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Authors Biography

Moinuddin Sarker, PhD, MCIC, FICER, has been working as the Vice President (VP) of Research and Development and Head of Science Team (VP and CTO); at the Natural State Research (NSR), Inc at Stamford, CT and the inventor of NSR's award winning technology to convert municipal waste plastics into liquid hydrocarbon fuel. He has a M. Sc (1992) and Ph. D. degree in Chemistry from University of Manchester Institute of Science and Technology (UMIST), Manchester, UK (1996). He has more than 22 years of professional research experience in different universities and research organizations all over the world including the US, Canada, the Netherlands, Germany, Taiwan, Bangladesh and the UK. During his research work, he carried out research in four different synchrotron radiation sources around the world: CRCL lab. Daresbury, Warrington, Cheshire, UK (1991-1996), Synchrotron Radiation Research Center (SRRC), Hsinchu, Taiwan, R.O.C (1996-1999), Berlin Electron Storage Ring Company for Synchrotron Radiation (BESSY II) (2000) and Advance Photon Sources (APS), Chicago, USA (2001-2004). He has three patent pending and 100 research publications to his credit in pier reviewed journals and conferences. Dr. Sarker is a distinguished member of 30 professional organizations such as American Association of Naval Engineer (ASNE), Association of Consumer Growth (ACG), Society of Automobile International (SAE), American Chemical Society (ACS), American Physical Society (APS), American Institute of Chemical Engineering (AIChE), International Union of Pure and Applied Chemistry (IUPAC), Canadian Society for Chemistry (CSC), Chemical Institute of Canada (CIC), Canada and many more. Dr. Sarker has been invited speaker various conferences in around the USA and World. Dr. Sarker is the inventor of the technology and product entitles: "Method for converting waste plastics to lower – molecular weight hydrocarbons, particularly hydrocarbon fuel materials and the hydrocarbon material produced thereby" (US and International Patent Pending). In 2010, Dr. Sarker has received, the International Renewable Energy Innovator of the year Awards 2010 at Washington DC and presented by Association of Energy Engineers (AEE), USA. E-mail address: msarker@naturalstateresearch.com

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Table of Content **Page #**

1. Introduction

Modern societies are over dependent on petroleum for fuels and for raw material in many industries. In the world, about 42% of this fuel is consumed to produce energy, 45% on transportation, 4% for plastic production, 4% as feedstock for the petrochemical industry, and 5% in other applications [1]. Hence, efforts have to be undertaken to find alternative means to substitute petroleum for energy. Furthermore, the gradual unattended accumulation of enormous amounts of plastic wastes produced all over the world has negative and hazardous impact on the environment. Plastics waste generation increased by 5.9% between 2001 and 2003[2]. The fraction of plastic in municipal solid wastes (MSW) is continuously rising. In Western Europe, 0.7% (w/w) of MSW is composed of plastics (20.6 million tons in 2002) [2]. In 2003, the major part of this waste (61%) was deposited in landfills, 22.5% was used for energy recovery, 1.7% was for feedstock recycling, and 14.8% was used in other recycling proposes[2]. Pyrolysis of plastic wastes may have an important role in converting them into economically valuable hydrocarbons, which can be used either as fuels or as feedstock in petrochemical industry [3].

The problem of environmentally compatible disposal and energy recovery from municipal solid wastes (MSW) has recently received increasing attention. The lack of landfill sites and assessments of the environmental consequences of landfilling have led many countries to ban landfilling of combustible wastes, including wet organic waste [4, 5]. There is also an increase in the reuse and recycling of MSW fractions, such as paper and cardboard, beverage cartons, and plastics [6]. Refuse derived fuel (RDF), made by drying, crushing, and then compressing the combustible fraction of MSW into pellets, constitutes a good material for pyrolysis, gasification, and combustion since RDF presents several advantages, including their relatively constant density and size, uniform composition, higher heating value, and easy transport[7]. The pyrolysis products of RDF are gases and carbonaceous residue. The gases can be used as fuel or as raw material for chemicals. The carbonaceous residue can be burnt as fuel or safely disposed of, since the heavy metals are fixed in the carbonaceous matrix [8].

