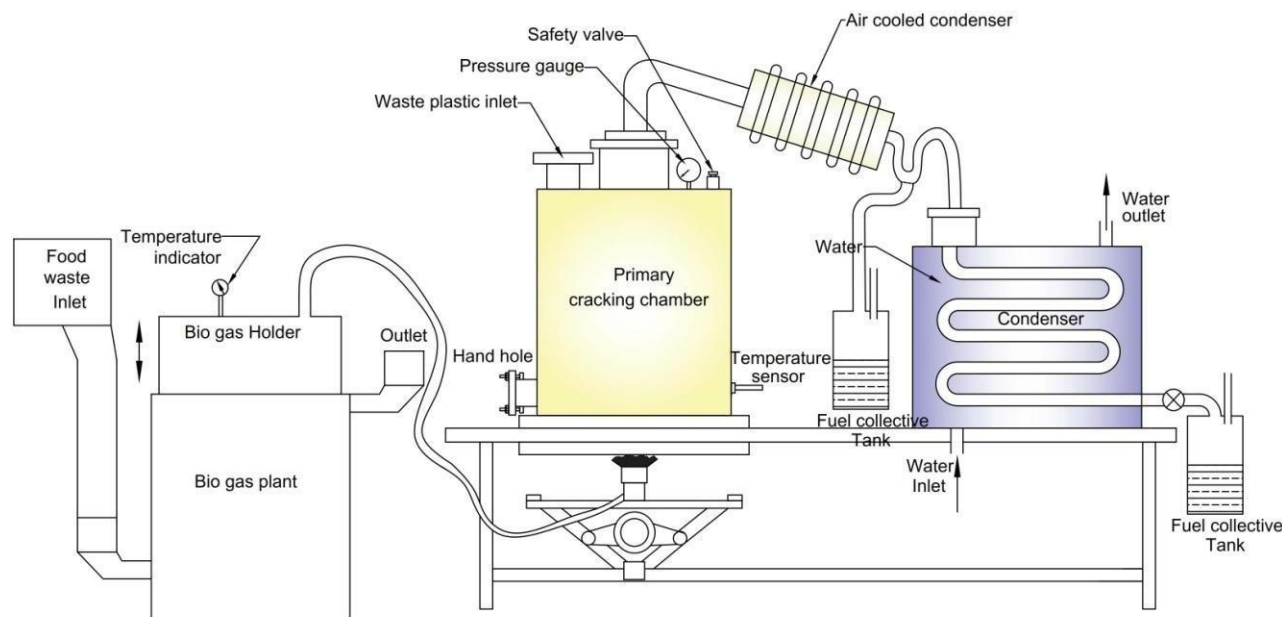


Fig. 1 Biogas fired waste plastic oil extraction plant

Fig. 1 Biogas fired waste plastic oil extraction plant

The reactor is a cylindrical vessel made up of cast iron. The top and bottom of the reactor are flatted. The reactors heated with a burner at the bottom. This burner is attached to the biogas tank. The biogas is burnt in this burner. The top of the reactor is fitted with a valve for loading the waste plastic. The valve will be opened during loading and closed after the completion of loading. Another opening is provided in the top fitted with a pipeline attached to air and water- cooled condensers to separate the low and high boiling hydrocarbon. The low and high boiling hydrocarbons were collected in separate containers.

Determination of physical properties

Physical properties of the high and low boiling fractions, petrol and diesel were determined using the following standard methods for fuel: IS-1448-P16 for density, IS-1448 P-32 for specific gravity, IS 1448 – P25 for kinematic viscosity, IP-36 for flash point and fire points, and IP -16 for pour point, Gross calorific value was determined as per IS – 1448.

SEM

SEM were recorded on a JEOL-JSM – IT 200 in Centralized Instrumentation and Service Laboratory (CISL), Department of Physics, Faculty of Science, Annamalai University.

EDX

EDX were recorded on a JSM – IT 200 in Centralized Instrumentation and Service Laboratory (CISL), Department of Physics, Faculty of Science, Annamalai University.

¹H NMR Spectra

¹H NMR spectra were recorded on a Bruker AVANCEE 1H NMR spectrometer operating at 400 MNz for ¹H. The spectra were recorded in CDCl₃ using tetraethyl silane as internal reference.

IR spectra

IR spectra were recorded on an IR spectrometer, Model Alpha–II used for laser-I, made by Bruker.

