A new technology proposed to recycle waste plastics into hydrocarbon fuel in USA

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Abstract
Energy crisis and environmental degradation by polymer wastes have been imperative to find and propose technologies for recovery of raw materials and energy from non-conventional sources like plastic wastes. A variety of methods and processes connected with global or national policies have been proposed worldwide. A new type of steel reactor is proposed for conversion of waste plastics to fuel like mixture of hydrocarbons. The results of the thermal degradation of waste plastics in the laboratory scale set-up based on this process in the paper. The melting and thermal cracking processes were carried out in a single batch process at the temperature range is 200–420 ºC. The final product consisted of light gas 6.3 % and liquid product 90%. 3.7% solid black products were produced. The light, ''gas'' fraction of the hydrocarbons mixture (C_1–C_4) and rest of liquid fuel made over 90% of the liquid product. It may be used for fuel production refinery or electricity generation.

Keywords: Waste plastic; Thermal degradation; Hydrocarbon; Fuel; Activated carbon.

1. Introduction
Effective utilization of plastic waste is vital for the implementation of well known "three Rs", reduction, reuse and recycle. Methods for achieving threes "three Rs" need to be established. In recent years approximately 15 million tones of post consumer plastic waste is generated through out Europe each year, while in the United States 20 million tones of waste are generated [1]. The effectiveness of utilizing the "three r" method depends on the quality and condition of the plastic material. However, at the present time, the rate of energy recovery from plastic waste stands at 41%, with 18% being effectively used for material recycling and only 3% being used for chemical recycling. This later percentage value needs to be substantially increased, so as to curb the consumption of natural resources and reduce pollution to the environment.

The rapid rate of plastic consumption throughout the world has led to the creation of increasing amounts of waste and this in turn poses greater difficulties for disposal. This is due to the fact that duration of life of plastic wastes is very small [2] and depending on the area of application, the service life of plastic product ranges from 1 to 35 years [3]. The weighted average service life of all plastics products is different in different countries based on the counties life style and economy. Plastic wastes can be classified as industrial and municipal waste plastic according to their origins; these groups have different qualities and properties and are subjected to different management strategies [4]. A waste plastic

represents a considerable part of municipal wastes; furthermore huge amount of waste plastic arise as a byproduct or faulty product in industry and agriculture [5]. Thermo plastics are composed of polyolefin such as high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PETE) and polyvinyl chloride (PVC) [6] and can be recycled. On the other hand thermosets mainly include epoxy resins and polyurethanes and cannot be recycled.

Several methods for chemical recycling are presently in use, such as direct chemical treatment involving gasification, smelting by blast furnace [7] or coke oven [8], and degradation by liquefaction [9] and gasification [10]. Condensation polymers such as PETE and nylon undergo degradation to produce monomer units [11], while from vinyl polymers such as polyolefins, a mixture containing numerous components may be obtained for use as a fuel. Catalytic cracking and reforming facilitate the selective degradation of waste plastics. The use of solid catalysts such as silica-alumina, ZSM-5, Zeolites, and mesoporous materials [11-15] for these purposes has been reported. These materials effectively convert polyolefins into liquid fuel, giving lighter fractions as compared to thermal cracking.

Thermal degradation of mixed plastics is currently receiving renewed interest as route for disposal if the large quantities of plastic wastes collected by different collecting systems. The advantage of thermal degradation of macromolecules in the absence of air (pyrolysis) compared to combustion is a reduction in the volume of product gases by a factor of 5-20 which leads to considerable savings in the gas conditioning equipment. Furthermore, it is possible to obtain valuable hydrocarbon compounds. The pyrolysis is complicated by the fact that plastics show poor thermal conductivity while the degradation of macromolecules requires large amounts of energy. The objective of this paper is to demonstrate a new technology utilizing thermal degradation for converting the vast amount of waste plastic to useful hydrocarbon fuel. The efficiency of this technology is robust and the applications are feasible at a low cost.

2. Method and materials

2.1 Sample preparation

Raw waste plastic samples collected from local municipality and they are decontaminated through washing and cut manually and prior to the experiment process. Grounded waste plastic size was 3-4 mm. Three different type of waste plastics (LDPE, HDPE and PP) are pre analyzed using different equipments. Gas Chromatography with pyroprobe and Mass Spectrometer, Thermogavimetric (TGA Pyris-1), Elemental Analyzer 2400 and FT-IR used for pre-analysis. Grounded waste plastics are transferd into reactor chamber manually and set up for thermal liquefaction process. This experiment is lab scale batch process.