Recently, the recycling of municipal (or mixed) plastic waste (MPW) has been a major environmental challenge. The worldwide production and application of plastics has grown rapidly over the last few years, and according to forecasts, the consumption of plastics is increasing at 4-5% annually [9-11]. The problem is that the growing production of plastics results in an increased mass of waste plastic and causes serious environmental risks. On the basis of data in papers, the average composition of the yearly produced plastics is 35% high-density polyethylene (HDPE), 23% polypropylene (PP), 10% polystyrene (PS), 13% polyvinyl chloride (PVC), 7% poly (ethylene terephthalate) (PET), and 12% other polymers worldwide. Because of the special habits of costumers, polyolefin (PE and PP) and PS are the most dominant plastics inside waste polymers. The dominant mass of waste plastics has been placed in a landfill or incinerated, but disposing of the waste to a landfill or incineration is becoming undesirable because of legal pressures [e.g., European Union (EU) directives]. Those directives try to limit the amount of landfilled or incinerated wastes. The main problems with the above-mentioned waste handling ways are high cost consumption of suitable waste deposition and greenhouse gas emission or other toxic pollutants (nitrous

and sulfur oxides, dust, dioxins, etc.) from incinerators. Therefore, the two main alternatives for recycling of municipal and industrial polymer wastes are pyrolysis and mechanical recycling. Generally, mechanical recycling is a popular way and carried out on single-polymer waste streams, because it is economical where high-purity selectively collected plastics are available. Other problems with mechanical recycling are the difficulties in the type of selective collection of plastic wastes, high-purity requirement, and fluctuating price and quality of wastes. When wastes are pyrolyzed, they can convert into valuable hydrocarbon products. Different types of waste polymers (HDPE, LDPE, PP, and PS) could be converted into hydrocarbons with favorable properties for further application (e.g., fuel-like) [12].

2. Material and Method

2.1. Materials

Polypropylene (PP) waste plastic was collected from local restaurant and PP color was black. PP black color waste plastic comes with food ingredient and oily substance. PP waste plastic was washed with soap and water then dried into laboratory room fan air. PP waste plastic cut into small pieces because it was hard shape food container and put into grinder machine for ground purpose and size was 2-3 mm. During waste plastic washing period also generate waste water and generated waste water kept into separate container for treatment purpose. Waste water treated by alkali and acidic solution with bentonite clay. Treated water was reuse for waste plastic washing purpose and this process is cycle process. In this experiment main goal was waste plastic remove from environment not to create another waste problem. PP standard plastic was collected from Sigma-Aldrich company and catalog number is 427853-1kg, lot number MKBD4354V, CAS number 9003-07-0 and formula C_3H_6. PP standard plastic color is transparent and small pellet size.

2.2. Raw Materials Pre- analysis

Before start liquefaction process polypropylene (PP) waste and PP standard plastic was per-analyzed by ICP, EA-2400, TGA, FT-IR spectrum 100 and GC/MS Clarus 500 with pyroprobe. By using ICP provided us raw materials metal content by followed ASTM method ASTM D1976. Elemental Analyzer 2400 indicates that raw materials carbon, hydrogen and nitrogen percentage. TGA analysis result provided onset temperature profile for raw samples liquefaction temperature profile setup in the experiment. FT-IR spectrum 100 analysis results indicate that raw sample functional group band energy which is similar to calorific value. Gas Chromatography and Mass Spectrometer (GC/MS) with pyroprobe was analysis both raw sample and determine polymer compounds such as aliphatic or aromatic group. Per –analysis result was described in the raw materials pre-analysis discussion section.