RESULTS AND DISCUSSION

Production of biogas

Production of biogas was done under mesophilic condition. The production of biogas will be higher under this condition. The measurement of biogas was done by measuring the height of the biogas holder. The pH of the food slurry inside the digester was measured on daily basis. The measurement was taken two times a day and the average were recorded. The food slurry was loaded into the digester continuously for 10 days. After 10 days only water was added into the digester for 5 days to maintain the pH value between 7 and 7.5. This was done to increase the biogas production. Day by day the production of biogas gets increased. Finally, it produced m³ of biogas.

The quantity of food waste slurry, pH of the slurry and the biogas produced were measured for 15 days. The results are given in Table 1.

Table 1. Observation on the production of biogas

Sl. No.	Days	Quantity of food waste (kg)	Quantity of water	slurry preparation in kg	pH of slurry	Volume of biogas produced m ³
1	1	2	2	4	6.2	Nil
2	2	2	2	4	6.4	0.5
3	3	3	3	6	6.6	0.9
4	4	2	2	4	6.7	1.3
5	5	2	2	4	6.9	1.7
6	6	3	3	6	7.0	2.0
7	7	3	3	6	7.2	2.5
8	8	2	2	4	7.4	2.8
9	9	3	3	6	7.4	3.5
10	10	3	3	6	7.5	3.8
11	11		2.5	2.5	7.5	3.9
12	12		2.5	2.5	7.4	4.0
13	13		2.5	2.5	7.2	4.2
14	14		2.5	2.5	7.1	4.3
15	15		2.5	2.5	7.1	4.5

Production of waste plastic oil

During degradation the temperature of the waste plastic–catalyst mix was recorded for every 10 min interval. The time and temperature were noted when the oil formation started. These readings are given in Table 2.

Table 2 Results of degradation of waste LDPE

Time(min)	Temperature of the polymer-catalyst mix (°C)	Volume of liquid collected in air cooled condenser(ml)	Volume of liquid collected in water cooled condenser (ml)
0	27	-	-
10	83	-	-
20	134	-	-
27	167	Oil commencing	-
30	180	20	-
40	230	90	40
50	273	70	60

60	346	10	42
70	315	-	20
74	342	-	Oilceased
	Total	190	162

From Table 2 it is seen that at 27 min liquid has formed in air cooled condenser. After 40 min the oil condensed in water cooled condenser is 40 ml. Hence, oil formation is supposed to commence after 27 min i.e., at a temperature 167 °C. After 74 min there is no oil formation. Therefore, the degradation is complete at 342 °C.

The material in the reactor was removed after cooling. It was weighed using a digital balance. The weight was found as 49.7 g. Amount of catalyst used in this case is 50 g. In this case the weight of the material remaining after the reaction suggests that only catalyst is present after the reaction excluding the formation of any solid product. Hence, the polymeric material taken has been completely converted into oil and gas in this case.

Normally, degradation of a polymer gives solid, liquid, and gaseous products. Solid material remaining after degradation should contain unchanged polymer, hydrocarbons which are solid at room temperature and coke or carbonaceous matter. Hence, the yield of the solid material is 0% in this case.

The weight of the liquid formed was found as (266 g). Hence, the yield the gaseous products is 46.8%.

Uadin et al., [11] have obtained 80.2% of oil by the cracking of LDPE using SA-2 as catalyst. However, they have used a temperature of 430°C. Moreover, they have taken only 10g of the material for study.

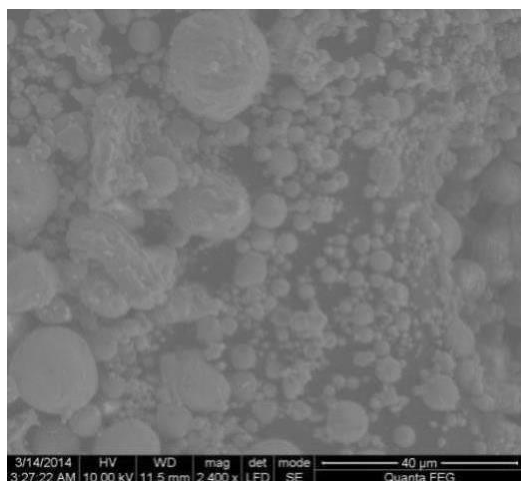
Gob in and Manos [29] have obtained 83% oil from LDPE by cracking it using clay and saponite, as the catalysts. However, they have used a temperature greater than 400°C. Also, they have made this study only in a small scale taking 2 g of the polymeric material.

