Method of Converting Municipal Proportional Waste Plastics into Liquid Hydrocarbon Fuel by Using Activated Carbon

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Abstract  The demand for fossil fuel is at an all time high worldwide. Annually ~30 billion barrels of petroleum is being consumed worldwide. In this busy society, transportation is vital and, for transportation, petroleum is an obligation. All the major forms of business, agricultural, exports and imports depend on transportation. Transportation requires petroleum to function. Vehicles in the road require fuels, airway transportation requires Aviation fuel and sea transportation requires fuel oil. For not only transportation but also, petroleum is required to make all kind of daily usable plastics. Depletion of petroleum is inevitable at this current rate of consumption. Emissions released from evaporation and combustion of these fuel contributes to too many environmental and health problems; including emitting greenhouse gases that contribute immensely to global warming. Annually ~7 billion tons of carbon dioxide is released to the environment due to petroleum emission. Moreover, when the plastics are discarded into the landfill, it becomes waste plastic and since plastic is non-biodegradable, it can remain in the landfill for thousands of year. Waste plastics presence in the landfill causes environmental problems e.g., it can cause soil to decay. Alternative source of energy created from Solar, Wind, Hydrogen Fuel, Biomass Fuel, Bio-Diesel, Green Diesel, Bio-ethanol, and Geo-thermal has been proposed as a solution to these problems. A developed process of thermally breaking down the hydrocarbon of chains of plastic has been studied and implemented to produce a liquid fuel in the presence of activated carbon. The activated carbon acts as a filter to absorb dye from the waste plastic during the thermal process to increase the quality of the final product. This fuel can be used for all kinds of transportation, and will emit much less emission compared to the current commercial fuel and it will be cost effective.

Keywords  Waste Plastic, Fuel, Activated Carbon, Thermal, GC/MS, FT-IR

1. Introduction

In recent years the production and consumption of plastics have increased drastically; as a consequence the responsible disposal of plastic wastes has created serious social and environmental arguments. At present both land filling and incineration of plastic wastes are widely practiced. In Japan, the percentage of municipal plastic wastes, as a fraction of municipal solid waste (MSW), that was land filled in the early 1980s was estimated to be 45%, incineration was 50%, and the other 5% was subjected to separation and recycling[1]. In the USA, more than 15% of the total MSW was incinerated in 1990; only about 1% of post-consumer plastics were recycled[2–4]. Land filling of plastic wastes is expected to decrease in the future as landfill space is depleted and plastic wastes are resistant to environmental degradation. Co-incineration of plastic wastes with other municipal solid wastes may be increasingly practiced, because the high caloric value of plastics can enhance the heating value of MSW and facilitate an efficient incineration, while their energy content can also be recovered. But the potential relationship between plastics fed into an incinerator and the formation of some highly toxic pollutants such as dioxins and furans is still unclear. It has been suggested that the chlorine content in PVC and other plastics is related to the formation of dioxins and furans, which are chlorinated polynuclear aromatic compounds. And although there is considerable evidence that these pollutants would still be generated in the absence of plastics, environmental pressures against incineration have never completely disappeared.

Plastic wastes can be classified as industrial and municipal plastic wastes according to their origins; these groups have different qualities and properties and are subjected to different management strategies. Industrial plastic wastes are those arising from the plastics manufacturing and processing industry. Usually they are homogeneous or heterogeneous plastic resins, relatively free of contamination and available in fairly large quantities. Recycling technologies for industrial plastic wastes are currently based on pelletization...
and molding into low grade plastic products; the recycled products have poor mechanical and color qualities and a lower market value[5]. The reclaimed product outputs of Japan in the early 1980s already amounted to some 15% of total industrial plastic wastes[1]. Thus for industrial plastic wastes, repelletization and remolding seem to be a simple and effective means of recycling. But when plastic wastes are heterogeneous or consist of mixed resins, they are unsuitable for reclamtion. In this case thermal cracking into hydrocarbons may provide a suitable means of recycling, which is termed chemical recycling. Municipal plastic wastes normally remain a part of municipal solid wastes as they are discarded and collected as household wastes. Plastics usually account for about 7% of the total MSW by weight and much more by volume. In order to recycle municipal plastic wastes, separation of plastics from other household wastes is required. Although MSW separation technologies have been studied extensively, it is still not possible to classify MSW mechanically and obtain marketable fractions. If household wastes are separately disposed into three parts: (1) combustibles such as paper, kitchen waste, textiles, and wood, (2) incombustibles such as metals, glass, ceramics, and (3) plastics, then the collected plastics will be mixed plastic wastes with major components of PE, PP, PS, PVC, etc. For mixed plastics some mechanical separation equipment is currently available[1, 6]. For example, using a wet separation process mixed plastics can be separated into two groups: those with a density greater than water such as PS and PVC, and those with a density lower than that of water such as PE, PP and expanded PS. The latter group is much larger than the first group. Consequently, recycling of municipal plastic wastes should deal with plastic mixtures of low and high PE, PP and PS, provided that the above separation procedures are practiced. Typical composition of such plastic mixture will be three parts PE, one part PP and one part PS. More investigations are needed to identify the sources and properties of plastic wastes, and their suitability for various recycling methods such as repelletization, remolding and pyrolysis[7]. Some other research group also performed with plastic to fuel production process with thermal degradation or thermal cracking process[8-10], catalytic cracking process[11-13], pyrolysis process[14-15] and kinetic method[16] also applied for plastic to fuel energy conversion process. Natural state research, Inc uses thermal degradation process to convert industrial and municipal waste mixture plastics to hydrocarbon liquid fuel. Activated carbon was added as a dye removing purposes because it’s removed the different color dyes of plastics from fuel products. As a result fuel color comes clear and transparent.