2.3. Process Description

Polypropylene waste plastic and polypropylene standard plastic to fuel production process was performed thermal degradation without catalyst under laboratory fume hood. Two experiments were performed same condition and same temperature profile. Temperature range was used for both experiments 150 ºC to 420 ºC. Both experiments set up procedure was same way and setup showed **figure 1** and setup description was showed number wise such as 1=

Reactor chamber, 2= Coil and insulator, 3= Condenser unit, 4=Temp. controller & display, 5=Electrical outlet, 6= 2'' ht. & 1'' dia. for gas pressure monitor, 7= 2'' ht. & 1'' dia. for glass monitor, 8= 2'' ht. & 1'' dia. for inside temperature monitor, 9=2'' ht. & 1'' dia. for thermocouple, 10=2'' ht. & 1'' dia. for glass monitor, 11=Condenser inner dia. 2'', 12=Collection tank, 13= Light gas collection neck, 14= Fuel product, 15= RCI purification system, 16 =Gas cleaning device, 17= Light gas collection Teflon bag, 18=Final fuel collection tank. Polypropylene waste plastic to fuel and polypropylene standard plastic to fuel production purposed raw sample were used 1000 gm every experiment. No catalyst and no vacuum system were applied both experiments. Polypropylene waste plastic to fuel process grounded polypropylene waste plastic transferred into reactor chamber then reactor covered with reactor cover and gas kit. Reactor screw was tighten properly for prevent gas loss. Then condensation unit was setup properly with fuel collection tank. Polypropylene waste plastic was starting too heated up from 150 ºC to 420 ºC.