2.2 Process description

Waste plastic to fuel production experimental purpose used three types of waste plastic such as high density polyethylene (HDPE), low density polyethylene (LDPE) and polypropylene (PP) waste plastic. 20% of HDPE, 30% of LDPE and 50% of PP waste plastic was used by weight %. Activated carbon used 1% by weight for this experiment. Waste plastic to fuel production process heat applied range 200 – 420 ºC. HDPE plastic was liquid detergent bottle (red color), LDPE shopping (grocery bag) bag (black color) and PP waste plastic used ketchup bottle (red color). Activated carbon used for color removal from the waste plasrics from produced fuel. Experimental waste plastic has different kind color which is absorbed by the activated carbon. Three kinds of waste plastics were mixed in different ratio for experiment setup. Temperature profile was setup for experiment higher from raw plastic melting point. We know HDPE, LDPE and PP plastic melting point are 130 ºC, 120ºC and 160ºC. We used temperature starting 200 ºC for quick melting and to produce the vapor faster. By using this technique we can save some time for fuel conversion from waste plastic. Grounded waste plastic are put into reactor inside then setup condenser unit and fuel collection device. Fuel collection device is hooked up to another two device one for fuel purification system with fuel sediment system (see Figure 1), fuel purification system hookup with final fuel collection device. Other one is hooked up with alkali solution chamber for cleaning light gas which is produced during production period and light gas is transferred into a Teflon bag by using small motor pump. Whole setup is conducted inside Labconco fume hood and this process is a fully closed system. This fuel production process did not use any kind of extra chemical or catalysts. This process doesn't need any vacuum system.
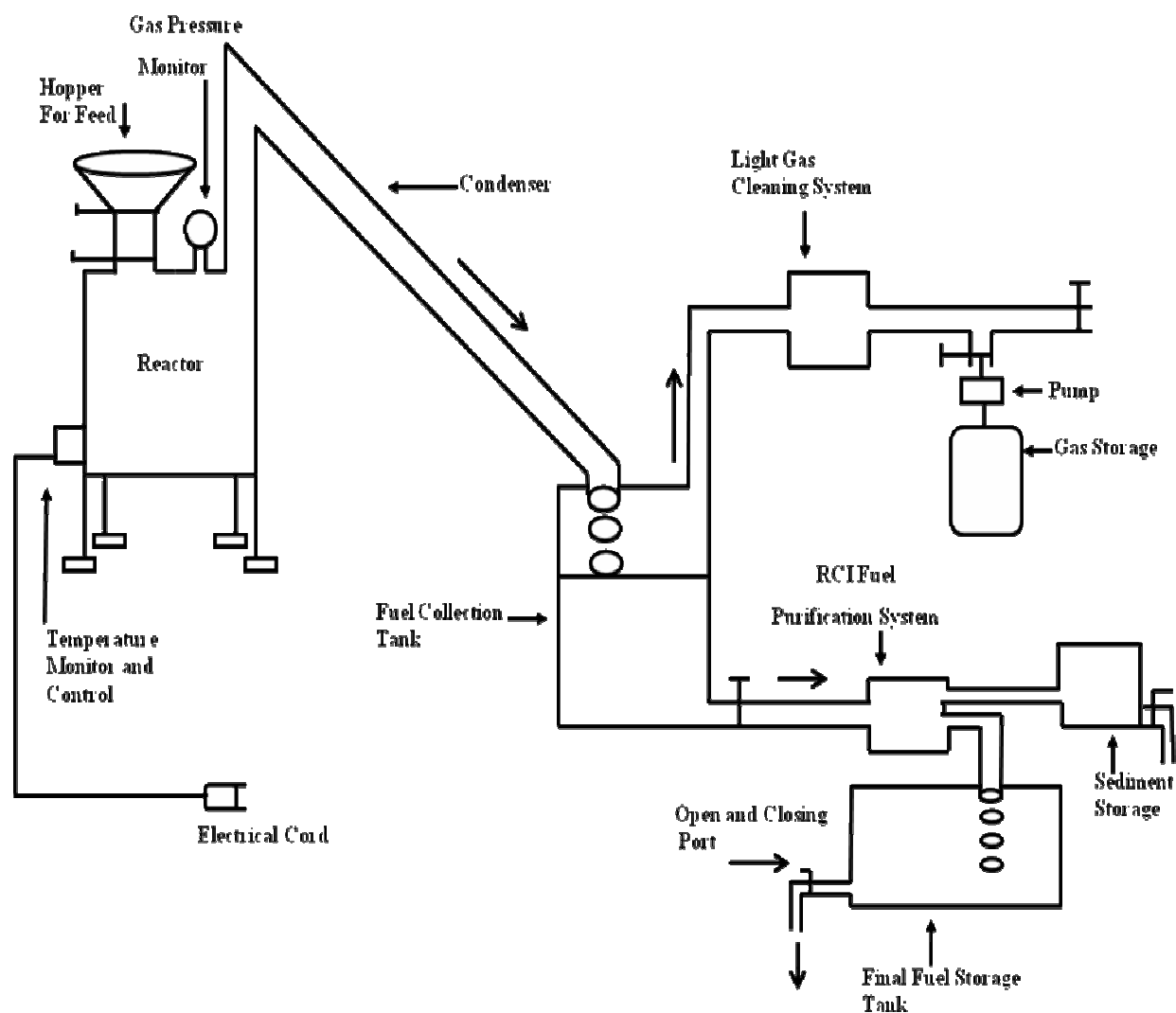
Figure 1. Schematic diagram of fuel production process with activated carbon

When temperature goes 275 ºC we saw liquid fuel was dropped into collection tank via condenser unit. When waste plastic is fully melted and turned into liquid slurry by increasing temperature gradually step by step until 420 ºC, liquid slurry to vapor and vapor turns into liquid form through condenser unit at the end we collect liquid fuel. This liquid fuel is transferred into a purification system by using a small fuel motor and the fuel is passed through a RCI purifier to micron filter system at the end we collect final pure fuel. Fuel sediment comes out through a different chamber and we can reuse another batch waste plastic to fuel production. During waste plastic to fuel production process some light gas was generated those light gas pass through from fuel collection tank to alkali solution chamber to remove contamination. That light gas was transferred into a Teflon bag for further use or analysis. During fuel production process no vacuum applied in this experiment resulting in moisture formation which reacts with heat during the fuel production. It creates $C + H_2O = CO + H_2$, $C + CO_2 = 2CO$. Those two reaction are heterogeneous, strongly endothermic and thus the raise in temperature. Both reactions are accompanied by other exothermic reaction which contributes to the formation and depletion. These are for instance $C + 1/2O_2 = CO$, $C + O_2 = CO_2$, at the end $CO + H_2O = CO_2 + H_2$. $C+ 2H_2 = CH_4$, $CO + 3H_2 = CH_4 + H_2O$, $CO_2 + 4H_2 = CH_4 + 2H_2O$. The above reaction indicates that the fuel produced is not affected by the moisture present. Thus, the vacuum is redundant for this process. The whole process was setup and finished in 4 to 4:30 mins. After the experiment finished we calculated the yield percentage and mass balance. From the experiment we found liquid fuel yielded at 90%. Rest of 10% was light gas and solid black residue. Fuel color is light yellow and liquid fuel density is 0.78 g/ml.

