

Polyethylene Terephthalate (Pete) And High Density Polyethylene (Hdpe) Mixture To Fuel Production

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Abstract: - High density polyethylene (HDPE) and polyethylene terephthalate (PETE) mixture to fuel production process was performed with Ferric Oxide (Fe_2O_3) and activated carbon. HDPE waste plastic was use 75 gm, PETE was use 25 gm, activated carbon was use 5 gm as a 5% and Ferric Oxide was use 2 gm as a 1%. PETE and HDPE waste plastics mixture to fuel production process temperature was use 420 °C and reactor was use Pyrex glass reactor. Total waste plastics sample was 100 gm and 100 gm of waste plastic mixture to fuel was collected 50.1 gm. PETE and HDPE waste plastic mixture to fuel density is 0.76 gm/ml. Liquid fuel was analysis by FT-IR, GC/MS and DSC for fuel functional group, compounds structure and enthalpy value determination. Product fuel is ignited and fuel can use an internal combustion engine.

Keywords: - HDPE, PETE, fuel, thermal, catalyst, hydrocarbon, waste plastics, FT-IR

I. INTRODUCTION

In modern life, the application of polymers is common. This kind of material is present in packaging, the electrical industry, in toys, etc. High-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET) are the most extensively used plastics. The polyethylene plastics (HDPE and LDPE) are the major components of the total plastic content of municipal solid waste. [1-4] Volume of plastics currently represent 24% of the MSW, due to their low density. Moreover, medical red-bag (infectious) waste contains a much higher fraction of plastics, as high as 40 wt %. The current methods for dealing with the environmental problems resulting from this solid waste include source reduction, reuse, recycling, landfill, and waste-to-energy conversion. Most solid wastes are disposed through landfilling. However, with the lack of landfill space and with current challenges both in implementing the recycling of plastics and in finding markets for the recyclables, combustion of these materials in waste-to-energy (WTE) plants offers an alternative of technological and economic interest. Combustion of waste plastics provides a number of advantages, such as destruction of hazardous contaminants, reduction of mass and volume (by more than 90%), and energy recovery, as well as rendering the waste unrecognizable from its original form (which is often a requirement for medical waste). [5]

Recycling of plastics has a positive environmental impact; in most cases it is not yet economically attractive. So far, industry has focused efforts in plastics recycling on the recovery and reuse of polymers by mechanical processing. However, mechanical technologies require relatively clean feedstocks that are expensive to collect and separate. For this reason, commercial recycling has not had a significant impact with the collection rate of less than 5% of total annual resin sales.[6] Producing hydrogen from waste plastics could complement conventional recycling techniques because it could use more complex materials that are not handled by existing processes, e.g. mixed plastics, polyester-cotton blends, rigid polyurethane foams. The challenge is to efficiently convert these polymers to hydrogen at a cost similar to that for the existing natural-gas-based technologies. Plastics have a high calorific value (i.e., polyethylene 43 MJ/kg, polypropylene 44 MJ/kg, polyvinyl chloride 20 MJ/kg), and their combustion can be an alternative to removing them. [7] This alternative must, however, be subjected to severe environmental controls in order to fulfill the legal restrictions concerning the emission of solid particles and gaseous effluents.[7,8,9] Landfills have also been used for plastic disposal, but these can pose a danger through the environment product degradation and the subsequent pollutant generation.[8,9] A promising alternative for the reprocessing of waste plastics is feedstock recycling, which

involves the conversion of plastics residue into raw chemicals, monomers for plastics or hydrocarbon feedstocks. In this way, thermal degradation has been used to convert different polyolefins into hydrocarbon mixtures. [10-12]

The thermal decomposition of polyolefins at temperatures of 400 °C or higher produce a mixture of hydrocarbons that is formed by a gas fraction (C₁-C₄), a liquid fraction (C₅-C₁₈), and a solid residue (C₁₉-C₇₀). For each number of C atoms, three main components are produced: the corresponding n-paraffin, α -olefin, and α , ω -diene. The relative proportion of these products is dependent on the thermal degradation operating conditions, which are determined mainly by the temperature.[13] The thermal degradation of polyolefins involves complex reactions through a radical mechanism, and their extension is very dependent on temperature, pressure, reactor geometry, and heat- and mass-transfer rates, as well as mixing intensity. Polymers and particularly polyolefins have high viscosity, which hinders mass- and heat-transfer phenomena.[14,15] The terminal double bond of α -olefins presents a high reactivity, in regard to a wide variety of chemicals, and, therefore, they are used to produce any derivative requiring an even-numbered, straight carbon chain. In this sense, α -olefins are utilized as intermediates in the manufacture of many commercial products, including plastics (e.g., HDPE and LDPE), synthetic lubricants (e.g., poly- α -olefins, polyol esters), surfactants (e.g., α -olefin sulfonates, alkyl benzene sulfonates, alkyl dimethyl amines), additives (e.g., alkenyl succinic anhydrides, and polyvinylchloride lubricants and stabilizers) and specialty chemicals (e.g., epoxides, halogenated α -olefins).[16]

II. MATERIALS

PETE waste was collected water bottle and HDPE was collected milk container for experimental purpose. Both waste plastics cut into small pieces and places into glass reactor including activated carbon and Ferric Oxide. Activated carbon and Ferric Oxide (Fe₂O₃) was collected from VWR. Com Company. Ferric Oxide (Fe₂O₃) was powder type and activated carbon was pellet type.