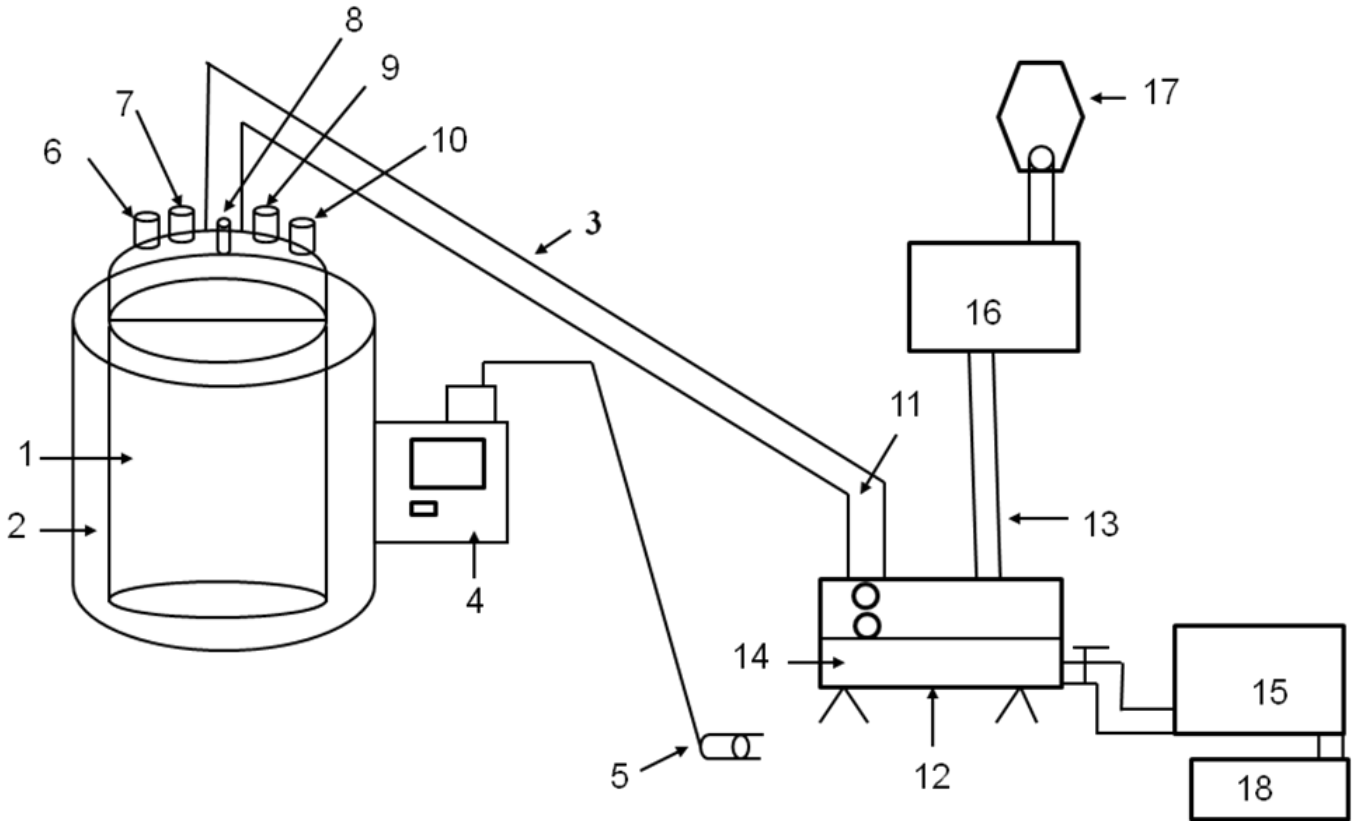

Figure 1: Polypropylene waste plastic and polypropylene standard plastic to fuel production process

Plastic was melted from 150 ºC then melted plastic turned into liquid slurry, then liquid slurry turned into vapor when temperature profile was increased gradually. Polypropylene waste plastic melting point temperature known 160 ºC and Polypropylene waste plastic to fuel production experimental temperature was setup 150 ºC to reduce experimental run times. Melted plastic started to produce vapor and vapor passed through condenser unit at the end collected liquid fuel drop wise. Light gas was collected from collection tank and light gas was purified by using alkali solution wash. Light gas transferred into Teflon bag by using small pump. Produced fuel was purified by RCI technology provided RCI purification system with centrifugal force. RCI purification has micron filter which can remove fuel sediment and water portion which was generated during condensation period. Polypropylene waste and

polypropylene standard plastic to fuel production process mass balance calculation result showed **table 1**. In mass balance calculation showed polypropylene waste plastic to fuel generated 814.1 gram, light gas generated 181.8 gram and leftover residue was 4.1 gram. In percentage calculation showed from 1000 gm polypropylene waste plastic to fuel yield percentage 81.41%, light gas yield percentage was 18.18% and residue yield percentage was 0.41%. On the other hand standard plastic to fuel production purposed 1000 gm sample was used and same temperature and experimental condition was same. Standard polypropylene plastic was pellet size and transparent color and it was fully analytical grade and purity was almost 99.99%. After experiment finished polypropylene standard plastic to fuel was converted 854.7 gram from initial feed1000 gram. Light gas was generated from this experiment 143.2 gram and residue was leftover 2.1 gram. 1000 gm raw sample to liquid fuel was 1130 ml and density was 0.76 g/ml. In percentage calculation from 1000 gm initial raw sample to liquid fuel percentage is 85.47%, light gas percentage is 14.32% and solid black residue percentage is 0.21%. From polypropylene waste plastic to fuel production percentage was less because polypropylene waste plastic has additives percentage higher. On the other hand polypropylene standard plastic to fuel percentage is higher because polypropylene standard plastic was pure grade plastic and additives percentage was less. Polypropylene waste plastic to fuel production input electricity was 6.324 kWh and polypropylene standard plastic to fuel production input electricity was 6.846 kWh. Polypropylene waste plastic to fuel production run was less and polypropylene standard plastic to fuel production time was little longer time. Produced light gas could be use as raw sample heat source for PP waste plastic to liquid fuel production then production cost will decrease. Left over residue can be use for road carpeting; roof carpeting or it can be use for dry cell battery and nano tube production. Left over residue has good Btu value and Btu value is more than 5000/lb.

Table 1: Polypropylene waste plastic and polypropylene standard plastic to fuel production yield percentage

Name of Plastics	Sample Weight (g.)	Liquid Fuel (g.)	Liquid Fuel (ml)	Sample as Light Gas (g.)	Residue Weight (g.)	Experiment input Electricity kWh	Liquid Fuel Yield %	Light Gas Yield %	Solid Residue Yield %
Standard PP	1000	854.7	1130	143.2	2.1	6.846	85.47	14.32	0.21
PP Waste Plastic	1000	814.1	1060	181.8	4.1	6.324	81.41	18.18	0.41

3. Result and Discussion

3.1. Analytical Procedure

Perkin Elmer TGA (pyris-1) was used for raw materials onset and inflection temperature measured. Helium gas was use for purge and temperature range was used 50-800 ºC and temperature increased range was 20ºC/ minute. From this analysis we calculated how much percentage conversion rate from PP waste and standard plastic to fuel by using thermal degradation process. TGA analysis gives us liquefaction temperature for plastic and leftover residue percentage. Perkin Elmer FT-IR spectrum 100 was used for two type of sample analysis. 1st pre-analysis of solid raw

