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FRACTIONAL DISTILLATION OF FUEL FROM MIXED PLASTIC WASTE

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Abstract

Mixed waste plastic of Low density polyethylene (LDPE) 30%, High density polyethylene (HDPE) 15%, Polypropylene (PP) 30%, and polystyrene (PS)25%, were collected from house hold waste, cleaned, dried, shredded into small pieces and then mixed with different percentage. In the first step pyrolysis was conducted in a temperature range(30- 450 °C).The pyrolysis produced 95% of liquid fuel , 3% solid residue (coke) , and 2% gases The fuel obtained from the first step is fractionated by fractional distillation column . The liquid fractions obtained were analyzed for composition using GC-MS. The physical properties of the pyrolytic oil show the presence of a mixture of different fuel fractions such as kerosene, gasoline and diesel in the oil.

1. Introduction

Due to the fossil fuel crisis and the erratic change of energy prices in the world in last century's researchers has to focus their studies on developing the alternate and green energy sources to be widely used that are environmentally friendly. On the other hand plastic waste is a real challenge to the environment worldwide, the huge amount of it cause an environmental problems; most of it buried in the landfill or burned hence it is non bio-degradablepolymer. [1-4]

Plastics are a generic group of synthetic or natural materials, composed of high-molecular chains whose sole or major element is carbon. In common usage the terms plastics,

Polymers and resins are roughly equivalent. It's made from petroleum derivatives and has unique chemical and physical properties. The plastics are mainly two types; thermoplastics and thermosetting plastics. The first type are composed of polyolefin (low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET) and polyvinyl chloride (PVC)) and they are mainly used in containers and packing, and can be recycled.[4-6]The plastics recycling methods divided into four types, one of them being the tertiary or chemical recycling methods. Chemical recycling is a thermal method by which the long chain of polymer are broken into short lighter hydrocarbons, known as pyrolysis.

Pyrolysis or thermolysisisa process of chemical and thermal decomposition, by which along chain molecule of polymers are broken into a mixture of small molecules.

Pyrolysis can be conducted at various temperature levels, reaction times, pressures, and in the presence or absence of reactive gases or liquids, and of catalysts. Plastics pyrolysis proceeds at low (<400◦C), medium (400–600◦C) or high temperature (>600◦C) and it produces gas, liquid (plastic oil) and solid char products. [7-11]

Several studies are reported for pyrolysis or thermal degradation of plastic wastes the majority of these studies focused on LDPE and

the yield of liquid fraction is low and most of it is heavy and waxy. [7-10].

In this study, four types of waste plastic were used in different percentage depends on: their presence in the garbage in Sudan and which one will give high yield when compare with others.

2. Material and Method

Polymer Materials

A waste plastic material used in present work were Low Density Polyethylene (L.D.P.E) 30% , High Density Polyethylene (H.D.P.E) 25% , Polystyrene(P.S) 15%, and Polypropylene (P.P) 30% in the form of plastic disposable glasses, poly shopping bags, packaging poly bags. And they are obtained from house hold garbage.

Methodology

2.1 Pyrolysis

100g of mixed waste plastic was shredded into small pieces and placed in the round bottom flask of the simple distillation unit. The condensable liquid products/wax was collected through the condenser and weighted. After pyrolysis, the solid residue left inside the reactor was weighed. Then the weight of gaseous/volatile product was calculated from the material balance. Reactions were carried out at 400°C and transferred into a fractional distillation unit.

2.2 Fraction distillation

The oil obtained was fractioned by using fraction column distillation in temprature range from 45 °C to 370 °C.

2.3 Gas chromatography mass spectroscopy

The quantitative analysis of total samples are done by using GM/MS technique (GC/MS-QP2010-Ultra) from japans'Simadzu Company, equipped with an AT-WAX (Heliflex capillary, Alltech) column (Rtx-5ms-30m×0.25 mm×0.25μm).The injector temperature was set to 250 ºC, while the mass spectroscopy (Ms) temperature was the oven temperature to 195 ºC. The carrier gas used was He at 1 mL/min flow. All the samples were analyzed by using scan mode in the range of m/z 30-550 mass to charges ratio.