III. PROCESS DESCRIPTION

PETE and HDPE mixture to fuel production process was performed under the laboratory fume hood and production process was batch process. Total sample was use for experiment 100 gm of waste plastics mixture. PETE was 25 gm and HDPE was 75 gm, ferric oxide was 2 gm and activated carbon was 5 gm. 25 gm of PETE and 75 gm of HDPE waste plastic to fuel production was determine from less percentage of PETE and high percentage of HDPE waste plastics mixture. Catalyst was use for reaction acceleration and helping to breakdown polymer bond by using thermal degradation process. For experimental temperature was use starting 180 °C to up to 420 °C and temperature was increase slowly. Experimental setup purpose was use boiling flask for raw sample melting and fuel collection, heat mental with temperature controller, condensation unit, clamp, grease, foil paper for cover up the heat loss. Small pieces waste plastics placed into boiling flask inside with Ferric Oxide and activated carbon. Then boiling flask was placed into heating chamber for waste plastic melting. Then condensation unit was setup with sample provided boiling neck and fuel collection boiling flask neck with thermal protect grease. Because during production period gas loss prevention. This experiment main goal was PETE and HDPE waste plastics to fuel production recover measurement. PETE waste plastic has carbon chain with hydrogen combination and PETE waste plastic has carbon, hydrogen, benzene with oxygen combination and PETE waste plastic oxygen percentage more than 30%. Both plastic was heated up at 180 °C to up to 420 °C. Experimental process was monitor closely inside laboratory fume hood because during fuel production period was notice that boiling flask inside gas was generated huge amount. Sometimes temperature profile was increase and sometimes temperature profile was decreased for quality fuel product. Production process flow chart is showing in figure 1. Production process flow chart is showing waste plastic and Ferric Oxide was placed into reactor chamber then condensation unit, and alkali solution was use for light gas cleaning NaOH, NaHCO₃ and water. Light gas was produce during fuel production period and gas was captured into Teflon bag by using small pump. Residue was collected after fuel production finished when is reactor was cool down. In mass balance calculation production result showed liquid fuel was 50.1 gm, light gas was produced 16.5 gm and residue and solid pest was 24.4 gm + 9 gm. During production period PETE waste plastic was unable to fuel conversion into fuel because PETE waste plastic has Oxygen content more than 30% which was not convertible. It's was coming as solid pest wise and it collected from condensation and weight was 9 gm. The PETE waste plastic to fuel production period its try to block the condensation unit and it coming out with liquid fuel which is shown in figure 2 and figure 3 and total experiment run time was 4 hour 35 minute. From liquid fuel to wax part was removing after filtering process and solid wax part keep into separate container. This type of solid wax portion was coming from PETE waste plastic because PETE has high percentage of Oxygen. Light gas analysis is under investigation. Liquid and light gas percentage was 66.6%, residue was 9% and solid pest was 24.4% which was not convertible see figure 2. Some portion of sediment part was come out with liquid fuel

and shown into figure 3. Fuel sediment was separated by filtering system. Fuel color is light yellow and fuel is ignite.