2. Experimental Section

2.1. Material

Waste plastics raw materials collected from local area grocery stores and coffee shops. The waste plastics collected comes with foreign materials such as paper, sand, food, coffee, insect etc. After collection waste plastic are separated out of all foreign material. Waste plastic components are a mixture of white color milk containers, red color coffee cups, transparent food containers, black color food containers and some different color shopping bags. Separated waste plastics are washed with liquid soap and dried in room temperature. During the washing period of the waste plastics a considerable amount of waste water is generated. The waste water is kept into a separate container for waste water treatment. The waste water is treated with acidic and alkali method with coagulation and flocculation process. For the waste water treatment process potash alum and sodium hydroxide solution with different normality is used.

2.2. Sample Preparation and Pre-analysis

Wash plastics are cut into small pieces, ~3-4 inch² using scissor. The small pieces of plastics are put into the grinder machine and grounded into 2-3 mm pieces. Grounded plastic mixed with ratio wise equally. Four category of waste plastic (HDPE, LDPE, PP & PS) was uses for the liquefaction process and ratio was 25% each sample by weight. The raw materials were analysed by using Perkin Elmer GC/MS with pyroprobe for solid materials and solid sample volatile temperature with pyroprobe 1200ºC. GC and MS result showed raw materials compound structure and FTIR was use for materials functional group and functional group wave band energy. TGA (Pyris-1) was used for materials onset temperature which was representing liquefaction average temperature.

2.3. Experimental Process

Plastic to fuel production process into laboratory scale was use thermal degradation at temperature 25-420 ºC under atmospheric pressure and under fume hood. For the experiment 1 kilogram of sample was used in a 316 stainless steel reactor. Reactor temperature can range up to 500 ºC. 25% LDPE, 25% HDPE, 25% PP and 25% PS with 5% activated carbon in a fully closed system. Waste plastic sample were put into the reactor chamber with activated carbon and heating started from room temperature up to 420 ºC. When the plastics started to melt as temperature was increased vapor started to form inside the reactor, the vapor then passes through a condenser unit. The condensation of the vapor becomes liquid in a form called plastic fuel (See fig.1). This waste plastic to fuel conversion rate is 89%. This produced fuel density is 0.78 g. /ml. No catalyst and no extra chemical used in this conversion process because already metal content are present in the plastic raw materials. Those metal contents act as a catalyst for breaking down long chain hydrocarbon to short chain hydrocarbon during the thermal degradation process. During plastic convert to fuel all vapor are not turn into fuel some vapor portion is come out as a light gas because gas boiling point is minus temperature. To clean the light gas (C1-C4) a 0.5 (N) NaOH/NaHCO3 and
after alkali wash light gases passing through also water wash and at the end we put light gas into gas storage tank by using small pump. This light gas percentage is 7%. The produced plastic fuel passes through RCI fuel purification unit due to centrifugal force fuel making clean and water and sediment come out separately its call fuel sediment, this sediment and water we can retreat. Activated carbon was added in the process to remove plastic dye because during the production period plastic industries use about 3% additive for different shape or model and that dye affects the quality of the end product. The activated carbon filters the heavy contents of the dye and neutralizes them during the thermal degradation process. Waste plastic to fuel production period some black solid residue is generated from the plastics. This residue amount is about 4%. This solid residue has good Btu value and experiment run time was 4.50 hours.

![Diagram of waste plastic into fuel production process](image)