3. Result and discussion

3.1 Analytical technique

Perkin Elmer FT-IR (Spectrum 100) used for raw sample per analysis and liquid sample analysis. Raw waste plastic sample analyzed by diamond crystal plate KRS 5 check there functional group and band energy value. Liquid fuel sample was analyzed by NaCl cell 0.025 mm thickness. Both samples analysis by same parameter used such as scan number was 32, resolution 4 and range 4000-450 cm^{-1}.

Perkin Elmer EA-2400 analyzer was used for raw waste plastics carbon; hydrogen and nitrogen percentages determine and follow ASTM method ASTM D5291.a. Carrier gas was used helium, oxygen and nitrogen.

Perkin Elmer Thermogavimetric (TGA Pyris-1) was used for raw waste plastics onset temperature measuring. Temperature range used starting 50 to 800 ºC and temperature ramping range used for onset temperature 10 ºC/min. Helium gas used as a carrier at 20 psi.

Perkin Elmer Gas Chromatography and Mass Spectrometer used for raw waste plastic and liquid fuel analysis. Raw sample analysis purposed was used pyroprobe (CDS 5000) to volatile solid sample and transfer into GC column. Liquid sample analysis purposed was use auto sampler system. GC temperature profile for liquid sample analysis was initial temperature 40ºC and hold for 1 min and final temperature 325 ºC, hold for 15 min. total experiment run time 44.50 minutes. GC column length 30 meter and mass program set up start mass 35 to 528 and ion mode EI+.

Perkin Elmer Differential Scanning Calorimeter (DSC) was used for liquid fuel boiling point and fuel enthalpy value indication. Program temperature range was 0-400 ºC and temperature increased rate was 10 ºC/min. Carrier gas was use nitrogen at 20 ml/ min.

3.2 Pre-analysis results

Pre-analysis of raw waste plastic by using TGA for onset measuring found onset results from HDPE, LDPE and PP waste plastic such as Onset 394.09 °C, Onset 426.52 °C and Onset 344.20 °C. EA-2400 (CHN Mode) analysis results are shown from raw HDPE, LDPE and PP (Table 1).

Table 1. Raw materials (waste plastic) Carbon, Hydrogen and Nitrogen percentage

Waste Plastic Name	Carbon (C) %	Hydrogen (H) %	Nitrogen (N) %
HDPE	86.31	14.34	0.06
LDPE	86.02	14.34	0.03
PP	86.32	14.52	0.01

FT-IR analysis of raw HDPE waste plastic following types of functional groups are appeared such as wave number 2915.41 cm^{-1}, functional group is C-CH$_3$, wave number 2847.92, functional group is C-CH$_3$, and wave number 1472.55 cm^{-1} , functional group is CH$_3$, wave number 1462.30 cm^{-1},functional group is CH$_3$ and wave number 730.18 cm^{-1}, functional group is –CH=CH-(cis) etc. FT-IR analysis of raw LDPE waste plastic following types of functional groups are appeared such as wave number 2916.29 cm^{-1}, functional group is C-CH$_3$, wave number 2848.45, functional group is C-CH$_3$, and wave number 1740.93 cm^{-1} , functional group is Non-Conjugated, wave number 1472.40 cm^{-1},1462.77 cm^{-1} functional group is CH$_3$, wave number 1240.07 cm^{-1} and 1020.04 cm^{-1} functional group is Acetates and wave number 730.18 cm^{-1} and 1240.07 cm^{-1} functional group is –CH=CH- (cis) etc. FT-IR analysis of raw PP waste plastic following types of functional groups are appeared such as wave number 2950.26 cm^{-1}, functional group is C-CH$_3$, wave number 2916.91 cm^{-1} and 2837.40 cm^{-1} functional group is C-CH$_3$, and wave number 1452.83 cm^{-1}, functional group is CH$_3$, wave number 1375.78 cm^{-1} functional group is CH$_3$, wave number 997.41 cm^{-1} and 972.74 cm^{-1} functional group is Secondary Cyclic Alcohol etc are present.

3.3 Liquid fuel analysis

Three types of mixture waste plastic to produced fuel analyzed by DSC (Figure 2). 50 µL fuel used for enthalpy and fuel boiling point measuring and aluminum pan use with seal cover system. After fuel sample analysis result was shown graph fuel boil start at 5 ºC and heat flow Endo up (mW) shown 2.1166 mW. We notice that produce fuel start boil at low temperature because this fuel has some low boiling hydrocarbon compound. DSC graph shown fuel boiling high peak temperature 127.15 ºC and peak height 48.6301 mW heat flow Endo up and peak raise from start to end point showed 142.20 ºC.