Evidence for the role of fly ash as catalyst using SEM image & EDX spectra SEM

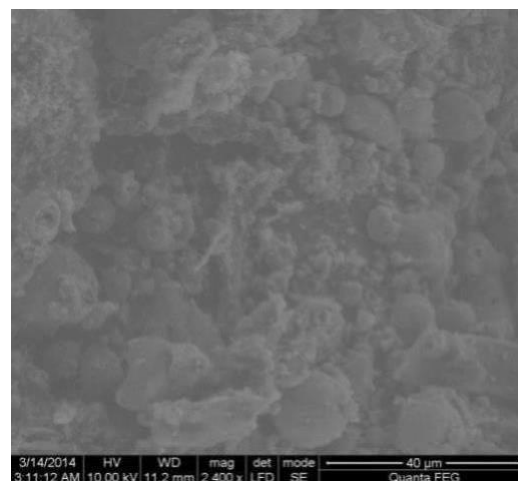
Image

A catalyst may undergo a physical change during the reaction in which it acts as a catalyst. However, it does not undergo any permanent chemical change. Its chemical nature is not altered after the reaction. The change in the physical nature can be detected by using SEM images.

SEM images were recorded for the catalyst before and after the degradation process. For the 40 μm , SEM images of the raw fly ash remaining after the reaction are shown in Fig 2. From the images shown in Fig2 it is obvious that the physical nature of ash is changed during the degradation. The same observation was made using SEM images corresponding to 20 μm , 5 μm , 4 μm and 2 μm .



SEM imageFlyAsh,40 μm



SEM image after degradation using 0.10, catalyst 40 μm

Fig.2 40 μm SEM images of fly ash before & after degradation

EDX spectra

The EDX spectrum of raw fly ash is compared with that obtained after degradation of the plastic. Examination of EDX spectra in Plates 1 and 2 shows that the peaks for Si, Al and O are not affected by the degradation. This shows that fly ash does not undergo a permanent chemical change during the degradation of LDPE. This EDX spectrum and SEM images show that fly ash is involved as a catalyst

in the degradation.

The physical properties of the low and high boiling fractions are given in Table 3. The properties of the high boiling fractions are compared with those of diesel. The properties of the low boiling fractions are compared with those of petrol. It is seen that the properties of the high boiling fraction are comparable to those of diesel. Also, the properties of the low boiling fractions are comparable to those of petrol. This shows that the high boiling fraction can be used as a substitute for diesel and the low boiling fraction can be used as substitute for petrol. Physical properties of high & low boiling fractions, petrol and diesel.

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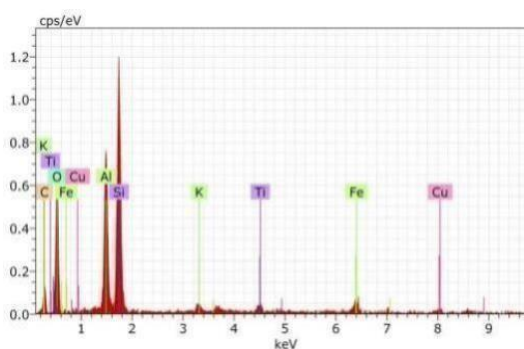


Plate-1 Flyash

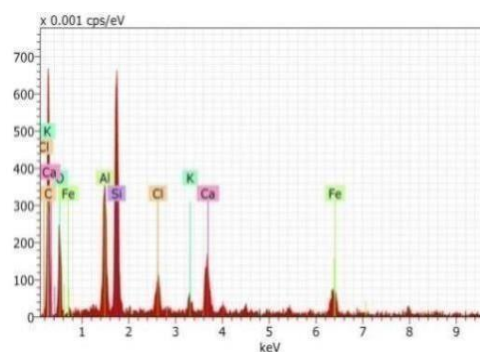


Plate-2 Fly ash after degradation

Fig-3 Photographic views EDX Spectrum

Table-3.Physical properties of oil fractions, Diesel & Petrol.

Property	Waste plastic oil			
	Low boiling Waste plastic oil Hydrocarbon	Petrol	High boiling Waste plastic oil Hydrocarbon	Diesel
Density ^{15°C} (kg/m ³)	771.8	730-770	818.0	820
Kinematicviscosityat ^{40°C} (cSt)	1.76	1.81	2.64	2.5
Flashpoint (°C)	61	-43	66	62
Firepoint (°C)	80	25	88	43
Pourpoint (°C)	Below -13	-4	Below-12	-
Grasscalorific value (MJ/kg)	42.7	45	41.9	42.3

¹H NMR Spectra

The ¹H NMR spectra of low and high boiling fractions are given in Plates 3 and 4 respectively