**Figure 1.** Proportional waste plastic into fuel production process

| Name of Test Method | Name of Metal | HDPE (White Color) ppm | LDPE (Red Color) ppm | PP (Transparent) ppm | PS (Red Color) ppm |
|---------------------|--------------|------------------------|----------------------|----------------------|-------------------|
| ASTM D1976           | Silver       | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Aluminium    | 197.4                  | 197.4                | 197.4                | 59.8              |
|                      | Boron        | <1.0                   | 2.8                  | <1.0                 | 2.8               |
|                      | Barium       | <1.0                   | <1.0                 | <1.0                 | 2.7               |
|                      | Calcium      | 452.1                  | 962.6                | 30.5                 | 33420             |
|                      | Chromium     | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Copper       | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Iron         | 20.3                   | 6.0                  | 3.9                  | 47.2              |
|                      | Potassium    | <1.0                   | 35.4                 | <1.0                 | 28.4              |
|                      | Lithium      | <1.0                   | <1.0                 | <1.0                 | 16.8              |
|                      | Magnesium    | 15.2                   | 25.1                 | 2.8                  | 842.7             |
|                      | Molybdenum   | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Sodium       | 23.4                   | 45.2                 | 5966                 | 118.8             |
|                      | Nickel       | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Phosphorus   | 39.3                   | 26.7                 | <1.0                 | <1.0              |
|                      | Lead         | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Antimony     | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Silicon      | 104.2                  | 90.2                 | 5.3                  | 17.2              |
|                      | Tin          | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Titanium     | 2.2                    | 2.7                  | <1.0                 | 60.8              |
|                      | Vanadium     | <1.0                   | <1.0                 | <1.0                 | <1.0              |
|                      | Zinc         | 2.2                    | 2.6                  | <1.0                 | 89.9              |
3. Results and Discussion

3.1. Analysis Technique

For analysis purpose a GC column was used (Perkin Elmer) with a elite-5MS length 30 meter, 0.25 mm ID, 0.5µm df, maximum program temperature 350ºC and minimum bleed at 330 ºC (cat.# N9316284) and also it can be used -60ºC. Capillary column internal silica coating of viscous liquid such as carbowax or wall bonded organic materials. GC/MS operational purpose was used carrier gas as Helium gas. For GC method setup initial temperature 40ºC and initial hold for 1 minute. Final temperature setup is 330ºC. Temperature ramping rate is 10ºC/minutes up to 325ºC and hold for 15 minutes 325 ºC. Total experiment runs time 44.50 minutes. MS method setup for sample analysis MS scan time 1 to 44.50 minutes and mass detection 35- 528 EI+ centroid. Internal scan time used 0.15 second. Mass detection is creating m/z ratio. FT-IR analysis purpose used Perkin Elmer FT-IR spectrum 100, range 4000- 400 cm⁻¹, number of scan 32 and resolution 4. NaCl cell was used as a fuel sample holder. NaCl cell thickness is 0.05 mm. Liquid fuel analysis by Perkin Elmer DSC and analysis purpose used temperature 5-400ºC, ramping rate 10ºC/min. 50 micro liter aluminium pan used for sample holding and nitrogen gas used for carrier. TGA (Pyris-1) was used raw sample analysis and by TGA can measurement raw sample onset temperature. Temperature profile was use for raw sample analysis 50 -800 ºC and ramping rate was 10ºC/ min. Helium gas was use as carrier gas.

3.2. Raw Material Analysis Result

ICP (Inductively coupled plasma atomic emission spectroscopy) analysis results showed (table 1) waste plastic has different category of metal present into raw material in ppm level. All metal comes from the plastic manufacture period when different kind of additives and catalyst are added for better quality and shape. Some research study indicates that waste plastic has different kind of additives. Plastics are manufactured by polymerization, polycondensation, or polyaddition reactions where monomeric molecules are joined sequentially under controlled conditions to produce high-molecular-weight polymers whose basic properties are defined by their composition, molecular weight distribution, and their degree of branching or cross-linking. To control the polymerization process, a broad range of structurally specific proprietary chemical compounds is used for polymerization initiation, breaking, and cross-linking reactions (peroxides, Ziegler-Natta, and metallocene catalysts). The polymerized materials are admixed with proprietary antioxidants (sterically hindered phenols, organophosphites), UV and light stability improvers (hindered amines and piperidyl esters), antistatic agents (ethoxylated amines), impact modifiers (methylalyl ebutadiene- styrene compounds), heat stabilizers (methyl tin mercaptides), lubricants (esters), biostabilizers (arsine, thiazoline, and phenol compounds), and plasticizers used to modify the plasticity, softness, and pliability of plastics (phthalates and esters)[17]. For that reason waste plastics conversion into fuel doesn’t need any kind of catalyst. Without catalyst waste plastic can conversion into fuel by using this technology.

| Name of Method | Name of Waste Plastic | Carbon % | Hydrogen % | Nitrogen % |
|----------------|-----------------------|----------|------------|------------|
| ASTM D5291.a   | HDPE                  | 83.57    | 14.78      | <0.30      |
|                | LDPE                  | 85.33    | 14.31      | <0.30      |
|                | PP                    | 79.93    | 14.17      | <0.30      |
|                | PS                    | 78.60    | 7.21       | <0.30      |

Table 2. Raw Materials Waste Plastic CHN% by EA-2400 (CHN Mode)

EA-2400 material analysis result indicate that C, H, N percentages are present into raw materials shown table 2. TGA (Pyris-1) raw materials analysis result showed HDPE waste plastic inflection point temperature 430.98 ºC and onset temperature 420.65 ºC, LDPE waste plastic inflection temperature 457.11 ºC and onset temperature 421.53 ºC, PP waste plastic inflection temperature 403.72 ºC and onset temperature 359.63 ºC and PS waste plastic inflection temperature 364.88 ºC and onset temperature 326.62 ºC.