Produce fuel onset temperature shown 5.15 ℃. 50 µL fuel boil start to finished enthalpy delta H value is shown 15629.0442 J/g and area need for finished boil 15629.044 mJ. We notice that from DSC graph fuel boil at 50 ℃ 13.99%, 150 ℃ fuel boil at 71.22 %, 250 ℃ fuel boil at 99.61 % and at end 393 ℃ finished fuel boil 100%. From this temperature limit shown produced fuel start boil from low temperature because this produce fuel has short chain hydrocarbon to long chain hydrocarbon and when temperature start to gradually fuel boil finished step by step that mean was goes small compound to bigger compound wise. This fuel has only short chain and long chain hydrocarbon because we used only LDPE, HDPE and PP waste plastic for this experiment. Production cost of 1 gallon of fuel by using this technique into lab scale $ 1.40 and total electricity need for 1 gallon fuel production 12.72 kWh.
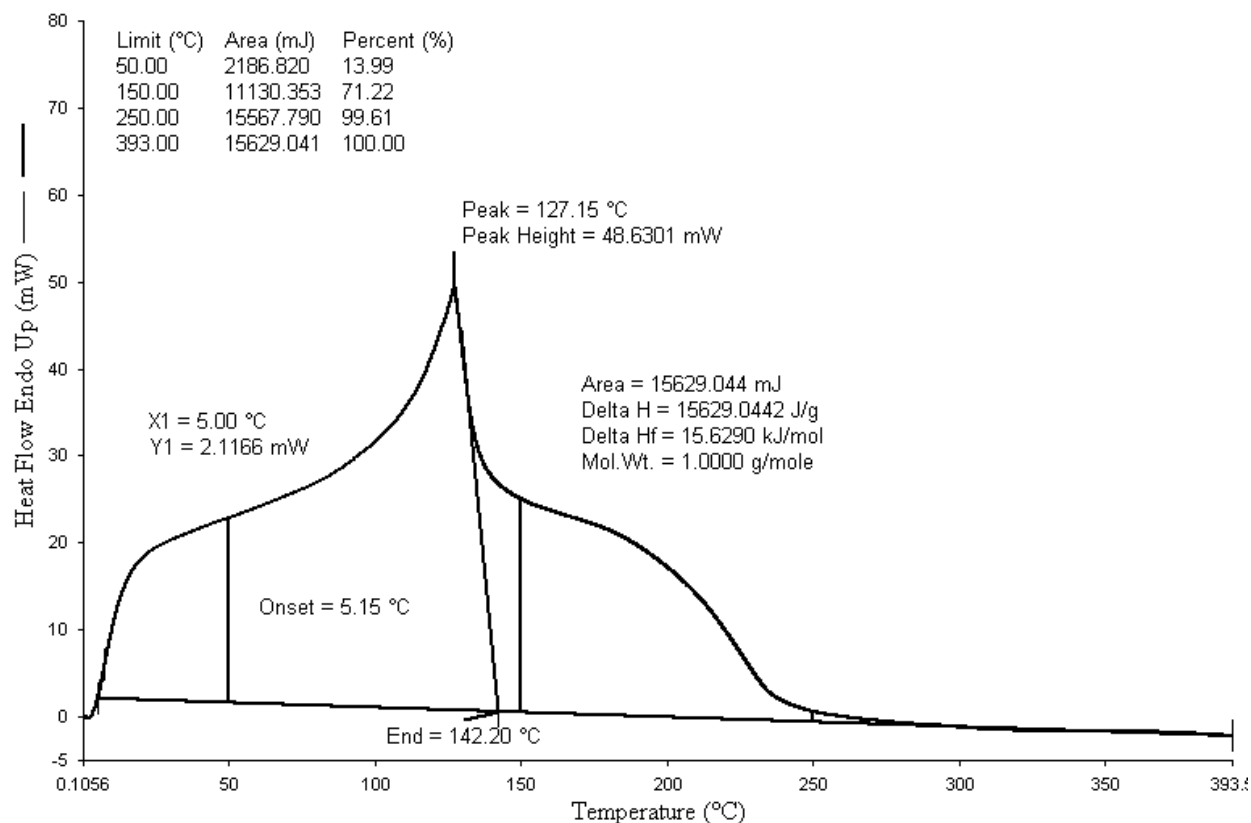

Figure 2. DSC graph of produce fuel

GC-MS Analysis of HDPE, LDPE & PP waste plastic mixture to fuel chromatogram and compound table shown in (Figure 3 and Table 2) in accordance with the various retention time and trace masses different types of hydrocarbon compound and benzene derivatives compounds are present in the analysis result index. Many compounds are emerged on the analysis carbon range C_3 to C_{27}. Based on the retention time and trace mass following hydrocarbon compounds as follows such as at the initial phase of the analysis at retention time 1.60 and trace mass 41, compound is 1-Propene, 2-methyl- (C_4H_8), retention time 1.87 and trace mass 42, compound is Cyclopropane, ethyl- (C_5H_{10}), retention time 1.91 and trace mass 39, compound is Pentane (C_5H_{12}), retention time 2.30 and trace mass 43,compound is Pentane, 2-methyl-, (C_6H_{14}), retention time 2.47 and trace mass 56, compound is 3-Hexene,(E)(C_6H_{12}), retention time 2.56 and trace mass 41, compound is Hexane (C_6H_{14}), retention time 2.62 and trace mass 69,compound is hexane (C_6H_{14}), retention time 2.62 and trace mass 69,compound name is 2-Pentene, 4-methyl-,(Z)- (C_6H_{12}), retention time 2.93 and trace mass 67,compound name is 2,4-Hexadiene, (Z,Z)-(C_6H_{10}), retention time 3.60 and trace mass 41, compound is Cyclopentane,1,2-dimethyl-,cis-(C_7H_{14}), retention time 4.58 and trace mass 41, compound is –Heptene-4-methyl-(C_8H_{16}), retention time 5.54 and trace mass 69, compound is Cyclopentane,1,1,3,4-tetramethyl-,cis-(C_9H_{18}), retention time 5.91 and trace mass 111, compound is Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5α)- (C_9H_{18}), retention time 6.57 and trace mass 109 compound is Cyclohexene,3,3,5-trimethyl-(C_9H_{16}), retention time 7.24 and trace mass 55, compound is 3-Octyne,2-methyl-(C_9H_{16}) , retention time 8.86 and trace mass 43, compound is Ocane,