Result and Discussion:

Thermal cracking of mixed waste plastic takes place by means of a radical chain transfer mechanism, comprising the usual initiation, propagation, and termination steps. The random scission of the C–C bond of the main chain occurs with heat to produce hydrocarbon radicals (HCRs), which form a broad hydrocarbon distribution wherein their main components in each fraction are the n-paraffin, the 1-alkene, and the corresponding alkadiene. Beside the branched products obtained via reaction between two radicals. [15-17]

Hence, in the thermal cracking of mixed waste plastic (PP, LDPE, PS and HDPE) with percentage (30%, 30%, 25%, 15%), yields about 95% liquid fuels, 3% light gas and about 2% solid residues. The produced fuel is then transferred into fractional distillation column.

Five fractions were collected in different temperature ranges. Two fractions were characterized using GC/MS. From the analysis of these fractions, we got some compound that is cyclic and aliphatic compounds such as aromatic compound, alcoholic compound and most of the compounds are aliphatic compound some are

single bond and some are double bond compounds. [12-14]

The first fraction was collected in temperature range (40–90).GC/MS analysis of 1'st fraction shows that it contains light hydrocarbon (C_5-C_{11}) as in (Fig. 1 and Table 1). All compounds are short chain hydrocarbon compound because when we fractionate waste plastic fuel to 1'st fractional fuel we used low temperature of 40 to 90 ºC temperature to collect all light fraction compound . Chromatogram and compound data table shown first compound is 1-Hydroxy-3-methyl-2-butanon ($C_5H_{10}O_2$) at retention time 1.549 and trace mass 43 this compound intensity is low in percentage of 0.14, 1-Pentene, 2-methyl- (C_6H_{12}) at retention time 1.664 and trace mass 56, Toluene (C_7H_8) at retention time 3.834 and trace mass 91, Styrene appears at retention time 7.644 is compound intensity is high in percentage of 21.1 and trace mass 104 , 2,4-Dimethyl-1-heptene (C_9H_{18}) at retention time 5.819 and trace mass 43, 1-Decene ($C_{10}H_{20}$) at retention time 11.662 and trace mass 56, 1-Heptanol, 2,4-diethyl- ($C_{11}H_{20}O$) at retention time 15.736 and trace mass 69. [17,18]

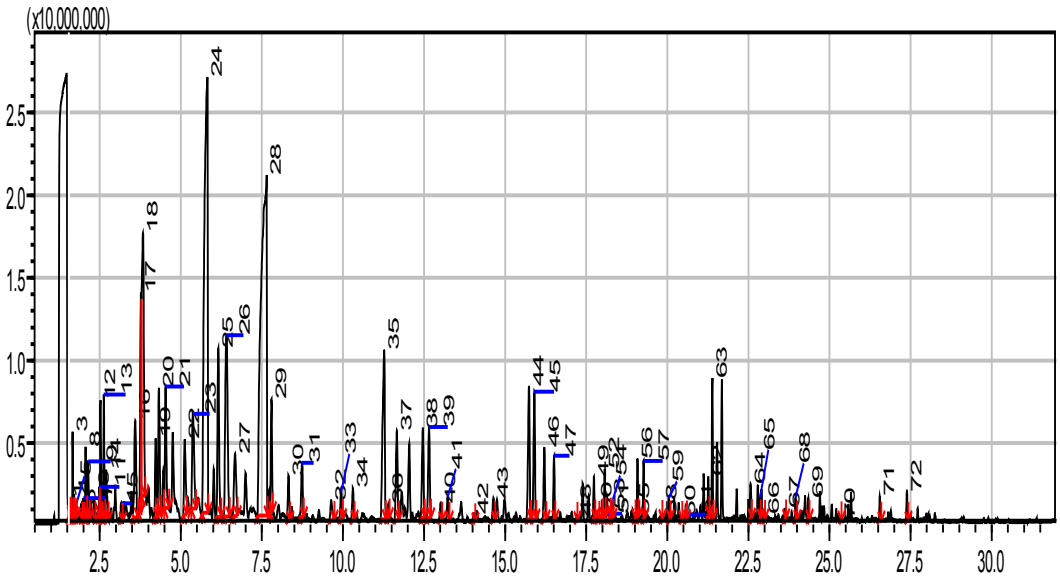

Figure 1: Fraction (1) light fraction

Table.1 : Represents the compounds and their percentages in fuels by using GC/MS spectroscopy: Fraction (1) light fraction