3.3. Liquid Fuel Analysis
Table 3. GC/MS chromatogram of proportional waste plastic into fuel compound list

| Number of Peak | Retention Time (min.) | Compound Name          | Compound Formula | Molecular Weight |
|----------------|-----------------------|------------------------|------------------|------------------|
| 1              | 1.51                  | Propane                | C₃H₈             | 44               |
| 2              | 1.61                  | 1-Propene, 2-methyl    | C₄H₈             | 56               |
| 3              | 1.91                  | Pentane                | C₅H₁₀            | 72               |
| 4              | 2.31                  | Pentane, 2-methyl      | C₆H₁₂            | 86               |
| 5              | 2.48                  | 1-Pentene, 2-methyl    | C₆H₁₂            | 84               |
| 6              | 2.56                  | Hexane                 | C₆H₁₂            | 86               |
| 7              | 3.05                  | 1-Pentene, 2,4-dimethyl| C₇H₁₂            | 98               |
| 8              | 3.14                  | 2,4-Dimethyl 1,4-pentadiene | C₇H₁₂         | 98               |
| 9              | 3.60                  | 1-Heptene              | C₇H₁₆            | 100              |
| 10             | 3.72                  | Heptane                | C₇H₁₆            | 96               |
| 11             | 4.55                  | Cyclohexane, (1-methylcyclohexene) | C₈H₁₆          | 112              |
| 12             | 4.60                  | 1-Heptene, 4-methyl    | C₈H₁₆            | 112              |
| 13             | 4.81                  | Toluene                | C₇H₈             | 92               |
| 14             | 5.15                  | 1-Octene               | C₈H₁₆            | 112              |
| 15             | 5.30                  | Octane                 | C₈H₁₈            | 114              |
| 16             | 5.94                  | Cyclohexane, 1,3,5-trimethyl- | C₉H₁₈          | 126              |
| 17             | 6.02                  | 2,4-Dimethyl 1-heptene | C₉H₁₈            | 126              |
| 18             | 6.43                  | Ethylbenzene           | C₈H₁₀            | 106              |
| 19             | 7.00                  | 1,3,5,7-Cyclooctatetraene | C₉H₈             | 104              |
| 20             | 7.52                  | Benzene, (1-methyl)-   | C₉H₁₂            | 120              |
| 21             | 8.05                  | Benzene, propyl-       | C₉H₁₂            | 120              |
| 22             | 8.54                  | α-Methylbutyrene       | C₉H₁₄            | 118              |
| 23             | 8.63                  | 1-Decene               | C₁₀H₂₀           | 140              |
| 24             | 8.77                  | Decane                 | C₁₀H₂₂           | 142              |
| 25             | 8.89                  | Octane, 3,3-dimethyl-  | C₁₀H₂₂           | 142              |
| 26             | 9.31                  | Benzene, 1-propenyl-   | C₁₀H₁₀           | 118              |
| 27             | 9.69                  | 2-Undecanethiol, 2-methyl- | C₁₂H₂₆S         | 202              |
| 28             | 9.79                  | Bicyclo[3.1.0]hex-3-en-2-ol | C₁₀H₁₀O        | 152              |
| 29             | 10.05                 | 2-methyl-5-(1-methylcyclohexyl), (1α,2α,5α)- | C₁₀H₂₀        | 140              |
| 30             | 10.28                 | Cyclohexane, 1,4-dimethyl-, | C₁₁H₂₂         | 154              |
| 31             | 10.42                 | 1-Undecane             | C₁₁H₂₄           | 156              |
| 32             | 11.13                 | Benzene, (3-methyl)-   | C₁₁H₂₄           | 156              |
| 33             | 11.18                 | (2,4,6-Trimethylcyclopentyl)-mercaptan | C₁₁H₂₀       | 146              |
| 34             | 11.85                 | 1-Decene               | C₁₂H₂₄           | 168              |
| 35             | 11.98                 | Dodecane               | C₁₂H₂₆           | 170              |
| 36             | 12.43                 | Decane, 2,3,5,8-tetramethyl- | C₁₃H₃₀         | 198              |
| 37             | 12.69                 | 2-Hexyl-1-octanol      | C₁₃H₃₀           | 214              |
| 38             | 13.33                 | 1-Tridecane            | C₁₃H₃₂           | 182              |
| 39             | 13.45                 | Tridecane              | C₁₃H₃₈           | 184              |
| 40             | 13.71                 | 1-Decanol, 2-hexyl-    | C₁₃H₅₄           | 242              |
| 41             | 14.08                 | Trichloroacetic acid, hexadecyl ester | C₁₈H₃₃Cl₃O₂    | 386              |
| 42             | 14.72                 | 1-Tetradecane          | C₁₄H₂₈           | 196              |
| 43             | 14.83                 | Tetradecane            | C₁₄H₃₀           | 198              |
| 44             | 15.82                 | Benzeneacetic acid, 4-pentadecyl ester | C₂₁H₃₈O₂    | 346              |
| 45             | 16.05                 | 1-Pentadecene          | C₁₅H₃₀           | 210              |
| 46             | 16.15                 | Pentadecane            | C₁₅H₃₂           | 212              |
| 47             | 16.37                 | Trichloroacetic acid, hexadecyl ester | C₁₈H₃₃Cl₃O₂    | 386              |
| 48             | 17.31                 | 1-Hexadecene           | C₁₆H₃₂           | 224              |
| 49             | 17.41                 | Hexadecane             | C₁₆H₃₄           | 226              |