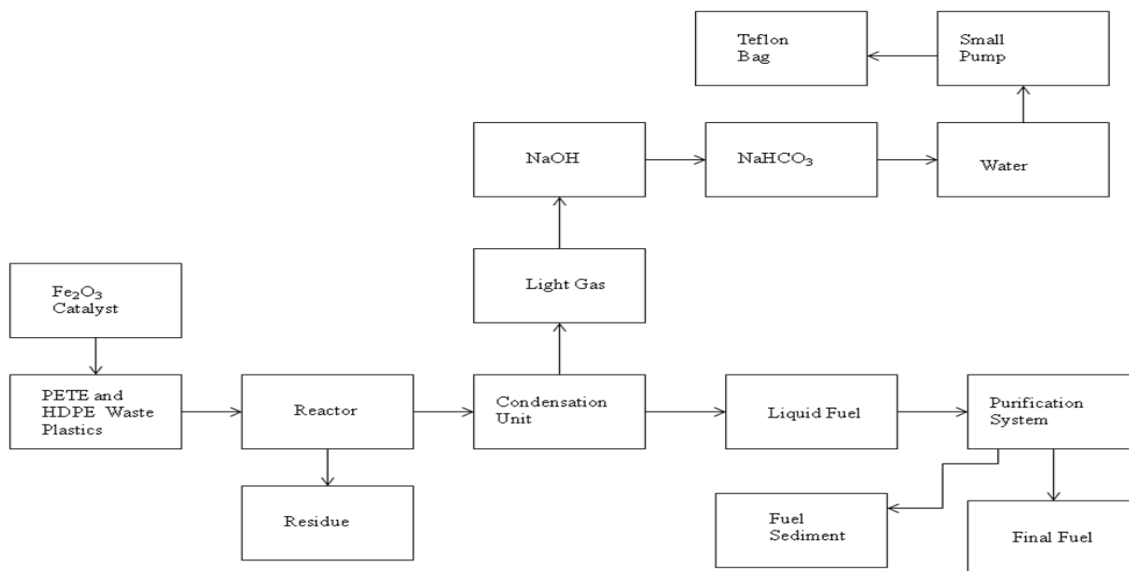


Figure 1: HDPE and PETE mixture to fuel production

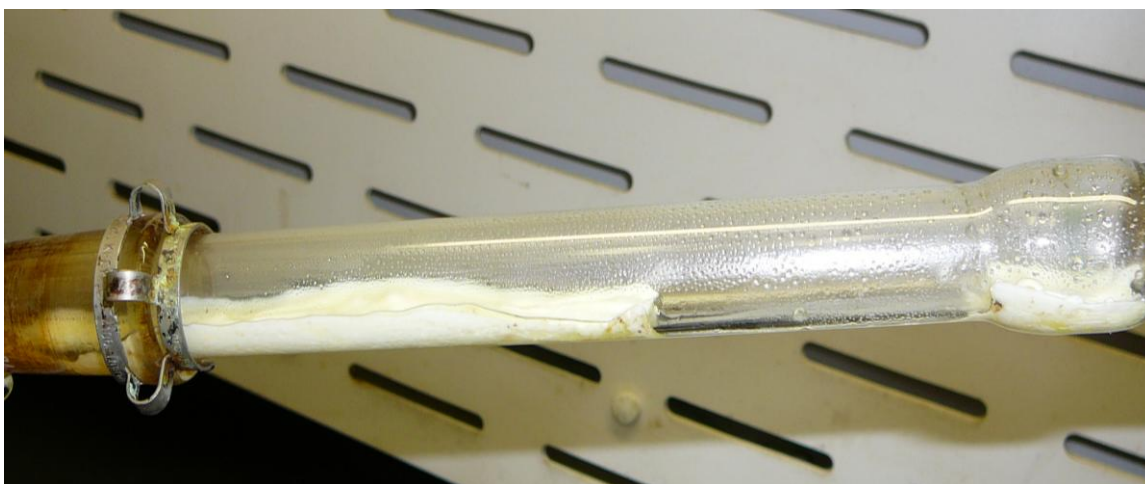


Figure 2: Wax type materials in the condensation pipe inside during PETE and HDPE waste plastic mixture to fuel production period.



Figure 3: PETE and HDPE waste plastics mixture to fuel with wax

IV. RESULT AND DISCUSSION

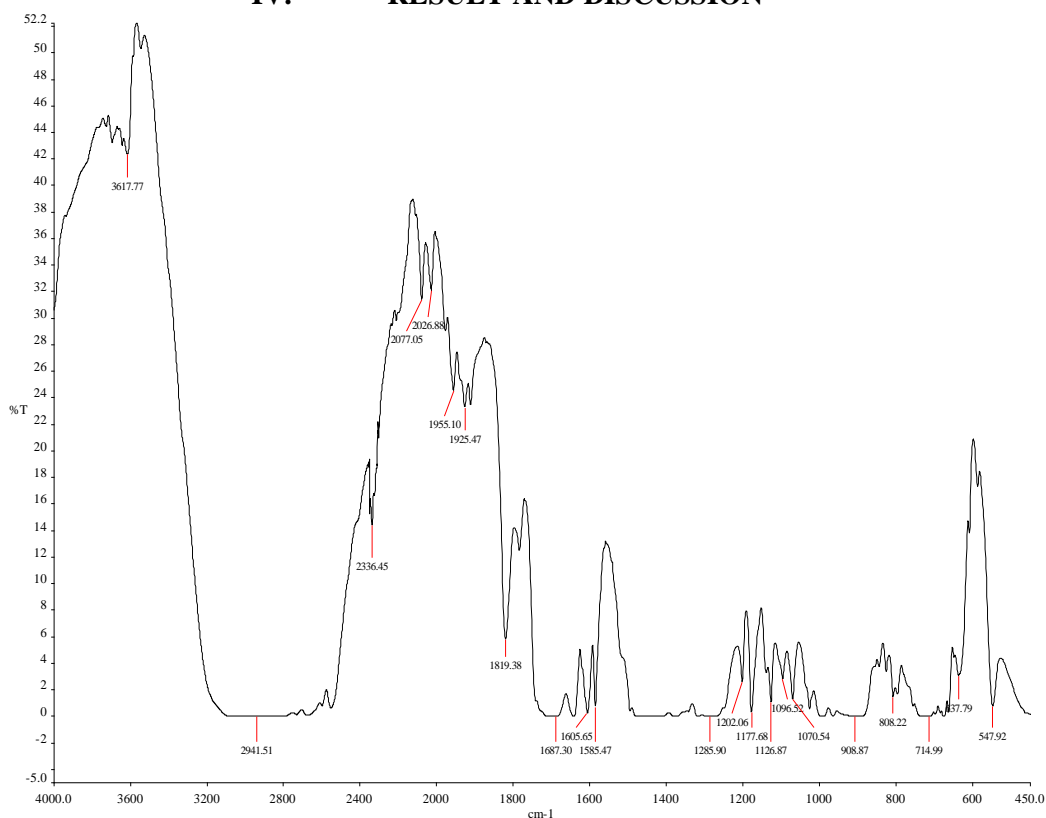


Figure 4: FT-IR spectrum of PETE and HDPE mixture to fuel

Table 1: FT-IR spectrum functional group list of PETE and HDPE mixture to fuel

Number of Wave	Wave Number	Compound/Functional Group
1	3617.77	Free OH
2	2941.51	C-CH ₃
3	2336.45	
4	2077.05	C-C= -C-C= -CH
5	2026.88	
6	1955.10	
7	1925.47	
8	1819.38	Non-Conjugated
9	1687.30	Non-Conjugated
10	1605.65	Non-Conjugated
11	1585.47	Conjugated
12	1285.90	
13	1202.06	
14	1177.68	~Formates
15	1126.87	
16	1096.52	
17	1070.54	
18	908.87	-CH=CH ₂ -
19	808.22	
20	714.99	-CH=CH-(cis)
21	637.79	-CH=CH-(cis)
22	547.92	