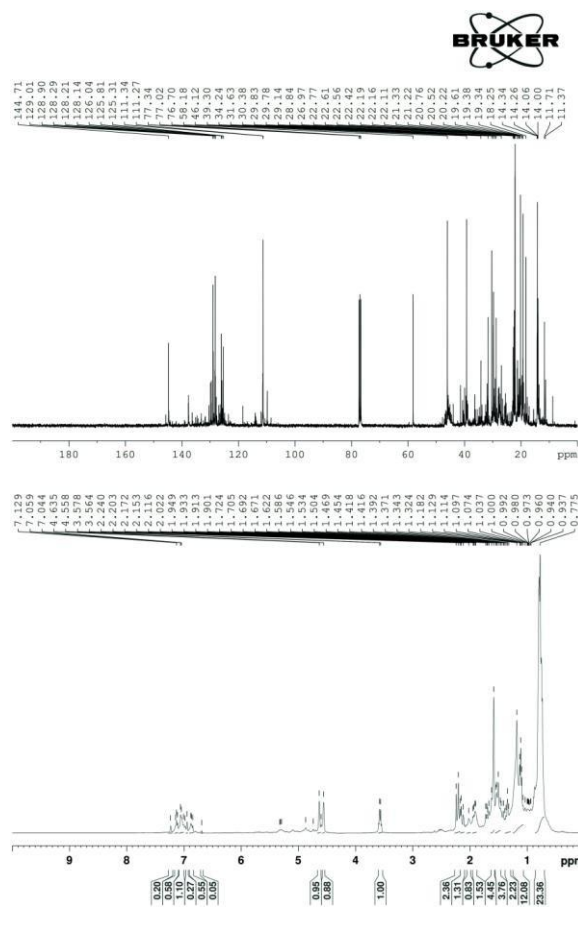
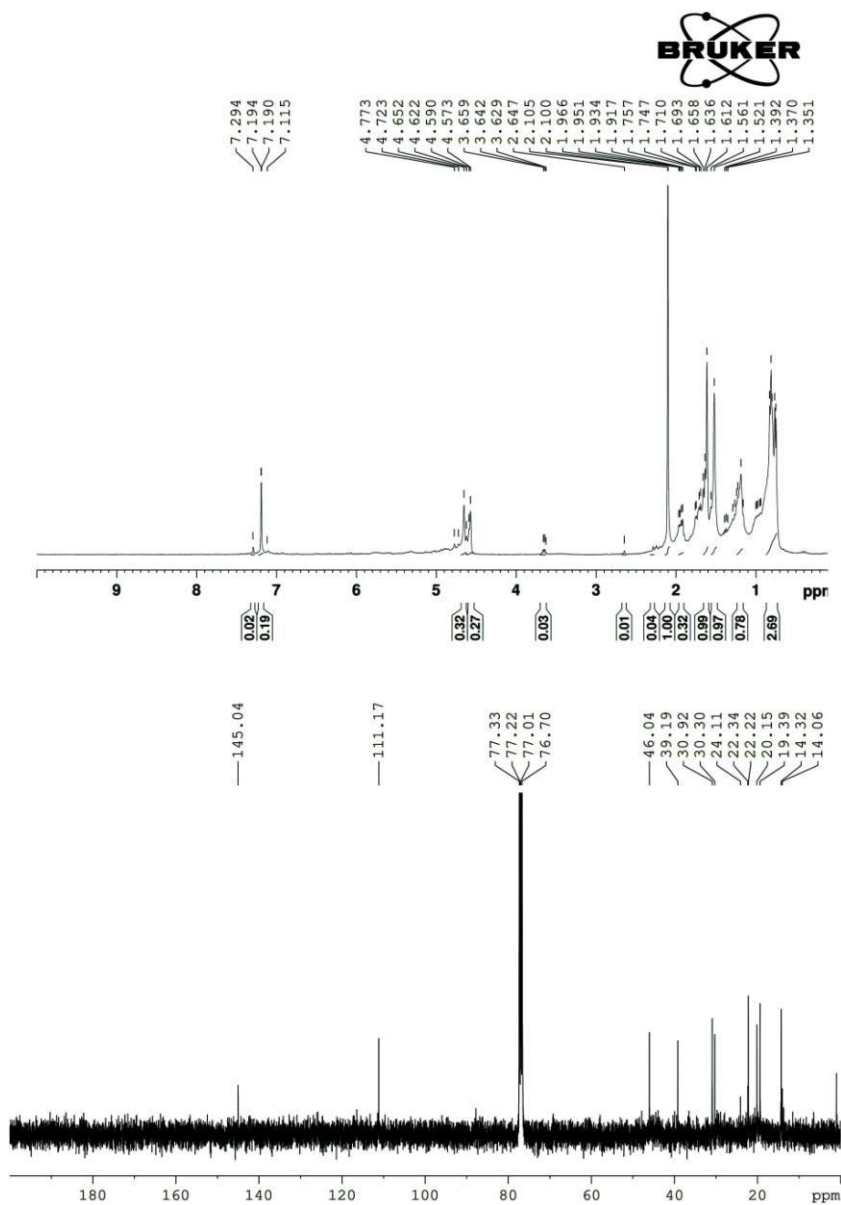