PP standard and PP waste plastic and secondly was used for liquid fuels from PP standard and waste plastic. Solid sample analysis purpose was use ATR system and liquid sample analysis purpose was used NaCl cell system. For liquid sample analysis scan number was 32, resolution was 4 cm^{-1} and wave range was 4000-400 cm^{-1}. By using FT-IR analysis was giving us wave functional group band energy which is resemble to calorific value. By using GC/MS analysis was solid hard standard and waste plastic also both liquid fuels. Sold sample was analysis by using pyroprobe and temperature was 1200 ºC to sample make volatile for GC column. When liquid fuel was analysis by using GC/MS that time was used auto sample system. Solid and liquid sample analysis purpose was same GC/MS column. Carrier gas was use for sample carrier helium gas. GC/MS program was set up for liquid fuel analysis initial temperature 40 ºC and hold for 1 minute, final temperature 325 ºC and temperature ramping rate 10 ºC per minute. Final temperature hold 15 minutes, equilibration time 0.5 minute and total experiment run time 45.50 minutes. Carrier gas was used Helium and Perkin Elmer Elite 5MS capillary column used for GC. Column length is 30 m, ID 0.25 mm and DF 0.5 um. Column temperature range -60 to 350 ºC. MS method set up for mass scan Ion mode EI +, data format Centroid, start mass 35.00, end mass 528, scan time 0.25 sec and inter scan time 0.15 sec. Perkin Elmer EA -2400 was used for raw waste plastics CHN percentage analysis. Finally ICP (Induced Couple Plasma) was used for trace metal analysis from raw materials and solid residue.

3.2. Raw Materials Pre-analysis Discussion

Table 2: Raw polypropylene waste and polypropylene standard plastic metal analysis by ICP

Test Method Name	Trace Metal Name	Raw PP Waste Plastic Result (ppm)	Raw PP Standard Plastic Result (ppb)
ASTM D1976	Silver	<1.0	<1.0
	Aluminum	<1.0	<1.0
	Boron	<1.0	<1.0
	Barium	<1.0	234.1
	Calcium	30.5	<50.0
	Chromium	<1.0	23.9
	Copper	<1.0	18.3
	Iron	3.9	<1.0
	Potassium	<1.0	<50.0
	Lithium	<1.0	<1.0
	Magnesium	2.8	<1.0
	Molybdenum	<1.0	2.2
	Sodium	5966	7563.4
	Nickel	<1.0	7.3
	Phosphorus	<1.0	<1.0
	Lead	<1.0	4.2
	Antimony	<1.0	2.9
	Silicon	5.3	<1.0
	Tin	<1.0	<1.0
	Strontium		7.4
	Titanium	<1.0	<1.0
	Thallium		<1.0
	Vanadium	<1.0	<1.0
	Zinc	<1.0	631.6