FTIR analysis of 25% PETE and 75% HDPE with 5% Activated Carbon and 2% Fe₂O₃ to fuel (figure 4 and table 1) according to their wave number and spectrum band following types of functional groups are appeared in the analysis. In the spectrum field we noticed that higher wave number are emerged in the initial phase and middle index of the spectrum in higher wave number small and bulky both functional groups are available and

in low wave number double bond and single bond functional groups are available such as methane group, trans and alkene group etc. Hereafter wave number 3617.77 cm^{-1} functional group is Free OH, wave number 2941.51 cm^{-1} , functional group is C-CH₃, wave number 2077.05 cm^{-1} , functional group is C-C= -C-C= -CH, wave number 2186.56 cm^{-1} functional group is C-C=C-C=CH, wave number 1819.38 cm^{-1} , 1687.30 cm^{-1} and 1605.65 cm^{-1} functional group is Non-Conjugated, wave number 1585.47 cm^{-1} , functional group is Conjugated, wave number 1177.68 cm^{-1} functional group is ~Formates, wave number 908.87 cm^{-1} functional group is -CH=CH₂-, and ultimately wave number 714.99 cm^{-1} and 637.79 cm^{-1} functional group is -CH=CH-(cis) as well. Energy values are calculated, using formula is $E=h\nu$, Where h =Planks Constant, $h = 6.626 \times 10^{-34}\text{ J}$, ν =Frequency in Hertz (sec^{-1}), Where $\nu = c/\lambda$, c =Speed of light, where, $c = 299,792,458\text{ m/s}$, $W = 1/\lambda$, where λ is wave length and W is wave number in cm^{-1} . Therefore the equation $E=h\nu$, can substitute by the following equation, $E=hcW$. According to their wave number several energy values are calculated such as for wave number $3671.77\text{ (cm}^{-1}\text{)}$ calculated energy, $E = 7.18 \times 10^{-20}\text{ J}$, wave number $2941.51\text{ (cm}^{-1}\text{)}$ calculated energy, $E = 5.84 \times 10^{-20}\text{ J}$, wave number $2077.05\text{ (cm}^{-1}\text{)}$, calculated energy, $E = 4.12 \times 10^{-20}\text{ J}$, wave number $1819.38\text{ (cm}^{-1}\text{)}$, calculated energy, $E = 3.61 \times 10^{-20}\text{ J}$, wave number $1585.47\text{ (cm}^{-1}\text{)}$, calculated energy, $E = 3.14 \times 10^{-20}\text{ J}$, wave number $908.87\text{ (cm}^{-1}\text{)}$, calculated energy, $E = 1.80 \times 10^{-20}\text{ J}$ and ultimately wave number $714.99\text{ (cm}^{-1}\text{)}$, calculated energy, $E = 1.42 \times 10^{-20}\text{ J}$ respectively .

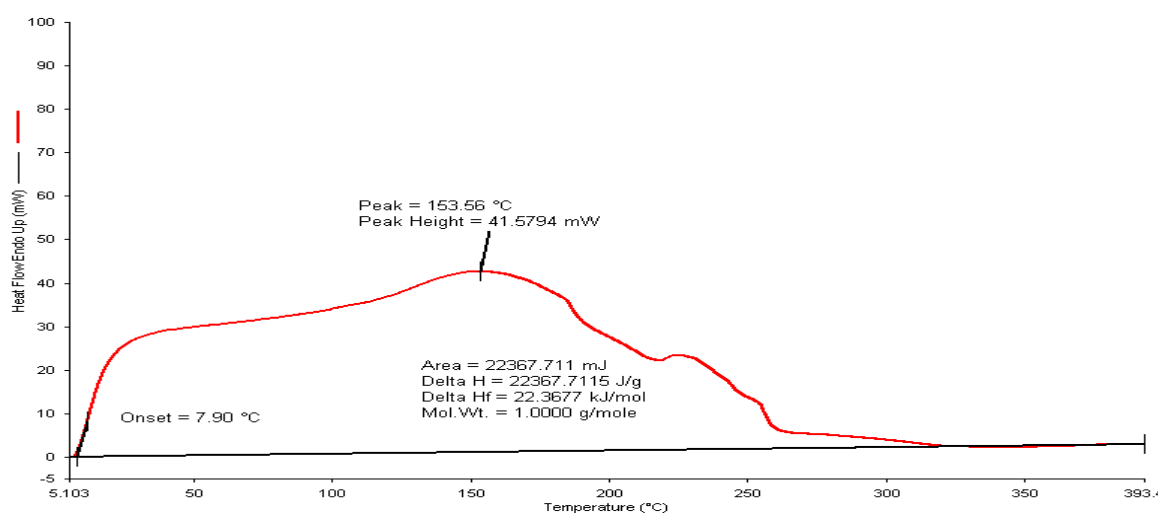


Figure 5: DSC graph of PETE and HDPE waste plastics mixture to fuel

PETE and HDPE waste plastics mixture to fuel product was analysis (Figure 5) by DSC for fuel enthalpy value. DSC run temperature was $5\text{ }^{\circ}\text{C}$ to $400\text{ }^{\circ}\text{C}$ and temperature ramping rate was $10\text{ }^{\circ}\text{C}$. DSC carrier gas was use Nitrogen and pan was use aluminum. DSC fuel graph showed onset temperature is $7.90\text{ }^{\circ}\text{C}$, Peak is 153.56 and peak height is 41.5794 mW . Graph area is 22367.711 mJ , delta H value or enthalpy value is 22367.7115 J/g and a delta Hf value is 22.3677 kJ/mol .