Plate-3 Low boiling waste plastic oil hydrocarbon



Pate-4 High boiling waste plastic oil hydrocarbon

Fig-4 ¹H NMR Spectroscopy

Polyethylene is formed by the continuous addition of ethylene molecules. A single molecule of polyethylene can be represented by the formula C_nH_{2n} where „n“ is very large. If the value of “n” is 5000 the molecular mass will be 70,000. When it undergoes pyrolysis it is converted

into a mixture of smaller alkenes with „n“having values in the range 5-25. In any alkene hydrogen atoms attached to olefinic carbons (doubly bonded carbons) are chemically different from those hydrogens attached to saturated carbons (carbons involving C-C single bonds). Let us consider alkene 1- decene whose structural formula is shown below.



In this molecule three hydrogen atoms are attached to olefinic carbons whereas 17 hydrogen atoms are attached to saturated carbons. The ratio of number of hydrogen atoms attached to saturated carbons to those attached to olefinic carbons is 17 / 3 (ca 5.67). If we consider large alkene C₁₂H₂₄ this ratio is 21/3 or 7. In a lower alkene C₆H₁₂ this ratio is 9 / 3 or 3. If we consider a mixture of alkenes the ratio of hydrogen atoms attached to saturated carbons to those attached to olefinic carbons will depend on the composition. If the mixture contains largely lower alkanes this ratio will be lower. If the mixture contains large alkenes then this ratio will be higher.

Nuclear magnetic resonance (NMR) spectroscopy provides a method of determining the ratio of hydrogen atoms attached to saturated carbons to those attached to olefinic carbons. NMR spectroscopy is the study of nuclei. Hydrogen atom has a nucleus with one proton and is represented as ¹H. The number 1 stands for the total number of protons and neutrons. In ¹H NMR spectroscopy the hydrogen is classified by the chemical nature. The signals appear at different positions. The positions are called chemical shifts. The protons attached to olefinic carbons have chemical shifts in the range of 4-6 ppm (parts per million). The hydrogen atoms attached to saturated carbons have their chemical shifts in the range 0 – 2 ppm.

The areas of the peaks are proportional to the number of hydrogen atoms of the particular type. The ratio of the areas will give the ratio of hydrogen atoms attached to the saturated carbons to those attached to the olefinic carbons. The ^1H NMR spectroscopy of the oil fraction obtained by low boiling waste plastic oil hydrocarbon is shown in Plate 3. In this case the ratio of the number of hydrogens attached to the saturated carbon of those attached to the olefinic carbon comes as 7. The ^1H NMR spectrum of the oil fraction obtained by high boiling waste plastic hydrocarbon Plate 4. In this case the ratio the number of hydrogen atoms attached to saturated carbons to those attached to the olefinic carbons is found as 11. Hence the low boiling oil fraction contains largely short chain alkanes and the high boiling fraction contains largely higher alkenes.

The formation of aromatic compounds like benzene, toluene and xylenes can also be detected using ^1H NMR. The chemical shifts of protons in benzene are 7.2 ppm. In toluene and xylenes the protons attached to aromatic carbons have shifts around 7.2 ppm whereas the methyl protons have chemical shifts around 2 ppm. Benzene has 100% aromatic protons. In toluene there are three methyl protons. The percentage of aromatic protons in toluene will be 62.5. In xylenes there are four aromatic protons and six methyl protons. Hence the percentage of aromatic protons will be 40. In alkanes and alkenes the percentage of aromatic protons will be zero. The percentage of aromatic protons can be found from the ^1H NMR spectrum.

Let the total area for aromatic protons be A_a and the total area for all the protons be A_t .

$$\text{Percentage of aromatic protons} = \frac{A_a}{A_t} \times 100$$

From the ^1H NMR spectra of the two fractions it was found the percentages of aromatic protons in the low and high boiling fractions are 4.8 and 3.65, respectively. This shows that both fractions contain only very small amounts of aromatic compounds.

IR Spectra

Infrared (IR) Spectroscopy is an important technique to study organic molecules. Organic molecules undergo vibrational motions. Due to the vibrations organic molecules absorb infrared radiation. All organic molecules show absorption around 3000 cm^{-1} due to C-H stretching vibrations. Alkenes absorb around 1600 cm^{-1} due to C=C stretching vibrations. There will be absorption around the region $1400 - 600\text{ cm}^{-1}$ due to C-C stretching and H-C-H bending vibrations.