| 50             | 18.27                 | Benzene, 1,1’-(1,3-propanediyl) bis- | C₁₇H₅₆        | 196              |
| 51             | 18.53                 | 3-Heptadecene, (Z)-   | C₁₇H₃₄           | 238              |
| 52             | 18.62                 | Heptadecane            | C₁₇H₃₆           | 240              |
| 53             | 18.98                 | 1-Hexadecan, 2-methyl- | C₁₇H₃₆           | 256              |
| 54             | 19.71                 | E-1,5-Heptadecenal     | C₁₇H₃₂O₂         | 252              |
| 55             | 19.80                 | Octadecane             | C₁₈H₃₈           | 254              |
| 56             | 20.87                 | 9-Nonadecane           | C₁₉H₃₈           | 266              |
| 57             | 20.97                 | Nonadecane             | C₁₉H₄₀           | 268              |
| 58             | 22.02                 | 1-Eicosene             | C₂₀H₄₀           | 280              |
| 59             | 22.12                 | Eicosane               | C₂₀H₄₂           | 282              |
| 60             | 23.30                 | Henicosane             | C₂₁H₄₄           | 296              |
| 61             | 25.75                 | Octacosane             | C₂₁H₳₈           | 394              |
| 62             | 27.06                 | Heptacosane            | C₂₅H₅₆           | 380              |
Waste plastic to produced fuel analysed by gas chromatography and mass spectrometer (GC/MS) seen fig. 2 and table 3. GC-MS analysis of proportionally mixture of HDPE, LDPE, PP & PS plastics to fuel in order to measure retention time and molecular weight numerous aliphatic, aromatic derivatives and different types of hydrocarbon compounds and hydrocarbon chain ranges  C₃ to  C₂₈. At the initial stage of the analysis phases at retention time and molecular weight 44, compound is Propane (C₃H₈), retention time 1.61 and molecular weight 56, and compound is 1-Propene, 2-methyl-(C₄H₈), retention time 1.91 and molecular weight 72, compound is Pentane (C₅H₁₂), retention time 2.31 and molecular weight 86, functional group is Pentane-2-methyl-(C₅H₁₄), retention time 2.48 and molecular weight 84, functional group is 1-Pentene-2-methyl-(C₆H₁₂), retention time 2.56 and molecular weight 86, compound is Hexane,(C₆H₁₄), retention time 3.05 and molecular weight 98, compound is 1-Pentene,2,4-dimethyl-(C₇H₁₄), retention time 3.72 and molecular weight 100, compound is (C₇H₁₆), retention time 4.55, molecular weight 96, compound is Cyclobutane, (1-methylbuthyldene)-(C₇H₁₂), retention time 4.60 and molecular weight 112, compound is 1-Heptene, 4 -methyl-(C₈H₁₆), retention time 4.81 and molecular weight 92, compound is Toluene (C₇H₈), retention time 5.15 and molecular weight 112, compound is 1-Octene (C₈H₁₆) etc. In the middle phase of the analysis index in according with the retention time and molecular weight also different types of compound is appeared. According to the their retention time and molecular weight such as retention time 6.02 and molecular weight 126, compound is 2, 4-dimethyl-1-heptene (C₉H₁₈), retention time 7.52 and molecular weight 120, compound is Benzene, (1-methylbuthyldene)-(C₉H₁₂), retention time 8.89 and molecular weight 142, compound is Octane,3,3-dimethyl-(C₁₀H₂₂), retention time 9.79 and molecular weight 152, compound is Hexadecane (C₁₆H₃₄), retention time 10.05 and molecular weight 140, compound is Cyclooctane, 1,4-dimethyl-, trans-(C₁₀H₂₀), retention time 10.28 and molecular weight and molecular weight 154, compound is 1-Undecene (C₁₁H₂₂), retention time 10.42 and molecular weight 156, compound is Undecane, (C₁₁H₂₄), retention time 11.13 and molecular weight 146, compound is Benzene, (3-methyl-3-butynyl)-(C₁₁H₁₄), retention time 11.18 and molecular weight 156, compound is (2,4,6-Trimethylcyclohexyl) methanol (C₁₀H₁₅O), retention time 11.85 and molecular weight 168, compound is 1-Dodecene (C₁₂H₂₄), retention time 11.98 and molecular weight 170, compound is Dodecane (C₁₂H₂₆) as well as retention time 12.43 and molecular weight 198, compound is Decane, 2,3,5,8-tetramethyl-(C₁₄H₃₀), retention time 12.69 and molecular weight 214, compound is 2-Hexyl-1-1-octanol-(C₁₀H₁₆O), retention time 13.33 and molecular weight 182, compound is 1-Tridecane,(C₁₃H₂₆), retention time 13.45 and molecular weight 184, compound is Tridecane (C₁₃H₂₈), retention time 13.71 and molecular weight 242, compound is 1-Decanol-2-hexyl-(C₁₀H₂₀O), retention time 14.72 and molecular weight 196, compound is 1-Tetradecane, (C₁₄H₂₈), retention time 14.83 and molecular weight 198, compound is Tetradecane, (C₁₄H₂₆), retention time 16.05 and molecular weight 210, compound is 1-Pentadecene, (C₁₅H₃₀) etc. In the end phase of the analysis index in according with retention time and molecular weight several compounds are emerged. However in accordance to retention time 16.37 and molecular weight 212, compound is Pentadecane, (C₁₅H₃₂), retention time 16.37 and molecular weight 386, compound is Trichloroacetic acid, hexadecyl ester (C₁₈H₃₃Cl₃O₂), retention time 17.41 and molecular weight 226, compound is Hexadecane (C₁₆H₃₄), retention time 18.98 and molecular weight 256, compound is 1-Hexadecanol,2-methyl- (C₁₆H₃₈O), retention time 19.80 and molecular weight 254, compound is Octadecane (C₁₈H₃₈), retention time 20.97 and molecular weight 268, compound is Nonadecane, (C₁₉H₃₈), retention time 22.12 and molecular weight 282, compound is Eicosane, (C₂₀H₄₂), retention time 23.30 and molecular weight 296, compound is Henicosane, (C₂₁H₄₄), retention time 25.75 and molecular weight 394, compound is Octacosane, (C₂₈H₅₈) and ultimately retention time 27.06 and molecular weight 380, compound is Heptacosane, (C₂₇H₅₈) etc.