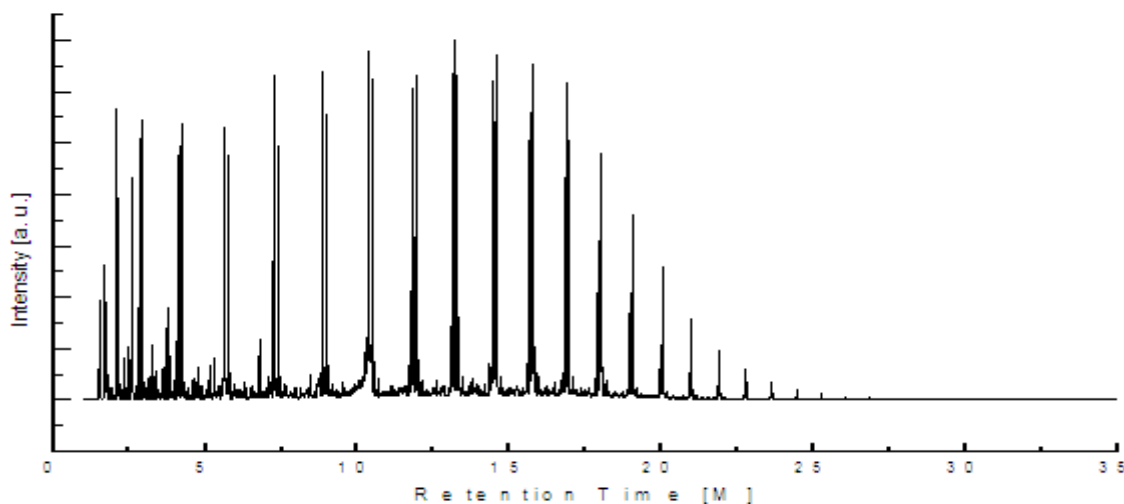


Figure 6: GC/MS Chromatogram of PETE and HDPE waste plastics mixture to fuel

Table 2: GC/MS Chromatogram compounds list of PETE and HDPE waste plastics mixture to fuel

Peak Number	Retention Time (M.)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular weight	Probability Percentage	NIST Library Number
1	1.48	41	Propane	C ₃ H ₈	44	58.1	18863
2	1.54	41	Butane, 1-isocyano-	C ₅ H ₉ N	83	28.1	39412
3	1.69	42	Cyclopropane, ethyl-	C ₅ H ₁₀	70	21.9	19072
4	1.71	43	Pentane	C ₅ H ₁₂	72	83.4	114462
5	1.79	67	1,3-Pentadiene	C ₅ H ₈	68	25.7	291890
6	1.95	42	Butane, 2,3-dimethyl-	C ₆ H ₁₄	86	13.8	291518
7	2.08	56	Cyclopropane, 1-ethyl-2-methyl-, cis-	C ₆ H ₁₂	84	20.9	113658
8	2.12	57	Hexane	C ₆ H ₁₄	86	85.5	61280
9	2.16	55	3-Hexene, (Z)-	C ₆ H ₁₂	84	22.9	114381
10	2.22	67	Cyclobutene, 3,3-dimethyl-	C ₆ H ₁₀	82	7.91	62288
11	2.33	56	Cyclopentane, methyl-	C ₆ H ₁₂	84	63.5	114428
12	2.41	79	1,3-Cyclopentadiene, 5-methyl-	C ₆ H ₈	80	16.1	419
13	2.50	67	Cyclopentene, 1-methyl-	C ₆ H ₁₀	82	13.8	107747
14	2.59	78	Benzene	C ₆ H ₆	78	68.5	291514
15	2.76	67	Cyclohexene	C ₆ H ₁₀	82	16.9	114431
16	2.85	56	1-Heptene	C ₇ H ₁₄	98	36.4	107734
17	2.94	43	Heptane	C ₇ H ₁₆	100	75.9	61276
18	3.02	41	2-Heptene	C ₇ H ₁₄	98	28.0	113119
19	3.10	81	Cyclopropane, trimethylmethylene-	C ₇ H ₁₂	96	9.97	63085
20	3.18	81	Cyclopentane, 1-methyl-2-methylene-	C ₇ H ₁₂	96	12.4	62523
21	3.25	83	Cyclohexane, methyl-	C ₇ H ₁₄	98	62.0	118503
22	3.36	69	Cyclopentane, ethyl-	C ₇ H ₁₄	98	74.2	231044
23	3.47	81	Norbornane	C ₇ H ₁₂	96	9.92	114371
24	3.57	81	Cyclobutane, (1-methylethylidene)-	C ₇ H ₁₂	96	18.9	150272
25	3.62	67	1-Ethylcyclopentene	C ₇ H ₁₂	96	42.5	114407
26	3.76	91	Toluene	C ₇ H ₈	92	42.5	291301
27	3.82	81	Cyclohexene, 1-methyl-	C ₇ H ₁₂	96	19.2	139432
28	3.96	79	3-Oxabicyclo[4.3.0]non-8-en-2-one, cis-	C ₈ H ₁₀ O ₂	138	15.0	153194
29	4.09	55	1-Octene	C ₈ H ₁₆	112	19.5	227923
30	4.13	55	Cyclopentane, 1-ethyl-2-methyl-	C ₈ H ₁₆	112	17.7	150594
31	4.23	43	Octane	C ₈ H ₁₈	114	42.3	229407
32	4.30	55	2-Octene, (Z)-	C ₈ H ₁₆	112	24.2	113889
33	4.34	95	Bicyclo[3.1.0]hexan	C ₈ H ₁₄	110	11.7	142175