The IR spectra of the plastic used for degradation, low boiling fraction obtained by degradation of the waste plastic and the high boiling oil fraction obtained after degradation are shown in Plates, 5, 6 and 7 respectively.

It is seen from Plate 5 that the polymer shows absorption in C-H stretching, C-C stretching H-C-H bending regions. There is no significant absorption in C=C stretching region. From Plate 6 it is seen that low boiling oil fraction have significant absorption in the C=C stretching region around 1650 cm^{-1} . From Plate 7 it is seen that the fraction also absorption around 1600 cm^{-1} . However, the intensity is less than that for the low boiling oil fraction. This is because in a definite amount the low boiling oil fraction will have more C=C bonds than the high boiling fraction.

Comparison with previous studies Serrano et al. [25] have observed that the rate of un catalytic degradation of LDPE is maximum at 477°C (T_{max}). The value of T_{max} decrease by used of

catalyst. When micrometer HZSM-5 was used as catalyst T_{max} was used 443°C and when nonocrystalline HZSM-5 was used as catalyst T_{max} was 396°C un catalytic degradation produced a mixture of hydrocarbons with various lengths.

Use of HZSM-5 as catalyst increases the formation of lower hydrocarbons and aromatic compounds. The formation of heavier hydrocarbons was eliminated completely. However, used of Al-M (M-4) give little aromatic compounds and higher amounts of hydrocarbons of various lengths

Panda et al. [27] have observed the formation of liquid is maximum for LDPE when the temperature was 500°C. The time required for complete degradation was about 73 min. use of sulphated zirconium hydroxide as catalyst has been found to reduce the reaction time. When cat/pol ratio was 0.1 the reaction time was reduced to about 65 min. the oil obtained was found to contain largely C₁₀-C₂₄ hydrocarbons [28].

Kyong – Hwan Lee et al. [29] have studied the degradation of LDPE, HDPE, PP and PS. They have used spent FCC catalyst. They have used a temperature of 400°C and cat/pol ratio of 0.1. They have observed that in the case of LDPE aromatic compounds are formed to the extent of 15-20% and hydrocarbons are formed to the extent of 70-75%. Naphthenes are formed to the extent of about 5%. They have observed that liquid formation commence after about 45 min and ceased of the after 240 min.

In all the above studies commercial expensive catalysts have been used. In this study, fly ash a waste product from thermal power plant have been used as the catalyst. The liquid formation commence after 27min at a temperature of 167°C and ceases after 74min and at a temperature

of 342°C. Thus, use of fly ash as catalyst reduces the temperature needed for degradation. The time required for the completion of degradation is also much less.