Before start experimental process raw sample was analyzed by ICP and determine trace metal because experiment did not use any catalyst and catalyst made by metal. Raw waste plastic has different types of metal as additives and those metal help to break down polymer with heat as a catalyst. By using ICP trace metal analysis of raw PP waste plastic **(table 2)** test method followed ASTM D1976 and general metal content traced in ppm level such as Silver <1.0 ppm, Aluminum <1.0 ppm, Boron <1.0 ppm, Barium <1.0 ppm, Calcium 30.5 ppm, Chromium <1.0 ppm, Copper <1.0 ppm, Iron 3.9 ppm, Potassium <1.0 ppm, Lithium <1.0 ppm, Magnesium 2.8 ppm, Molybdenum <1.0 ppm, Sodium 5966 ppm, Nickel <1.0 ppm, Phosphorus <1.0 ppm, Lead <1.0 ppm, Antimony <1.0 ppm, Silicon 5.3 ppm, Tin <1.0 ppm, Titanium <1.0 ppm, Vanadium <1.0 ppm, Zinc <1.0 ppm. On the other hand PP standard raw plastic was analysis by ICP and ASTM test method was followed ASTM D1976 for general trace metal analysis purpose and traced metal found in the PP standard plastic in ppb level such as Silver <1.0 ppb, Aluminum <1.0ppb, Boron <1.0 ppb, Barium 234.1ppb, Calcium <50.0 ppb, Chromium 23.9 ppb, Copper 18.3ppb, Iron <1.0 ppb, Potassium <50.0 ppb, Lithium <1.0 ppb, Magnesium <1.0 ppb, Molybdenum 2.2 ppb, Sodium 7563.4 ppb, Nickel 7.3 ppb, Phosphorus <1.0 ppb, Lead 4.2 ppb, Antimony 2.9 ppb, Silicon <1.0 ppb, Tin <1.0 ppb, Strontium 7.4 ppb, Titanium <1.0, Thallium <1.0 ppb, Vanadium <1.0ppb, Zinc 631.6. PP waste and PP standard plastic ICP analysis result indicate that PP waste plastic has high amount of metal content present and less metal content present in the PP standard plastic, because PP standard plastic is pure and this is analytical grade plastic. PP plastic are made for consumer use for that reason PP plastic manufacturing period additive are adding almost 3-4% for plastic durability.

Different types of compounds and additives used in plastic materials Manufacture Company. 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 (methacrylatebutadiene- 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). World production of plastic additives is on the order of 18 billion pounds per year with plasticizers representing a 60% of the total amount [13, 14].

Table 3: Raw polypropylene waste and polypropylene standard plastic C, H and N Percentage by EA-2400 CHN mode

Test Method Name	Name of Plastics	Carbon %	Hydrogen %	Nitrogen %
ASTM D5291.a	Raw PP Waste Plastic	79.93	14.17	<0.30
	Raw PP Standard Plastic	88.72	10.96	<0.30

Elemental Analyzer 2400 analysis result showed **table 3** for raw PP waste plastic and PP standard plastic and ASTM test method followed ASTM D5291_a and determine carbon hydrogen and nitrogen percentage using CHN mode. PP waste plastic result showed carbon percentage is 79.93 %, hydrogen percentage is 14.17 % and nitrogen percentage is less then <0.03%. On the other hand PP standard plastic showed carbon percentage is 88.72%, hydrogen percentage is 10.96 % and nitrogen percentage is less than <0.30%. Carbon and hydrogen percentage are different because their additives adding percentage. 99.99% analytical grade standard PP plastic was used for analysis and PP waste plastic was also analyzed same technique. PP waste plastic has less carbon percentage than PP standard plastic because PP plastic has additives percentage high.

Table 4: TGA analysis result of polypropylene waste and polypropylene standard plastic

Name of Sample	Sample Weight (g.)	Onset temperature (ºC)	Inflection point Temperature (ºC)	Left over Residue (g.)
PP standard plastic	3.156	420.74	445.35	0.126
PP waste plastic	2.952	359.63	403.72	0.177

Perkin Elmer TGA (pyris-1) analysis result showed in **table 4** for polypropylene (PP) standard plastic and PP waste plastic onset temperature profile, and based on this temperature profile experimental liquefaction temperature was setup for PP standard and PP waste plastic to fuel production process. PP standard plastic was analysis by TGA and onset result showed 420.74 ºC, inflection point temperature is 445.35 ºC. PP standard plastic initially used 3.156 gm for analysis purposed and left over residue remain 0.126 gm. TGA analysis result indicate that PP standard plastic conversion rate 96% and leftover residue 4% . On the other hand PP waste plastic analysis result showed onset temperature 359.63 ºC, inflection point temperature 403.72 ºC and left over residue is 0.177 gm. PP waste plastic conversion rate is 94% and leftover residue is 6% by TGA. PP waste plastic conversion rate less than from PP standard plastic because it has high percentage of additives.