34	4.62	67	e, 1,5-dimethyl- 1-Methyl-2- methylenecyclohexane	C ₈ H ₁₄	110	32.2	113437
35	4.72	41	Cyclopentane, propyl-	C ₈ H ₁₆	112	13.6	142655
36	4.77	83	Cyclohexane, ethyl-	C ₈ H ₁₆	112	65.0	113476
37	4.82	43	2,4-Dimethyl-1- heptene	C ₉ H ₁₈	126	60.1	113516
38	5.15	91	Ethylbenzene	C ₈ H ₁₀	106	62.6	114918
39	5.29	81	Cyclohexane, ethylidene-	C ₈ H ₁₄	110	10.7	118885
40	5.43	55	Cyclohexane, cyclopropyl-	C ₉ H ₁₆	124	21.6	26670
10	5.47	41	1,8-Nonadiene	C ₉ H ₁₆	124	27.3	227629
42	5.63	56	1-Nonene	C ₉ H ₁₈	126	19.5	107756
43	5.77	43	Nonane	C ₉ H ₂₀	128	34.9	228006
44	5.85	55	cis-2-Nonene	C ₉ H ₁₈	126	15.2	113508
45	5.97	55	trans--4-Nonene	C ₉ H ₁₈	126	12.9	113512
46	6.06	41	2,4-Undecadien-1-ol	C ₁₁ H ₂₀ O	168	10.4	136410
47	6.30	55	Cyclohexane, propyl-	C ₉ H ₁₈	126	30.4	249350
48	6.53	67	Cyclopentene, 1- butyl-	C ₉ H ₁₆	124	32.4	113491
49	6.79	77	Benzaldehyde	C ₇ H ₆ O	106	75.1	291541
50	7.10	55	1,9-Decadiene	C ₁₀ H ₁₈	138	13.7	155383
51	7.26	41	1-Decene	C ₁₀ H ₂₀	140	18.3	107686
52	7.31	55	Cyclopentanol, 1-(1- methylene-2- propenyl)-	C ₉ H ₁₄ O	138	14.0	152742
53	7.40	43	Decanes	C ₁₀ H ₂₂	142	37.4	114147
54	7.46	55	cis-3-Decene	C ₁₀ H ₂₀	140	14.0	113558
55	7.60	41	9- Oxabicyclo[6.1.0]no nane, 1-methyl-, cis-	C ₉ H ₁₆ O	140	10.3	46594
56	7.67	55	Cyclopentane, 1- methyl-3-(2- methylpropyl)-	C ₁₀ H ₂₀	140	11.0	63333
57	8.46	105	Acetophenone	C ₈ H ₈ O	120	13.2	34989
58	8.70	41	1,10-Undecadiene	C ₁₁ H ₂₀	152	11.0	113574
59	8.85	55	1-Undecene	C ₁₁ H ₂₂	154	7.08	5022
60	8.91	41	Pentafluoropropioni c acid, 10-undecenyl ester	C ₁₄ H ₂₁ F ₅ O ₂	316	5.12	280071
61	8.99	57	Undecane	C ₁₁ H ₂₄	156	39.3	114185
62	9.04	55	3-Undecene, (Z)-	C ₁₁ H ₂₂	154	13.9	142598
63	9.53	105	Benzoyl bromide	C ₇ H ₅ Br O	184	6.12	226735
64	10.23	105	Cyclohexanamine, N-(benzoyloxy)-	C ₁₃ H ₁₇ NO ₂	219	23.6	185471
65	10.38	55	1-Dodecene	C ₁₂ H ₂₄	168	7.03	107688
66	10.50	57	Dodecane	C ₁₂ H ₂₆	170	31.8	291499
67	10.55	55	3-Dodecene, (E)-	C ₁₂ H ₂₄	168	11.2	113960