3,5-dimethyl-($C_{10}H_{22}$), retention time 9.65 and trace mass 41, compound is 2-Undecanethiol, 2-methyl-($C_{12}H_{26}S$).
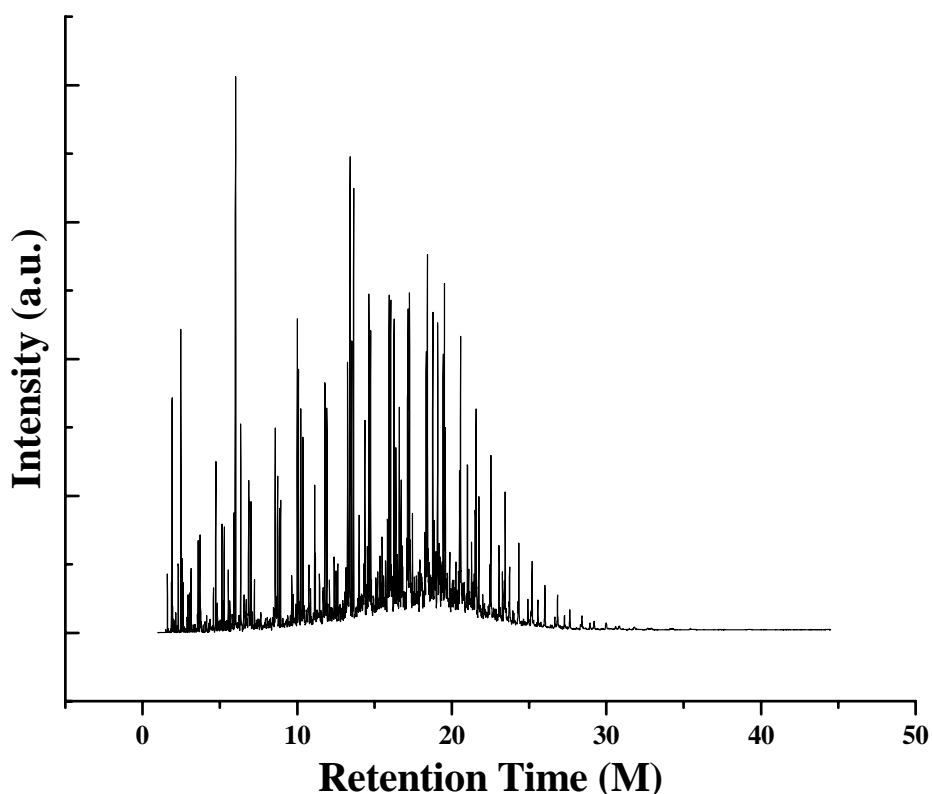

Figure 3. GC/MS chromatogram of produce fuel

Table 2. Fuel chromatogram compound list with retention time

Peak Number	Retention Time (M)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	NIST Number
1	1.60	41	1-Propene, 2-methyl-	C_4H_8	56	18911
2	1.87	42	Cyclopropane, ethyl-	C_5H_{10}	70	114410
3	1.91	39	Pentane	C_5H_{12}	72	291244
4	2.30	43	Pentane, 2-methyl-	C_6H_{14}	86	61279
5	2.47	56	3-Hexene, (E)-	C_6H_{12}	84	114481
6	2.56	41	Hexane	C_6H_{14}	86	61280
7	2.62	69	2-Pentene, 4-methyl-	C_6H_{12}	84	118192
8	2.94	67	2,4-Hexadiene, (Z,Z)-	C_6H_{10}	82	113646
9	3.14	81	2,4-Dimethyl 1,4-pentadiene	C_7H_{12}	96	114468
10	3.54	56	1-Hexene, 2-methyl-	C_7H_{14}	98	114433
11	3.60	41	Cyclopentane, 1,2-dimethyl-, cis-	C_7H_{14}	98	114027
12	3.72	43	Heptane	C_7H_{16}	100	61276
13	3.75	81	1,3-Pentadiene, 2,4-dimethyl-	C_7H_{12}	96	114450
14	4.58	41	3-Heptene, 4-methyl-	C_8H_{16}	112	114150
15	4.74	70	Heptane, 4-methyl-	C_8H_{18}	114	113916
16	4.84	81	Cyclohexene, 3-methyl-	C_7H_{12}	96	19639
17	5.13	41	1-Octene	C_8H_{16}	112	1604

Table 2. (Continued)

18	5.21	95	2,4-Hexadiene, 2,5-dimethyl-	C_8H_{14}	110	114376
19	5.28	43	Octane	C_8H_{18}	114	229407
20	5.54	69	Cyclopentane, 1,1,3,4-tetramethyl-, cis-	C_9H_{18}	126	27589
21	5.91	111	Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5α)-	C_9H_{18}	126	2479
22	6.01	56	2,4-Dimethyl-1-heptene	C_9H_{18}	126	113516
23	6.35	69	Cyclohexane, 1,3,5-trimethyl-, (1α,3α,5β)-	C_9H_{18}	126	2480
24	6.56	109	Cyclohexene, 3,3,5-trimethyl-	C_9H_{16}	124	114765
25	6.86	41	cis-2-Nonene	C_9H_{18}	126	113508
26	7.01	43	Nonane	C_9H_{20}	128	228006
27	7.24	55	3-Octyne, 2-methyl-	C_9H_{16}	124	62452
28	7.64	41	3-Decyn-2-ol	$C_{10}H_{18}O$	154	53449
29	8.47	41	2-Decene, (Z)-	$C_{10}H_{20}$	140	114151
30	8.59	41	1-Decene	$C_{10}H_{20}$	140	118883
31	8.73	57	Decane	$C_{10}H_{22}$	142	114147
32	8.85	43	Octane, 3,5-dimethyl-	$C_{10}H_{22}$	142	114062
33	8.93	43	Decane, 4-methyl-	$C_{11}H_{24}$	156	5261
34	9.65	41	2-Undecanethiol, 2-methyl-	$C_{12}H_{26}S$	202	9094
35	10.01	43	3-Dodecene, (E)-	$C_{12}H_{24}$	168	142606
36	10.08	69	Cyclooctane, 1,4-dimethyl-, cis-	$C_{10}H_{20}$	140	61409
37	10.24	41	1-Undecene	$C_{11}H_{22}$	154	34717
38	10.37	57	Undecane	$C_{11}H_{24}$	156	114185
39	11.14	69	(2,4,6-Trimethylcyclohexyl)methanol	$C_{10}H_{20}O$	156	113757
40	11.17	41	E-2-Octadecadecen-1-ol	$C_{18}H_{36}O$	268	131102
41	11.44	69	1-Isopropyl-1,4,5-trimethylcyclohexane	$C_{12}H_{24}$	168	113584
42	11.79	41	3-Dodecene, (E)-	$C_{12}H_{24}$	168	113960
43	11.92	43	Dodecane	$C_{12}H_{26}$	170	291499
44	12.39	43	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	149589
45	13.26	55	1-Tridecene	$C_{13}H_{26}$	182	107768
46	13.65	69	E-14-Hexadecenal	$C_{16}H_{30}O$	238	130980
47	14.01	43	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	114065
48	14.38	69	7-Octadecyne, 2-methyl-	$C_{19}H_{36}$	264	114518
49	14.64	55	1-Hexadecene	$C_{16}H_{32}$	224	118882
50	14.75	57	Tetradecane	$C_{14}H_{30}$	198	113925
51	15.49	43	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	149589
52	15.84	43	1-Nonadecanol	$C_{19}H_{40}O$	284	13666
53	15.94	41	1-Tridecene	$C_{13}H_{26}$	182	232738