Table 5: Polypropylene raw waste plastic functional group name from FT-IR spectrum

Number of Peak	Wave Number (cm^{-1})	Functional Group Name	Number of Peak	Wave Number (cm^{-1})	Functional Group Name
1	2950.26	C-CH_3	5	1167.10	
2	2916.91	CH_2	6	997.41	Secondary Cyclic Alcohol
3	2837.40	C-CH_3	7	972.74	
4	1452.83	CH_2	8	841.01	
5	1375.78	CH_3			

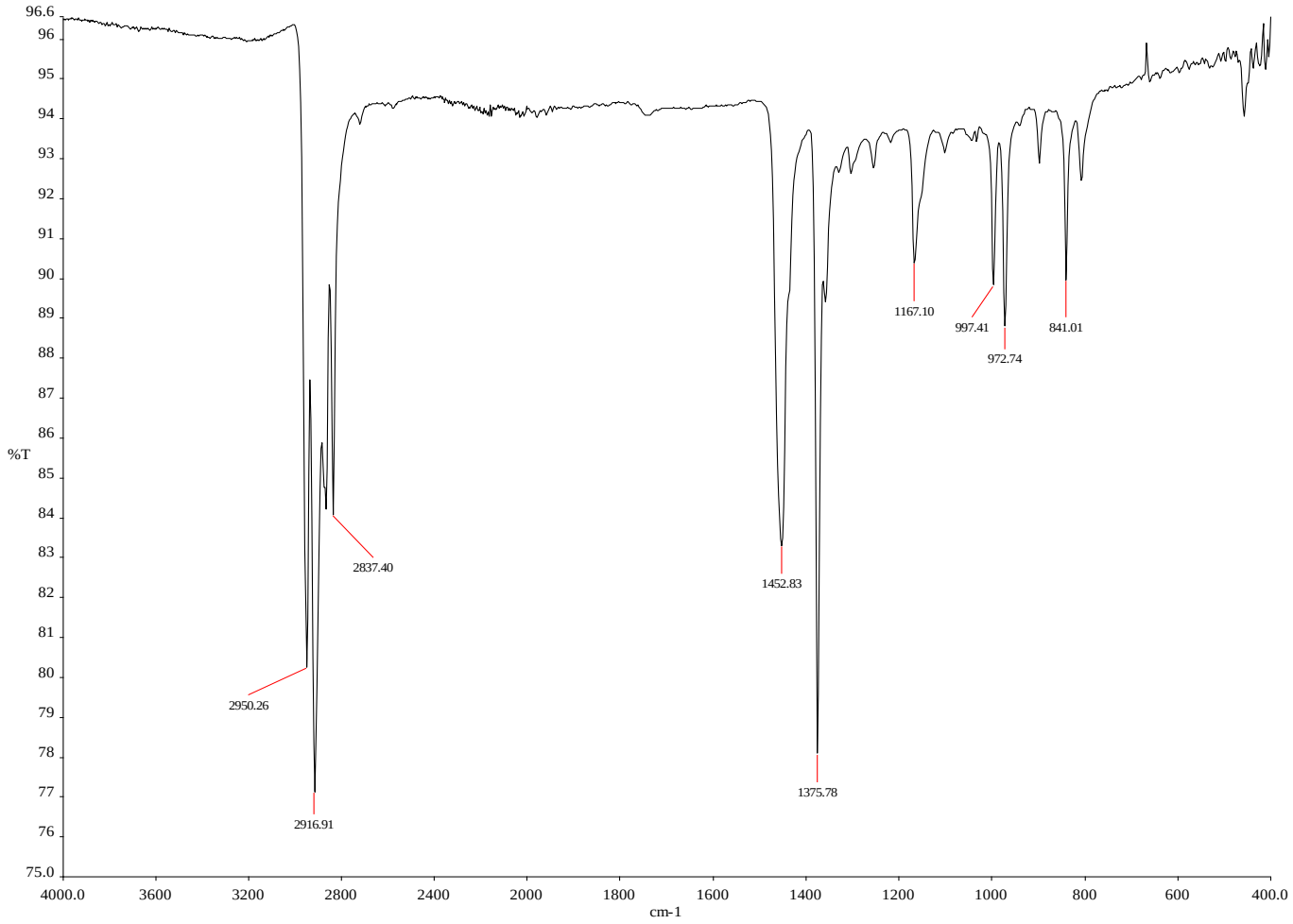

Figure 2: FT-IR spectrum of polypropylene raw waste plastic

Perkin Elmer FT-IR analysis of polypropylene raw waste plastic (**fig.2 and table 5**) 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 and 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, cis and trans alkene etc. Hereafter wave number 2950.26 cm^{-1}, functional group is C-CH_3, wave number 2916.91 cm^{-1} functional group is CH_2, wave number 2837.40 cm^{-1}, functional group is C-CH_3, wave number 1452.83 cm^{-1} functional group is CH_2 and wave number 1375.78 cm^{-1} functional group is CH_3 and ultimately wave number 997.41 cm^{-1} functional group is Secondary Cyclic Alcohol as well. Energy values are calculated, using formula is $E=h\upsilon$, Where h=Planks Constant, $h=6.626x10^{-34}$ J, υ= Frequency in Hertz (sec^{-1}), Where $\upsilon=c/\lambda$, c=Speed of light, where, $c=3x10^{10}$ m/s, $W=1/\lambda$, where λ is wave length and W is wave number in cm^{-1}. Therefore the equation $E=h\upsilon$, can substitute by the following equation, E=hcW. According to their wave number several energy values are calculated such as for 2950.26 (cm^{-1}) calculated energy, $E=5.86x10^{-20}$ J, wave number 2916.91 (cm^{-1}), calculated energy, $E=5.79x10^{-20}$ J, wave number 2837.40 (cm^{-1}), calculated energy, $E=5.63x10^{-20}$ J, wave number 1452.83 (cm^{-1}), calculated energy, $E=2.88x10^{-20}$ J,

wave number 1375.78 (cm^{-1}), calculated energy, $E=2.73x10^{-20}$ J and subsequently wave number 997.41 (cm^{-1}), calculated energy, $E=1.98x10^{-20}$ J respectively.