Table 4. FT-IR spectrum of proportional waste plastic to fuel functional group

| Number of Wave | Wave Number (cm⁻¹) | Functional Group Name   | Number of Wave | Wave Number (cm⁻¹) | Functional Group Name   |
|----------------|--------------------|------------------------|----------------|--------------------|------------------------|
| 2              | 3077.91            | H Bonded NH            | 18             | 1631.40            | Non-Conjugated         |
| 3              | 2936.32            | C-CH₃                  | 19             | 1605.83            | Conjugated             |
| 4              | 2729.80            | C-CH₃                  | 22             | 1440.16            | CH₂                    |
| 5              | 2671.87            | C-CH₃                  | 23             | 1377.41            | CH₃                    |
| 8              | 2185.74            | C=O - C=O             | 29             | 1092.91            | Secondary Cyclic Alcohol |
| 11             | 1870.93            | Non-Conjugated         | 30             | 1020.53            | Acetates               |
| 12             | 1816.65            | Non-Conjugated         | 31             | 989.91             | -CH₂                   |
| 13             | 1797.55            | Non-Conjugated         | 32             | 965.28             | -CH₂-(trans)           |
| 14             | 1742.17            | Non-Conjugated         | 33             | 909.21             | -CH₂                   |
| 15             | 1720.87            | Non-Conjugated         | 36             | 728.08             | -CH₂-(cis)             |
| 16             | 1684.15            | Conjugated             | 37             | 697.90             | -CH₂-(cis)             |
| 17             | 1642.02            | Conjugated             |                |                    |                        |
Figure 3. FT-IR spectrum of proportional waste plastics to fuel

Figure 4. DSC graph of proportional waste plastics into fuel

Peak = 159.53 °C
Peak Height = 29 6585 mW

Area = 19040.587 mJ
Delta H = 19040.5867 J/g
Delta Hf = 19.0406 kJ/mol
Mel Wt = 1 0000 g/mole