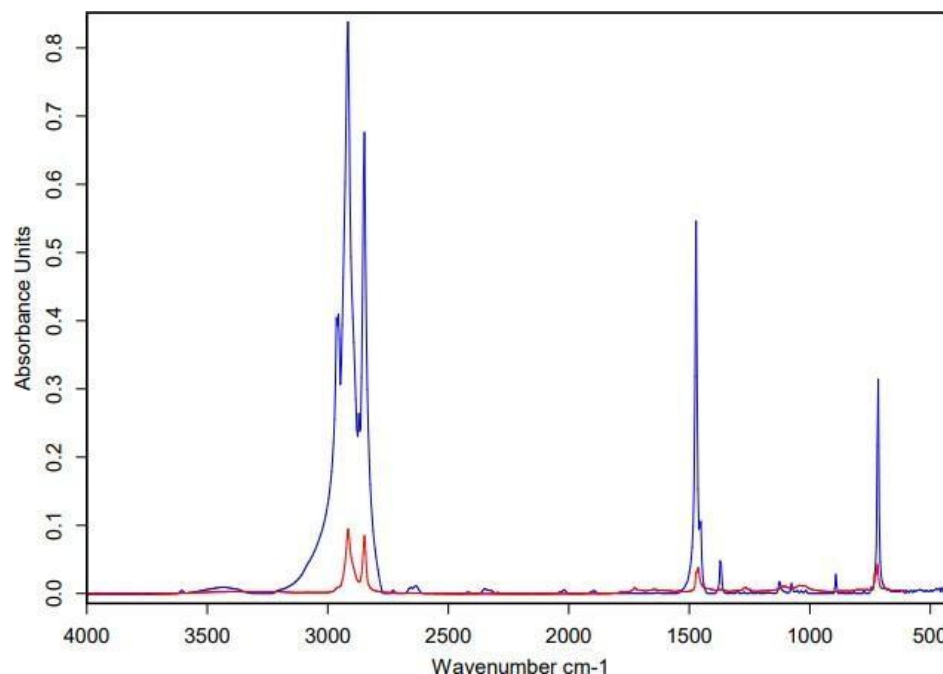


Plate. 5 LDPE plastic cover

Conclusion

Waste plastic made of LDPE obtained from hospitals, has been successfully converted into liquid and gaseous hydrocarbons. For heating the plastics biogas obtained by biodegradation of food waste has been used. These two types of wastes are treated in a single step. Hence, the waste plastic oil has been separated into low and high boiling fractions in a single experiment. ^1H NMR and IR spectra suggest that high boiling fraction contains largely higher alkenes and low boiling fraction contains largely lower alkenes. ^1H NMR spectra suggest that both fractions contain very little aromatic compounds. The physical properties of high boiling fractions are comparable to those of diesel and the physical properties of low boiling fraction

are comparable to those of petrol. Hence the low and high boiling fractions can be used as a substitute for petrol and diesel.

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Declarations

Ethics approval and consent to participate Informed consent was obtained from all individual participants included in the study.

Ethics approval - Human and/ or animal studies

Not applicable

Competing interests

I wish to disclose a competing interest(s) such as those defined above or others that may be perceived to influence the results and discussion reported in this paper.

Conflict of interest

The authors declare that they have no conflict of interest.

Credit authorship contribution statement

D. Raja Kullayappa - Conceptualization, Methodology, Data curation, Writing - original draft.

G. Karthikeyan - Supervision, Review & Editing, Validation

P. Premkumar – Investigation, Formal analysis, Visualization

C. G. Saravanan – Project administration, Demonstration

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Availability of data and materials

All data are available within manuscript

References

1. Beedu, R., Modi, P. (2014). Design of Bio Gas Generation Plant Based on Food Waste. *International Journal of Current Engineering and Technology*,417.
2. Iqbal, S. A., Rahaman, S., Rahman, M., & Yousuf, A. (2014). Anaerobic digestion of kitchen waste to produce biogas.*Procedia Engineering*,90, 657-662.
3. OjikutuAbimbola, O., & Osokoya Olumide, O. (2014). Evaluation of biogas production from food waste.*IJES*,3(1), 01-07.
4. Jayaraj, S., Deepanraj, B., & Sivasubramanian, V. (2014, May). Study on the effect of pH on biogas production from food waste by anaerobic digestion. In*Proceedings of the 9th Annual Green Energy Conference, Tianjin, China*(pp. 25-28).
5. Yamashiro, T., Lateef, S. A., Ying, C., Beneragama, N., Lukic, M., Masahiro, I,... & Umetsu, K. (2013). Anaerobic co-digestion of dairy cow manure and high concentrated food processing waste.*Journal of Material Cycles and Waste Management*,15, 539-547.
6. Panyaping, K., & Moontee, P. (2018). Potential of biogas production from mixed leaf and food waste in anaerobic reactors.*Journal of Material Cycles and Waste Management*,20, 723-737.
7. Uddin, M. A., Koizumi, K., Murata, K., & Sakata, Y. (1997). Thermal and catalytic degradation of structurally different types of polyethylene into fuel oil.*Polymer*

- degradation and stability*,56(1), 37-44.
8. Ding, W., Liang, J., & Anderson, L. L. (1997). Thermal and catalytic degradation of high density polyethylene and commingled post-consumer plastic waste. *Fuel Processing Technology*,51(1-2), 47-62.
 9. Aguado, J., Serrano, D. P., Escola, J. M., Garagorri, E., & Fernandez, J. A. (2000). Catalytic conversion of polyolefins into fuels over zeolite beta. *Polymer Degradation and Stability*,69(1), 11-16.
 10. Walendziewski, J., & Steininger, M. (2001). Thermal and catalytic conversion of waste polyolefines. *Catalysis Today*,65(2-4), 323-330.
 11. Walendziewski, J. (2002). Engine fuel derived from waste plastics by thermal treatment. *Fuel*,81(4), 473-481.
 12. Karagöz, S., Yanik, J., Uçar, S., Sağlam, M., & Song, C. (2003). Catalytic and thermal degradation of high-density polyethylene in vacuum gas oil over non-acidic and acidic catalysts. *Applied Catalysis A: General*,242(1), 51-62.
 13. Gobin, K., & Manos, G. (2004). Polymer degradation to fuels over microporous catalysts as a novel tertiary plastic recycling method. *Polymer Degradation and Stability*,83(2), 267-279.
 14. Jan, M. R., Shah, J., & Gulab, H. (2010). Degradation of waste high-density polyethylene into fuel oil using basic catalyst. *Fuel*,89(2), 474-480.
 15. Jan, M. R., Shah, J., & Gulab, H. (2010). Catalytic degradation of waste high-density polyethylene into fuel products using BaCO₃ as a catalyst. *Fuel processing technology*, 91(11), 1428-1437.
 16. Jan, M. R., Shah, J., & Gulab, H. (2013). Catalytic conversion of waste high-density polyethylene into useful hydrocarbons. *Fuel*,105, 595-602.
 17. Premkumar, P., Nalluri, P., & Munaf, A. A. (2021, February). Effect of waste plastic oil diesel blend on variant injection pressure of a diesel engine. In *AIP conference proceedings* (Vol. 2316, No. 1, p. 030020). AIP Publishing LLC.
 18. Premkumar, P., Saravanan, C. G., & Gopalakrishnan, M. (2014). Conversion of