68	10.68	41	6-Dodecene, (Z)-	C ₁₂ H ₂₄	168	11.9	142611
69	11.68	55	1,12-Tridecadiene	C ₁₃ H ₂₄	180	14.3	7380
70	11.81	55	1-Tridecene	C ₁₃ H ₂₆	182	14.9	107768
71	11.84	41	Z-10-Pentadecen-1-ol	C ₁₅ H ₃₀ O	226	6.23	245485
72	11.93	57	Tridecane	C ₁₃ H ₂₈	184	51.0	114282
73	11.97	55	2-Tridecene, (Z)-	C ₁₃ H ₂₆	182	9.81	142613
74	12.11	55	5-Tridecene, (E)-	C ₁₃ H ₂₆	182	7.90	142619
75	13.05	55	E-10-Pentadecenol	C ₁₅ H ₃₀ O	226	5.13	245484
76	13.11	154	Biphenyl	C ₁₂ H ₁₀	154	74.5	114218
77	13.17	55	1-Hexadecene	C ₁₆ H ₃₂	224	6.44	118882
78	13.29	57	Tetradecane	C ₁₄ H ₃₀	198	38.5	113925
79	13.32	55	3-Tetradecene, (E)-	C ₁₄ H ₂₈	196	9.80	139981
80	14.46	55	1-Pentadecene	C ₁₅ H ₃₀	210	8.21	69726
81	14.56	57	Pentadecane	C ₁₅ H ₃₂	212	40.1	107761
82	14.59	55	Dichloroacetic acid, 3-pentadecyl ester	C ₁₇ H ₃₂ Cl ₂ O ₂	338	3.63	280648
83	14.72	55	E-2-Hexadecacen-1-ol	C ₁₆ H ₃₂ O	240	12.8	131101
84	15.67	55	1-Hexadecene	C ₁₆ H ₃₂	224	10.8	118882s
85	15.77	57	Hexadecane	C ₁₆ H ₃₄	226	39.5	114191
86	15.80	55	1-Hexadecene	C ₁₆ H ₃₂	224	6.50	118882
87	15.93	55	Cyclopentane, undecyl-	C ₁₆ H ₃₂	224	4.54	10583
88	16.73	55	E-2-Octadecadecen-1-ol	C ₁₈ H ₃₆ O	268	14.0	131102
89	16.82	55	E-14-Hexadecenal	C ₁₆ H ₃₀ O	238	9.46	130980
90	16.91	57	Heptadecane	C ₁₇ H ₃₆	240	36.1	107308
91	16.94	55	8-Heptadecene	C ₁₇ H ₃₄	238	11.3	113620
92	17.91	55	E-15-Heptadecenal	C ₁₇ H ₃₂ O	252	19.6	130979
93	18.00	57	Octadecane	C ₁₈ H ₃₈	254	29.9	57273
94	18.03	55	E-7-Octadecene	C ₁₈ H ₃₆	252	8.53	130920
95	18.96	55	1-Nonadecene	C ₁₉ H ₃₈	266	11.4	113626
96	19.04	57	Nonadecane	C ₁₉ H ₄₀	268	15.1	114098
97	19.20	55	9-Nonadecene	C ₁₉ H ₃₈	266	15.7	113627
98	19.95	55	1-Nonadecene	C ₁₉ H ₃₈	266	7.73	113626
99	20.02	57	Eicosane	C ₂₀ H ₄₂	282	33.2	290513
100	20.19	55	1-Eicosanol	C ₂₀ H ₄₂ O	298	7.62	113075
101	20.91	43	1-Docosene	C ₂₂ H ₄₄	308	9.91	113878
102	20.97	57	Heneicosane	C ₂₁ H ₄₄	296	30.0	107569
103	21.88	57	Heneicosane	C ₂₁ H ₄₄	296	15.8	107569
104	22.06	55	10-Heneicosene (c,t)	C ₂₁ H ₄₂	294	10.0	113073
105	22.72	43	1-Docosene	C ₂₂ H ₄₄	308	15.0	113878
106	22.76	57	Heneicosane	C ₂₁ H ₄₄	296	12.6	107569
107	23.62	57	Heneicosane	C ₂₁ H ₄₄	296	12.6	107569
108	24.44	57	Heneicosane	C ₂₁ H ₄₄	296	7.93	107569
109	25.25	57	Nonadecane	C ₁₉ H ₄₀	268	8.83	114098

110	26.03	57	Eicosane	C ₂₀ H ₄₂	282	7.88	149863
111	26.81	43	Heptacosane	C ₂₇ H ₅₆	380	7.25	150574

PETE and HDPE waste plastic to fuel production process was thermal with Ferric Oxide catalyst to accelerated the reaction. Product fuel percentage was 66.6% and rest of percentage was residue and white color solid pest. Because PETE waste plastic has Oxygen content and it was not convertible. Product fuel was analysis by GC/MS (Figure 6) and chromatogram was analysis by using NIST library wise. In GC/MS analysis indicate that product fuel has hydrocarbon compounds including oxygen content, alcoholic group, aromatic group, nitrogen content and halogenated compounds. Analysis was perform base on retention time (m) and traces mass (m/z). During GC/MS analysis period fuel compounds, molecular weight, trace mass, probability percentage and NIST library number was determine showed into table 2. Initial compounds was detected from GC/MS chromatogram Propane (C₃H₈) (t=1.48, m/z=41) molecular weight 44 and probability percentage is 58.1%, and largest carbon number compounds is Heptacosane (C₂₇H₅₆) (t=26.81, m/z= 43) molecular weight is 380 and probability percentage is 7.25%. Aromatics group compounds is appeared into GC/MS analysis Toluene (C₇H₈) (t=3.36, m/z=91) molecular weight is 92 and probability percentage is 42.5%, Ethylbenzene (C₈H₁₀) (T=5.15, m/z=91) molecular weight is 106 and probability percentage is 62.6% and so on. Alcoholic compounds was detected 2,4-Undecadien-1-ol (C₁₁H₂₀O) (t=6.06, m/z=41) compound molecular weight is 168 and probability percentage is 10.4%, 1-(1-methylene-2-propenyl)-Cyclopentanol (C₉H₁₄O) (t=7.31, m/z=55) molecular weight is 138 and probability percentage is 14.0% and so on. Oxygen compounds appeared into GC/MS analysis and showed Benzaldehyde (C₇H₆O) (t=6.79, m/z=77) molecular weight is 106 and probability percentage is 75.1% E-14-Hexadecenal (C₁₆H₃₀O) (t=16.82, m/z=55) molecular weight is 238 and probability percentage is 9.46%. Nitrogen and halogen group compounds was appeared form GC/MS analysis such as 1-isocyano-Butane (C₅H₉N) (t=1.54, m/z=41) molecular weight is 83 and probability percentage is 28.1%, Dichloroacetic acid, 3-pentadecyl ester (C₁₇H₃₂Cl₂O₂) (t=14.59, m/z=55) molecular weight is 338 and probability percentage is 3.63%. Product fuel has short chain hydrocarbon C₃H₈ to long chain hydrocarbon C₂₇H₅₆ for that reason fuel can use as a diesel or heating fuel.