Table 2. (Continued)

54	16.05	57	Pentadecane	$C_{15}H_{32}$	212	107761
55	16.73	43	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242	114709
56	17.15	55	Cyclododecanemethanol	$C_{13}H_{26}O$	198	108275
57	17.18	55	1-Hexadecene	$C_{16}H_{32}$	224	118882
58	17.27	57	Hexadecane	$C_{16}H_{34}$	226	114191
59	17.46	55	E-2-Octadecadecen-1-ol	$C_{18}H_{36}O$	268	131102
60	17.93	43	1-Hexadecanol, 2-methyl-	$C_{17}H_{36}O$	256	36540
61	18.34	55	1-Heptadecanol	$C_{17}H_{36}O$	256	113250
62	18.42	71	Heptadecane	$C_{17}H_{36}$	240	107308
63	18.78	83	1-Nonadecene	$C_{19}H_{38}$	266	107568
64	18.88	43	1-Heptadecene	$C_{17}H_{34}$	238	233150
65	19.44	55	1-Octadecene	$C_{18}H_{36}$	252	229404
66	19.52	71	Octadecane	$C_{18}H_{38}$	254	57273
67	19.86	55	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	348	15853
68	20.50	55	1-Docosene	$C_{22}H_{44}$	308	113878
69	20.57	85	Eicosane	$C_{20}H_{42}$	282	290513
70	21.51	43	1-Docosene	$C_{22}H_{44}$	308	113878
71	21.57	57	Eicosane	$C_{20}H_{42}$	282	290513
72	22.48	55	1-Docosene	$C_{22}H_{44}$	308	113878
73	22.53	57	Heneicosane	$C_{21}H_{44}$	296	107569
74	23.45	57	Heneicosane	$C_{21}H_{44}$	296	107569
75	24.33	57	Octacosane	$C_{28}H_{58}$	394	134306
76	25.19	57	Tetratetracontane	$C_{44}H_{90}$	618	23773
77	25.57	69	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	348	15853
78	26.02	57	Heptacosane	$C_{27}H_{56}$	380	79427
79	28.42	57	Heptacosane	$C_{27}H_{56}$	380	79427

Also at retention time 10.1 and trace mass 43, compound is 2-Cyclohexane-1-ol, 2-methyl-5-(1-methylethenyl)-($C_{10}H_{16}O$), oxygenated compound are formed because in the glass reactor chamber much amount of steams are produced and also experiment executed in the presence of air. Retention time 10.87 and trace mass 43, compound is 1-Dodecene ($C_{12}H_{24}$) etc. In the middle phases of the analysis index results in accordance with the retention time and trace masses various kinds of compounds are detected such as at retention time 11.44 and trace mass 69, compound is 1-Isopropyl-1,4,5-trimethylcyclohexane ($C_{12}H_{14}$). Retention time 11.79 and trace mass 41, compound is 3-Dodecene, (E)- ($C_{12}H_{24}$). Retention time 11.92 and trace mass 43, compound is Dodecane ($C_{12}H_{26}$), retention time 11.92 and trace mass 71, compound is Dodecane ($C_{12}H_{26}$), retention time 12.40 and trace mass 43, compound is Decane, 2,3,5,8-tetramethyl-($C_{14}H_{30}$), at retention time 13.65 and trace mass 69, compound is E-14-Hexadecenal ($C_6H_{30}O$), benzene compounds are formed because when raw polystyrene are made benzene are added into the reactants retention time 15.84 and trace mass 43, compound is 1-Dodecanol, 3,7,11-trimethyl-($C_{15}H_{32}O$) etc. In the ultimate phase of the analysis index several compound are detected as according to their retention time and trace masses such as retention time 16.04 and trace mass 57, compound is Pentadecane ($C_{15}H_{32}$), retention time 17.93 and trace mass 43, compound is 1-Heptadecene ($C_{17}H_{34}$), retention time 19.52 and trace mass 57, compound is Octadecane ($C_{18}H_{38}$), retention time 20.57 and trace mass 85, compound is Eicosane ($C_{20}H_{42}$), retention time 22.53 and trace mass 57, compound is Heneicosane ($C_{21}H_{44}$), retention time 23.45 and trace mass 57, compound is Heneicosane ($C_{21}H_{44}$), retention time 25.19 and trace mass 57, compound is Heneicosane ($C_{21}H_{44}$), retention time 26.02 and

trace mass 57, compound is Heptacosane ($C_{27}H_{56}$) and eventually retention time 27.64 and trace mass 57, compound is Heptacosane ($C_{27}H_{56}$).