Onset = 158.94 °C
After fuel sample analysis by FT-IR (Spectrum 100) was found some functional group seen fig.3 and table 4. From FT-IR fuel spectrum showed alkane, alkeny and alkyne group are present. FT-IR analysis traces following types of functional group are found such as wave number 3077.91 cm$^{-1}$, functional group is H bonded NH, ascending wave number 2936.32 cm$^{-1}$, 2729.80 cm$^{-1}$, 2671.87 cm$^{-1}$, functional group is C=CH$_3$. Again several wave number same as following ascending way suppose 1870.93 cm$^{-1}$, 1816.65 cm$^{-1}$, 1797.55 cm$^{-1}$, 1742.17 cm$^{-1}$, 1720.87 cm$^{-1}$, 1631.40 cm$^{-1}$ compound is Non-Conjugated, then wave number 1684.15 cm$^{-1}$ and 1642.02 cm$^{-1}$, 1603.83 cm$^{-1}$ compound is Conjugated. Subsequently wave/frequency number 1440.16 cm$^{-1}$, compound is CH$_2$, wave number 1377.41 cm$^{-1}$, functional group is CH$_3$, wave number 1029.91 cm$^{-1}$, compound is Secondary Cyclic Alcohol, wave number 1020.53 cm$^{-1}$, functional group is Acetates. Again iteratively wave number 989.91 cm$^{-1}$ and 909.21 cm$^{-1}$ wave functional group is –CH=CH$_2$ and following way wave number 965.28 cm$^{-1}$, functional group is -CH=CH-(trans) and finally wave number 728.08 cm$^{-1}$ and 697.90 cm$^{-1}$ functional group is –CH=CH-(cis) respectively.

Table 5. Liquid fuel analysis of ASTM test result

| Name of Method | Test Name | Results | Units |
|---------------|-----------|---------|-------|
| ASTM D240     | Gross Heat of Combustion | 19118    | BTU/lb |
| ASTM D240     | Gross Heat of Combustion (Calculated) | 129142   | BTU/gal |
| ASTM D4052    | API Gravity @ 60°F | 42.9     | °API  |
| ASTM D86-07b  | IBP Recovery 5% | 75.6     | °C     |
| ASTM D86-07b  | IBP Recovery 10% | 110.0    | °C     |
| ASTM D86-07b  | IBP Recovery 20% | 122.8    | °C     |
| ASTM D86-07b  | IBP Recovery 30% | 138.9    | °C     |
| ASTM D86-07b  | IBP Recovery 40% | 153.3    | °C     |
| ASTM D86-07b  | IBP Recovery 50% | 168.9    | °C     |
| ASTM D86-07b  | IBP Recovery 60% | 200.0    | °C     |
| ASTM D86-07b  | IBP Recovery 70% | 240.0    | °C     |
| ASTM D86-07b  | IBP Recovery 80% | 273.3    | °C     |
| ASTM D86-07b  | IBP Recovery 90% | 301.1    | °C     |
| ASTM D86-07b  | IBP Recovery 95% | 335.6    | °C     |
| ASTM D86-07b  | IBP Recovery 100% | 368.9    | °C     |
| ASTM D86-07b  | IBP Recovery | 376.1    | °C     |
| ASTM D86-07b  | Residual | 2.0      | Vol%   |
| ASTM D86-07b  | Total recovery | 96.0     | Vol%   |
| ASTM D86-07b  | Loss | 2.0      | Vol%   |
| ASTM D2500    | Automatic Cloud point | 10.9     | °C     |
| ASTM D2500    | Cloud Point | 51.6     | °F     |
| ASTM D97      | Pour point | 8.0      | °C     |
| ASTM D97      | Pour point | 46.4     | °F     |
| ASTM D2386    | Freezing Point | 10.0     | °C     |
| ASTM D2386    | Freezing Point | 50.0     | °F     |
| ASTM D2624    | Temperature | 23.3     | °C     |
| ASTM D2624    | Electrical Conductivity | 6.0      | pS/M   |
| ASTM D453     | Sulphur | 2.3      | Mg/Kg  |
| ASTM D4176    | ASTM Color | <4.5     |       |
| ASTM D4176    | Appearance: Clean and Bright | Pass     |       |
| ASTM D4176    | Free Water Content/Particles | No Water or Particles Present |       |
| ASTM D4176    | Haze Rating | 2.0      |       |
| ASTM D4176    | Special Observation | No Special Observations |       |
| ASTM D4737    | Cetane Index by D4737 (Procedure A) | 41.8     |       |
| ASTM D5708_MOD | Vanadium | <1.00    | ppm    |
| ASTM D5708_MOD | Nickel | <1.00    | ppm    |
| ASTM D5708_MOD | Iron | <1.00    | ppm OR, mg/Kg |
| ASTM D482     | Average Ash | <0.001   | Wt%    |
| ASTM D93      | Procedure Used | Below Room Temperature | °C     |
| ASTM D4530    | Average Micro Method Carbon Residue 10% distillation | 0.3      | Wt%    |
| ASTM D664     | Procedure Used | <0.10    | mgKOH/gm |
| ASTM D664     | Acid Number | <0.10    | mgKOH/gm |
| ASTM D664     | Copper Corrosion @ 50°C (122°F)/3 hrs. | 1a       |       |
| ASTM D2709    | Sediment and Water | 0.005    | Vol%   |
| ASTM D5291    | Carbon Content | 87.30    | Wt%    |
| ASTM D5291    | Hydrogen Content | 12.53    | Wt%    |
| ASTM D5291    | Nitrogen Content | <0.75    | Wt%    |
Table 6. Solid black residue analysis result by ICP