Peak Number	Retention Time (M)	Treace Mass (m/z)	Area%	Compound Name	Compound Formula
1	1.549	43	0.14	1-Hydroxy-3-methyl-2-butanon	$C_5H_{10}O_2$
2	1.620	57	0.02	1-Butanol, 2-methyl	$C_5H_{12}O_2$
3	1.664	56	0.56	1-Pentene, 2-methyl-	C_6H_{12}
4	1.712	57	0.12	n-Hexane	C_6H_{14}
5	1.923	56	0.08	Cyclopentane, methyl	C_6H_{12}
6	1.995	67	0.16	1,3-pentadiene,2-methyl, (E)	C_6H_{10}
7	2.064	56	0.51	1-Pentene,2,4-dimethyl-	C_7H_{14}
8	2.145	81	0.55	Bicyclo[2.1.0]pentane,1,4-dimethyle-	C_7H_{12}
9	2.524	56	1.17	1-Heptene	C_7H_{14}
10	2.626	43	1.21	Heptane	C_7H_{16}
11	3.586	69	1.97	2-Octene, 2,6-dimethyl-	$C_{10}H_{20}$
12	3.834	91	6.06	Toluene	C_7H_8
13	3.772	43	2.82	Heptane, 4-methyl-	C_8H_{18}
14	4.325	55	1.93	1-Octene	C_8H_{16}
15	4.531	43	1.97	Octane	C_8H_{18}
16	5.120	43	1.40	Heptane, 2,4-dimethyl-	C_9H_{20}
17	5.372	69	2.16	Cyclohexane, 1,3,5-trimethyl	C_9H_{18}
18	5.819	43	15.94	2,4-Dimethyl-1-heptene	C_9H_{18}
19	6.409	91	4.79	Ethylbenzene	C_8H_{10}
20	6.673	109	1.52	Cyclohexene, 3,3,5-trimethyl-	C_9H_{16}
21	7.644	104	21.10	Styrene	C_8H_8
22	7.798	43	1.52	Nonane	C_9H_{20}
23	11.271	113	4.12	alpha.-Methylstyrene	C_9H_{10}
24	11.463	71	1.60	Heptane, 3,3,5-trimethyl-	$C_{10}H_{22}$
25	11.662	56	1.69	1-Decene	$C_{10}H_{20}$
26	12.654	71	1.60	Heptane, 2,5,5-trimethyl-	$C_{10}H_{22}$
27	14.639	91	0.42	Benzene, butyl-	$C_{10}H_{14}$
28	15.736	69	2.63	1-Heptanol, 2,4-diethyl-	$C_{11}H_{24}O$
29	16.209	56	1.07	1-Undecane	$C_{11}H_{22}$
30	16.508	57	0.86	Undecane	$C_{11}H_{22}$
31	17.738	92	0.50	Benzene, (3-methyl-3-butenyl	$C_{11}H_{16}$

The fifth fraction was collected in temperature range (340–370).GC/MS analysis of 5'th fraction shows that it contains light hydrocarbon (C_8-C_{36}) as in (Fig. 2 and Table 2). Most of these compounds are long chain hydrocarbons becuse most of the light fraction were fractionated in the other fractions. Chromatogram and compound data table shown first compound is 1-Heptene, 2-methyl- (C_8H_{16}) at retention time 3.192 and trace mass 56 and show the lower area percentage of 0.21, Styrene (C_8H_8) at retention time 5.191 and trace mass 104, Nonane (C_9H_{20}) at retention time 5.306 and trace mass 43, 1-Decene ($C_{10}H_{20}$) at retention time 7.371 and trace mass 56, 1-Undecene ($C_{11}H_{22}$) at retention time 9.692 and trace mass 55, 1-Dodecene ($C_{12}H_{24}$) at retention time 11.949 and trace mass 55, Nonane, 2-methyl-5-propyl- ($C_{13}H_{28}$) at retention time 14.253 and trace mass 57, Pentadecane ($C_{15}H_{32}$) at retention time 19.954 and trace mass 57, 3-Hexadecene, (Z)- ($C_{16}H_{32}$) at retention time 16.111 and trace mass 55, Heptadecane ($C_{17}H_{36}$) at retention time 18.019 and trace mass 57, Octadecane ($C_{18}H_{38}$) at retention time 24.345 and trace mass 57, Nonadecane ($C_{19}H_{40}$) at retention time 23.054 and trace mass 57, Eicosane ($C_{20}H_{42}$) at retention time 25.514 and trace mass 57, 1-Heneicosanol ($C_{21}H_{44}O$) at retention time 27.551 and trace mass 97, Behenic alcohol ($C_{22}H_{46}O$) at retention time 25.451 and trace mass 83, n-Tetracosanol-1 ($C_{24}H_{50}O$) at retention time 26.537 and trace mass 97, 1-Heptacosanol ($C_{27}H_{56}O$) at retention time 28.500 and trace mass 97, Tetratetracontane ($C_{34}H_{70}$) at retention time 27.597 and trace mass 57,
Hexatriacontane ($C_{36}H_{74}$) at retention time 27.739 and trace mass 57.