V. CONCLUSION

PETE and HDPE waste plastic to fuel production process was successfully with Fe₂O₃ and activated carbon. Laboratory scale batch process was under laboratory fume hood at temperature 420 °C. Product fuel density is 0.76 g/ml and conversion rate was liquid and light gas 66.6 % and rest of percentage was wax and solid black residue. Fuel was analysis by FTIR to identify functional group inside fuel and found that C-CH₃, C=C, -C-C=, -CH, -CH=CH₂-, -CH=CH-(cis), Non-Conjugated and Conjugated. Product fuel has enthalpy value. GC/MS analysis result indicates that fuel has hydrocarbon chain C₃ to C₂₇, aromatic group, alcoholic group, oxygen content, nitrogen content and halogen content. PETE and HDPE waste plastics mixture to fuel production period produce fuel and wax mixture can separated by using filtering system. Solid waxy portion can separate by micron filter process. Then fuel can use as a clean fuel in to internal combustion engine. Residue and catalyst recovery is under investigation. By using this technology PETE and HDPE to fuel recovery process can work easy ways at temperature 420 °C. Although PETE has high percentage of Oxygen content (33.3%) and rest of percentage can convert as liquid fuel. The technology can solve the PETE and HDPE waste plastics dumping and landfill problem as well as environmental problem.

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REFERENCES

- [1] Mastral, J. F.; Esperanza, E.; Garcia, P.; Juste, M. Pyrolysis of HDPE in a fluidised bed reactor. Influence of the temperature and residence time. *J. Anal. Appl. Pyrolysis* 2002, 63, 1.
- [2] Williams, P. T.; Williams, E. A. Fluidised bed pyrolysis of low density PE to produce petrochemical feedstock. *J. Anal. Appl. Pyrolysis* 1999, 51, 107.
- [3] Kaminsky, W.; Schmidt, H.; Simon, C. M. Recycling of mixed plastics by pyrolysis in a fluidised bed. *Macromol. Symp.* 2000, 152, 191.
- [4] Onu, P.; Vasile, C.; Ciocilteu, S.; Iojoiu, E.; Darie, H. Thermal and catalytic decomposition of PE and PP. *J. Anal. Appl. Pyrolysis* 1999, 49,145.

- [5] Seeker, R. Combustion By-Product Formation: An Overview. In Proceedings of the Twenty-Third Symposium (International) on Combustion; The Combustion Institute: Pittsburgh, PA, 1990; pp 867-885.
- [6] Stefan Czernik and Richard J. French, Production of Hydrogen from Plastics by Pyrolysis and Catalytic Steam Reform, *Energy & Fuels* 2006, 20, 754-758
- [7] Arandes, J. M.; Abajo, I.; Lopez-Valerio, D.; Fernandez, I.; Azkoiti, M. J.; Olazar, M.; Bilbao, J. Transformation of several plastic wastes into fuels by catalytic cracking. *Ind. Eng. Chem. Res.* 1997, 36, 4523.
- [8] Aguado, J.; Serrano, D. P.; Escola, J. M.; Garagorri, E.; Fernandez, J. A. Catalytic conversion of polyolefins into fuels over zeolite beta. *Polym. Degrad. Stab.* 2000, 69, 11.
- [9] San You, Y.; Kim, J-H.; Seo, G. Liquid-phase catalytic degradation of polyethylene wax over MFI zeolites with different particle size. *Polym. Degrad. Stab.* 2000, 70, 365.
- [10] Ranzi, E.; Dente, M.; Faravelli, T.; Bozzano, G.; Fabini, S.; Nava, R.; Cozzani, V.; Tognotti, L. Kinetic modeling of polyethylene and polypropylene thermal degradation. *J. Anal. Appl. Pyrolysis* 1997, 40-41, 305.
- [11] Westerhout, R. W. J.; Waanders, J.; Kuipers, J. A. M.; van Swaaij, W. P. M. Recycling of polyethene and polypropene in a novel bench-scale rotating cone reactor by high-temperature pyrolysis. *Ind. Eng. Chem. Res.* 1998, 37, 2293.
- [12] Bockhorn, H.; Hornung, A.; Hornung, U.; Schawaller, D. Kinetic study on the thermal degradation of polypropylene and polyethylene. *J. Anal. Appl. Pyrolysis* 1999, 48, 93.
- [13] J. Aguado, D. P. Serrano, G. Vicente, and N. Sanchez, Enhanced Production of α -Olefins by Thermal Degradation of High-Density Polyethylene (HDPE) in Decalin Solvent: Effect of the Reaction Time and Temperature, *Ind. Eng. Chem. Res.* 2007, 46, 3497-3504
- [14] Sato, S.; Murakata, T.; Baba, S.; Saito, Y.; Watanabe, S. Solvent effect on thermal degradation of polystyrene. *J. Appl. Polym. Sci.* 1990, 40, 2065.
- [15] Karaduman, A.; Sümsük, E. H.; Cüçük, B.; Bilgesu, A. Y. Thermal degradation of polystyrene wastes in various solvents. *J. Anal. Appl. Pyrolysis* 2002, 62, 273.
- [16] J. Aguado, D. P. Serrano, G. Vicente, and N. Sanchez, Enhanced Production of α -Olefins by Thermal Degradation of High-Density Polyethylene (HDPE) in Decalin Solvent: Effect of the Reaction Time and Temperature, *Ind. Eng. Chem. Res.* 2007, 46, 3497-3504