| Test Method Name | Metal Name | Results (ppm) | Test Method Name | Metal Name | Results (ppm) |
|------------------|------------|---------------|------------------|------------|---------------|
| ASTM D1976       | Aluminiun  | 1.517         | ASTM D1976       | Magnesium  | 1.480         |
|                  | Arsenic    | 24.5          |                  | Manganese  | 8.8           |
|                  | Antimony   | <1.0          |                  | Nickel     | 11.9          |
|                  | Boron      | 3.3           |                  | Potassium  | 127.7         |
|                  | Barium     | 11.8          |                  | Sodium     | 213.4         |
|                  | Beryllium  | <1.0          |                  | Silver     | <1.0          |
|                  | Calcium    | 134,300       |                  | Selenium   | <1.0          |
|                  | Cadmium    | <1.0          |                  | Silicon    | 8.4           |
|                  | Chromium   | 4.0           |                  | Tin        | 273.7         |
|                  | Copper     | 3.8           |                  | Titanium   | 558.4         |
|                  | Iron       | 538.7         |                  | Vanadium   | <1.0          |
|                  | Lead       | <1.0          |                  | Zinc       | 433.3         |
|                  | Lithium    | 29.3          |                  |            |               |

Table 7. Carbon, Hydrogen and Nitrogen percentage into solid residue by EA-2400 (CHN mode)

| Name of Method | Name of Sample | Carbon % | Hydrogen % | Nitrogen % |
|----------------|----------------|----------|------------|------------|
| ASTM D5291.a   | Solid black residue | 56.51    | 0.95       | <0.30      |

In accordance with some functional group were calculated energy value of each band of derived compound such as for H bonded NH, energy value is $6.11 \times 10^{-20}$ J, for C-CH$_3$ energy value is $5.83 \times 10^{-20}$ J, for C=C---C=C energy value is $2.04 \times 10^{-20}$ J, for Non-Conjugated energy value is $3.71 \times 10^{-20}$ J and for compound -CH=CH-(cis) energy value is $1.44 \times 10^{-20}$ J respectively. Euclidean Search Hit List: 0.456 F91080 TRICHLOROACETONITRILE, 0.448 F37460 2,5-DIHYDROXYACETOPHENONE, 0.366 F65155 2-METHOXYPHENYLACETONITRILE, 0.356 F65470 3-METHYLACETOPHENONE, 0.327 F54150 2-HYDROXYACETOPHENONE, 0.295 F22850 4-CHLOROACETOPHENONE, 0.292 F64700 2-METHOXYACETOPHENONE, 0.272 F00508 ETHYL ACETOXYDROXAMATE, 0.262 F38558 3,4-DIMETHOXYACETOPHENONE, 0.229 F65156 3-METHOXYPHENYLACETONITRILE, (Perkin Elmer FT-IR tutorial library).

For proportional waste plastic to fuel analysis purpose was use DSC equipment for measuring boiling point temperature and enthalpy value (Fig.4). For fuel analysis purpose was used Nitrogen (N$_2$) gas as a carrier. Program setup was initial temperature 10°C and height 400°C and temperature ramping rate was per minute 10°C. After fuel analysis found some information such as onset temperature 158.94°C, peak temperature 159.5°C, peak height 29.6585 mW and enthalpy delta H is 19040.5867 J/g.

ASTM test also performed according to standard method as follows such as API Gravity @60 °F (ASTM D4052), Barometric Pressure (ASTM D86), ASTM color (ASTM D1500), metal analysis (ASTM D5708), Ash @775 °C (ASTM D482) etc showed table 5, solid black residue ICP analysis result showed table 6 and black residue carbon, hydrogen and nitrogen percentage showed table 7.

4. Conclusions

Waste plastic are major problem for environment. Waste plastics are releasing gas emission into environment because waste plastic are not bio degradable. This waste plastic can remain long period in landfill. The thermal degradation process applied with mixture waste plastics of high density polyethylene (HDPE), low density polyethylene (LDPE), Polypropylene (PP) and Polystyrene (PS) using stainless steel reactor with activated carbon. The polymer has been selected for the experiment 25% each of HDPE, LDPE, PP and PS by weight. The temperature used for thermal degradation at 25-420°C. The obtained products are liquid fuel, light gas and black carbon solid residue. Various technique (Gas Chromatography and Mass Spectrometer, FT-IR and DSC) are used for produced fuel analysis. GC/MS result is showing hydrocarbon compound ranges from C$_3$-C$_{28}$ and light gas are present C$_1$-C$_4$. Using activated carbon with waste plastic its removing plastic dye from fuel, this activated used as filtered. Activated carbon is seated with black residue end of the experiment is not come out with liquid fuel. Activated carbon using with this experiment fuel is clean and color is bright yellow. This fuel burns cleaner and burning time is also longer.

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