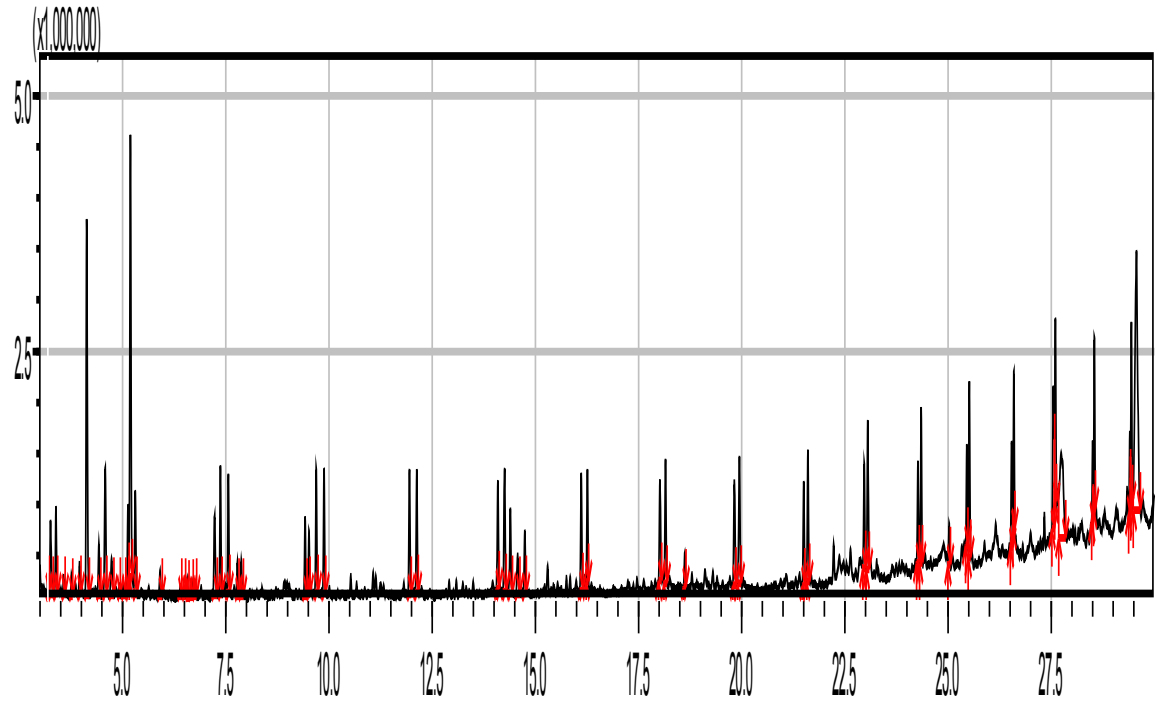

Figure 2: Fraction (5) Heavy fraction

Table.3:Represents the compounds and their percentages in fuels by using GC/MS spectroscopy: Fraction (5) Heavy Fraction

Peak Number	Retention Time (M)	Treace Mass (m/z)	Area%	Compound Name	Compound Formula
1	3.192	56	0.21	1-Heptene, 2-methyl-	**C_8H_{16}**
2	3.256	55	1.17	1-Octene	**C_8H_{16}**
3	3.386	43	1.26	Octane	**C_8H_{18}**
4	3.572	83	0.27	Cyclopentane, 1,1,3,4-tetramethyl-, cis-	**C_9H_{18}**
5	3.762	43	0.33	Heptane, 2,4-dimethyl-	**C_9H_{20}**
6	3.958	69	0.46	Cyclohexane, 1,3,5-trimethyl-	**C_9H_{18}**
7	4.131	43	6.14	2,4-Dimethyl-1-heptene	**C_9H_{18}**
8	4.425	69	0.89	Cyclohexane, 1,2,4-trimethyl-, (1.alpha.,2.beta.,4.beta.)-	**C_9H_{18}**
9	4.578	91	2.19	Ethylbenzene	**C_8H_{10}**
10	4.731	91	0.71	Ethinamate	**$C9H_{11}NO2$**
11	4.916	109	0.13	2,4-Heptadiene, 2,6-dimethyl-	**C_9H_{16}**
12	5.191	104	6.92	Styrene	**C_8H_8**
13	5.130	56	1.44	1-Nonene	**C_9H_{18}**
14	5.306	43	1.69	Nonane	**C_9H_{20}**
15	5.909	105	0.41	Benzene, (1-methylethyl)-	**C_9H_{12}**
16	7.228	118	1.36	.alpha.-Methylstyrene	**C_9H_{10}**