GC/MS chromatogram 6.01 (M) retention time and compound trace mass 56, trace compound is 2,4-Dimethyl-1-heptene, compound formula is C_9H_{18} and m/z=56 (Figure 4). NIST library Trace compound structure shown below and this compound peak intensity are high then other all compounds. This compound peak intensity is 100%. This peak intensity means that this fuel has this compound concentration is higher than other compounds. This compound belongs in aliphatic alkenes group compounds.

2,4-Dimethyl-1-heptene compound structure

Figure 4. GC/MS trace high intensity peak 2, 4-Dimethyl-1-heptene compound with relative intensity and m/z

From GC/MS chromatogram 13.65 (M) retention time trace compound is 2nd heights peak intensity compound is E-14-Hexadecenal and compound formula is $C_{16}H_{30}O$ and this compound is oxygenate compound, this compound trace mass m/z = 69 (Figure 5). This compound trace form produce fuel was analyzed by GC/MS NIST library. This compound is shown in GC/MS graph 2nd heights peak intensity compound and it representative concentration level is lower than 2, 4-Dimethyl-1-heptene compound. This compound trace intensity showed only 90%. This compound also has aliphatic alkenes group oxygenate (Kiton) groups.

FT-IR analysis of HDPE, LDPE and PP waste plastic mixture to fuel (Figure 6) in accordance with the wave number following types of functional groups appeared in the analysis such as at the initially wave number 3622.06 cm^{-1}, functional group is Free OH, wave number 2884.97 cm^{-1}, functional group is C-CH$_3$, wave number 2728.95 cm^{-1}, functional group is C-CH$_3$, wave number 1821.69 cm^{-1}, 1781.47 cm^{-1}, 1650.58 cm^{-1} and 1721.23 cm^{-1} functional group is Non-Conjugated etc. As well as at the end of the analysis index wave number 1458.00 cm^{-1} and 1382 cm^{-1} functional group is CH$_3$, wave number 992.23 cm^{-1} and 908.29 cm^{-1} functional group is –CH=CH$_2$, wave number 964.89 cm^{-1}, functional group is –CH=CH-(trans) and ultimately wave number 722.75 cm^{-1} and 674.665 cm^{-1} functional group is –CH=CH-(cis) as well. Some groups are emerged single and double bonded functional groups. Non-Conjugated groups are available in the spectrum analysis of fuel such as several wave numbers are in range of that boundaries. On the other hand methyl and methylene groups are seen in the same analysis spectrum. Carbon-carbon bond functional groups are cis and trans alkenes etc.
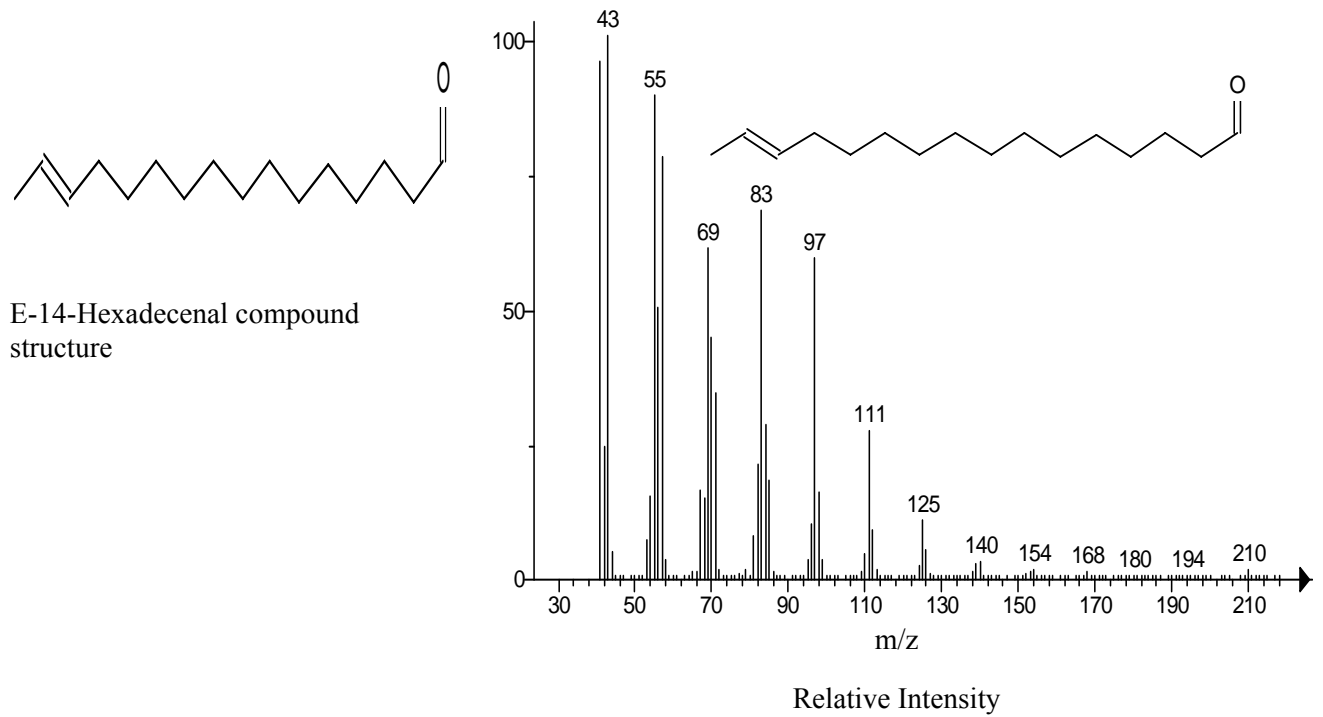
E-14-Hexadecenal compound
structure