- Hospital Low Density Polyethylene Waste into Hydrocarbons using fly ash as catalyst. *International Journal of Engineering Trends and Technology (IJETT)*,16(5), 241-251.
19. Premkumar, P., Saravanan, C.G. & Gopalakrishnan, M. (2014) Complete catalytic conversion of High density polyethylene into Hydrocarbons without wax formation using Fly Ash as Catalyst. *International journal of Engineering Science and Technology (IJEST)*, 6(11), 786- 792.
 20. Alawa, B., Choudhary, J., & Chakma, S. (2023). Discernment of synergism in co-pyrolysis of HDPE and PP waste plastics for production of pyro-oil: Mechanistic investigation with economic analysis and health risk assessment. *Process Safety and Environmental Protection*,169, 107-131.
 21. Nishino, J., Itoh, M., Ishinomori, T., Kubota, N., & Uemichi, Y. (2003). Development of a catalytic cracking process for converting waste plastics to petrochemicals. *Journal of Material Cycles and Waste Management*,5, 89-93.
 22. Na, J. G., Jeong, B. H., Chung, S. H., & Kim, S. S. (2006). Pyrolysis of low-density polyethylene using synthetic catalysts produced from fly ash. *Journal of Material Cycles and Waste Management*,8, 126-132.
 23. Dutta, N., Mondal, P., & Gupta, A. (2022). Optimization of process parameters using response surface methodology for maximum liquid yield during thermal pyrolysis of blend of virgin and waste high-density polyethylene. *Journal of Material Cycles and Waste Management*,24(3), 1182-1193.
 24. Soliman, A., Farag, H.A., Nassef, E., Amer, A. and ElTaweel, Y., 2020. Pyrolysis of low- density polyethylene waste plastics using mixtures of catalysts. *Journal of Material Cycles and Waste Management*,22, pp.1399-1406.
 25. Serrano D.P, Agudo. J, Escola J.M, Rodriguez J.M, San Miguel. G, An investigation into the catalytic cracking of LDPE using Py- GC/MS, *Journal of Analytical and Applied Pyrolysis* 74(2005) 370-378
 26. Praveen Kumar Kanduri, Srinivas Seethamraju, In situ and ex situ catalytic co-pyrolysis of lignocellulosic biomass and plastic (low density and high density polyethylene) using spent FCC catalyst, *Waste and Biomass Valorization*31 oct 2022
 27. Achyut. K Panda, Abdullah Alotaibi, Ivan V. Kozhevnikov, N. Raveendran Shiju, Pyrolysis of

plastics to liquid fuel using sulphated zirconium hydroxide catalyst, *Waste and Biomass Valorization*(2022)11:6337-6345.

28. Sameh Samir Ali, Tamer Elsmahy, Eleni Koutra, Michael Kornarous, Mostafa El- Sheikh, Esraa A. Abdelkarim, Daochen Zhu, Jianzhong Sun, Degradation of conventional plastic waste in the environment, *Science of the Total Environment*(IF 10.753) Pub Date: 2021-01-21 , DOI:10.1016.
29. Kyong –Hwan Lee, Nam-Sun Noh, Dae-Hyun Shin, Younghwa Seo, Comparison of plastic types for catalytic degradation of waste plastics into liquid product with spent FCC catalyst, *Polymer degradation and stability*78(2002) 539-544.
30. Purti Humairah Monashofian Putra, Shaifulazuar Rozali Muhamad Fazly Abdul Patah Aida Idris, Review of microwave pyrolysis as a sustainable plastic waste management techniques, *Journal of Environmental Management, Volume 303, 1 Feb 2022, 114240.*