17	7.371	56	1.81	1-Decene	$C_{10}H_{20}$
18	7.564	57	1.76	Undecane	$C_{11}H_{24}$
19	7.779	71	0.47	Octane, 3,3-dimethyl-	$C_{10}H_{22}$
20	7.875	43	0.57	Heptane, 2,5,5-trimethyl-	$C_{10}H_{22}$
21	9.420	69	1.13	1-Decene, 2,4-dimethyl-	$C_{12}H_{22}$
22	9.517	69	0.93	2-Undecene, 4,5-dimethyl-, [R*,S*-(Z)]-	$C_{13}H_{26}$
23	9.692	55	1.81	1-Undecene	$C_{11}H_{22}$
24	11.949	55	1.94	1-Dodecene	$C_{12}H_{24}$
25	12.125	57	1.80	Dodecane	$C_{12}H_{26}$
26	14.090	55	1.59	1-Tridecene	$C_{13}H_{26}$
27	14.253	57	1.88	Nonane, 2-methyl-5-propyl-	$C_{13}H_{28}$
28	14.396	69	1.38	11-Methyldodecanol	$C_{13}H_{28}$
29	14.572	69	0.75	3-Eicosene, (E)-	$C_{20}H_{40}$
31	14.746	69	1.01	2-Isopropyl-5-methyl-1-heptanol	$C_{11}H_{24}O$
32	16.111	55	1.78	3-Hexadecene, (Z)-	$C_{16}H_{32}$
33	16.259	57	1.57	Hexadecane	$C_{16}H_{34}$
34	18.019	55	1.49	1-Heptadecene	$C_{17}H_{34}$
35	18.019	57	1.88	Heptadecane	$C_{17}H_{36}$
36	19.822	55	1.62	1-Pentadecene	$C_{15}H_{30}$
37	19.945	57	2.18	Pentadecane	$C_{15}H_{32}$
38	21.501	55	1.57	1-Heptadecene	$C_{18}H_{34}$
39	21.605	57	1.90	Heptadecane	$C_{18}H_{36}$
40	22.967	83	1.57	1-Nonadecene	$C_{19}H_{38}$
41	23.054	57	2.08	Nonadecane	$C_{19}H_{40}$
42	24.270	83	1.40	1-Octadecene	$C_{18}H_{36}$
43	24.345	57	2.10	Octadecane	$C_{18}H_{38}$
44	25.027	69	0.58	1-Dodecanol, 2-octyl-	$C_{20}H_{42}O$
45	25.451	83	1.26	Behenic alcohol	$C_{22}H_{46}O$
46	25.514	57	2.37	Eicosane	$C_{20}H_{42}$
47	26.537	97	1.50	n-Tetracosanol-1	$C_{24}H_{50}O$
48	26.592	57	1.92	Heneicosane	$C_{21}H_{44}$
49	27.551	97	2.23	1-Heneicosanol	$C_{21}H_{44}O$
50	27.597	57	2.19	Tetratetracontane	$C_{34}H_{70}$
51	27.739	57	4.01	Hexatriacontane	$C_{36}H_{74}$
52	28.500	97	0.95	1-Heptacosanol	$C_{27}H_{56}O$
53	28.542	57	2.07	Tetratriacontane	$C_{34}H_{70}$
54	29.401	97	1.09	Cyclotetracosane	$C_{24}H_{48}$
55	29.439	57	2.12	Tetratetracontane	$C_{34}H_{70}$

Conclusion

Consumption of plastics has increased over the years and the concern with their waste generated too. Because of this many studies have been done with the aim to recover or recycle the waste. Pyrolysis has been effective compared to other recycling methods, because it can reuse the energy and the raw materials contained in those waste.

Liquid resulting from the simple distillation with a percentage 95 % was a mixture of alkanes and alkenes up to 36 carbon chains. After Fractional distillation 5 fractions were collected in various temperature rang the first fraction is light with short hydrocarbon from C5 to C12 it was suitable for the production of light kerosin. And the other fractions of higher alkenes in this mixture

produced long chains hydrocarbons obtained 4 fractions fuel was 88% including naphtha chemical, kerosene, diesel and fuel oil and temperature range was for naphtha, kerosene, diesel and fuel oil with carbon range C8-C36.

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