Relative Intensity

Figure 5. GC/MS trace 2nd high intensity peak E-14-Hexadecenal compound with relative intensity and m/z
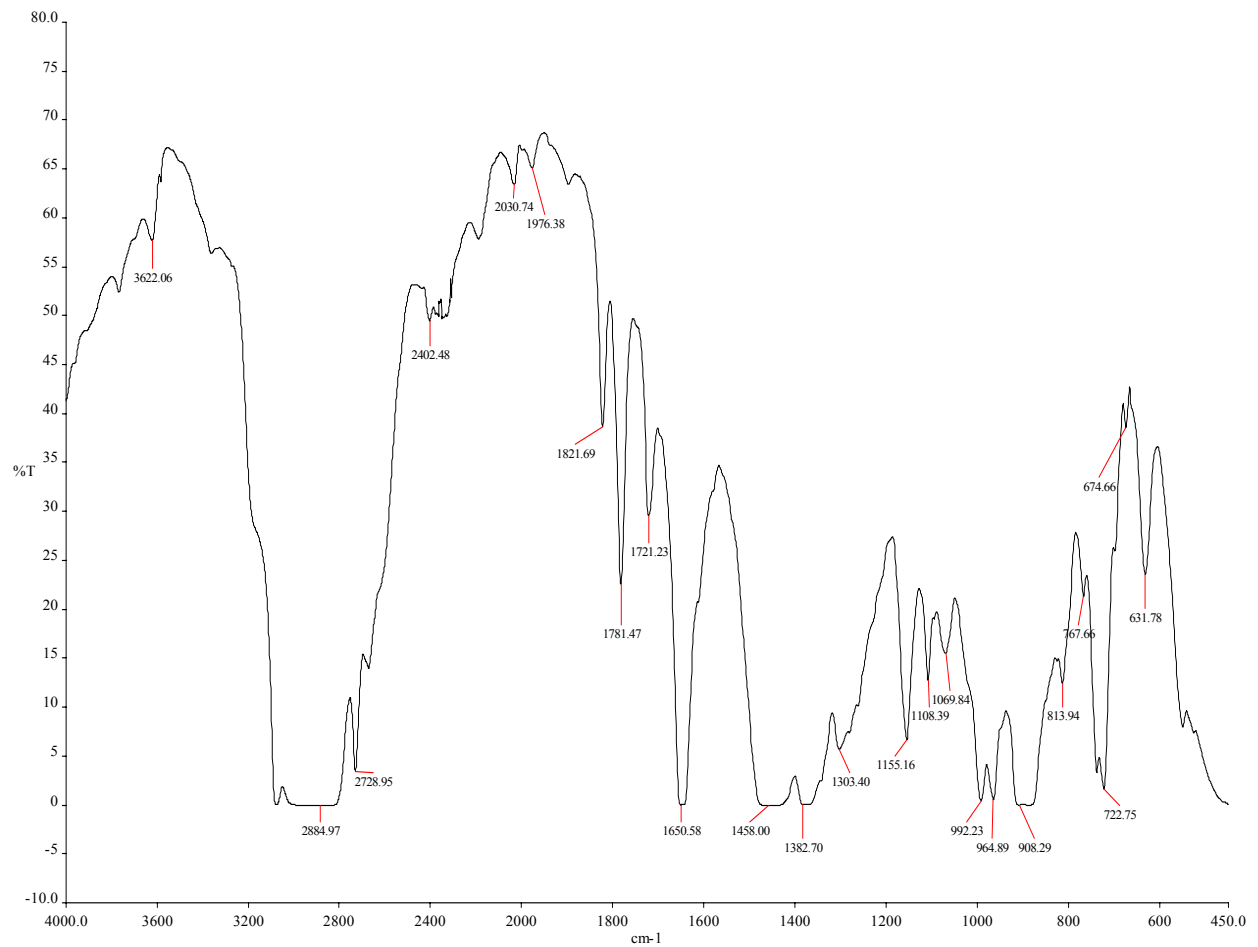
Figure 6. FT-IR spectrum of produce fuel

4. Conclusion

Recycled waste plastic LDPE; HDPE and PP mixture was used for fuel production process at medium heat temperature range from 200–420 ºC. Fuel yield percentage is close to 90% and conversion rate is considerable. Mixture of three types of waste plastic at low density and high density polyethylene and polypropylene thermal degradation process without catalyst to produce oil is profitable alternative oil when compared to the waste recycling system. This method not only solve the disposal waste plastic recycling problem of the three types waste plastic, also provides fuel recovery benefit from the production of thermal degradation process fuel as a diesel or heating fuel substitute fuel. The large quantity of valuable fuel from three types of waste plastics such HDPE, LDPE and PP main source of thermal degradation process to thermal fuel by the alternative scenario for our future nation. Therefore, we determined that benefits from economies of scale can be achieved when the three type of wastes plastic are co-processed in the same plant. Integration of the three types of mixture of plastic wastes into co-processing at one plant reduced management infrastructure costs when compared to operating independent plants for each waste plastic. Our production analysis cost showed that 1 gallon of fuel production in lab scale cost $ 1.40. Also, if raw materials and transportation costs increased also, at the maximum conversion rate of production still remained profitable options. Therefore, maximum economic benefits would be gained if a thermal degradation process facility was established that has the efficiency to provide the maximum conversion rate. Although end-product solid black residue distribution was excluded from this process, the construction of a thermal fuel plant near a community or area that mainly uses all kind of diesel engines for electricity generation would result in more benefits to the plant due to the when commercial plant will start large quantity production then decrease in product distribution cost.

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