Table 6: Polypropylene standard plastic functional group name

Number of Peak	Wave Number (cm^{-1})	Functional Group Name	Number of Peak	Wave Number (cm^{-1})	Functional Group Name
1	2951.15	$C\text{-}CH_3$	7	1166.91	
2	2916.69	CH_2	8	997.53	Secondary Cyclic Alcohol
3	2868.32	CH_2	9	973.10	
4	2837.42	$C\text{-}CH_3$	10	899.27	
5	1455.62	CH_2	11	841.27	
6	1376.36	CH_3	12	808.65	

From FT-IR analysis of polypropylene standard plastic (**fig. 3 and table 6)** 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 and 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, cis and trans alkene etc. Hereafter wave number 2951.15 cm^{-1}, functional group is $C\text{-}CH_3$, wave number 2916.69 cm^{-1} functional group is CH_2, wave number 2868.32 cm^{-1} functional group is CH_2, wave number 2837.42 cm^{-1}, functional group is $C\text{-}CH_3$, wave number 1455.62 cm^{-1} functional group is CH_2 and wave number 1376.36 cm^{-1} functional group is CH_3 and ultimately wave number 997.53 cm^{-1} functional group is Secondary Cyclic Alcohol as well. Energy values are calculated, using formula is $E=h\upsilon$, Where h=Planks Constant, $h=6.626x10^{-34}$ J, υ= Frequency in Hertz (sec^{-1}), Where $\upsilon=c/\lambda$, c=Speed of light, where, $c=3x10^{10}$ m/s, $W=1/\lambda$, where λ is wave length and W is wave number in cm^{-1}. Therefore the equation $E=h\upsilon$, can substitute by the following equation, E=hcW. According to their wave number several energy values are calculated such as for 2951.15 (cm^{-1}) calculated energy, $E=5.86x10^{-20}$ J, wave number 2916.69 (cm^{-1}), calculated energy, $E=5.79x10^{-20}$ J, wave number 2868.32 (cm^{-1}), calculated energy, $E=5.69x10^{-20}$ J ,wave number 2837.42 (cm^{-1}), calculated energy, $E=5.63x10^{-20}$ J, wave number 1455.62 (cm^{-1}), calculated energy, $E=2.89x10^{-20}$ J, wave number 1376.36 (cm^{-1}), calculated energy, $E=2.73x10^{-20}$ J and subsequently wave number 997.41 (cm^{-1}), calculated energy, $E=1.98x10^{-20}$ J respectively.

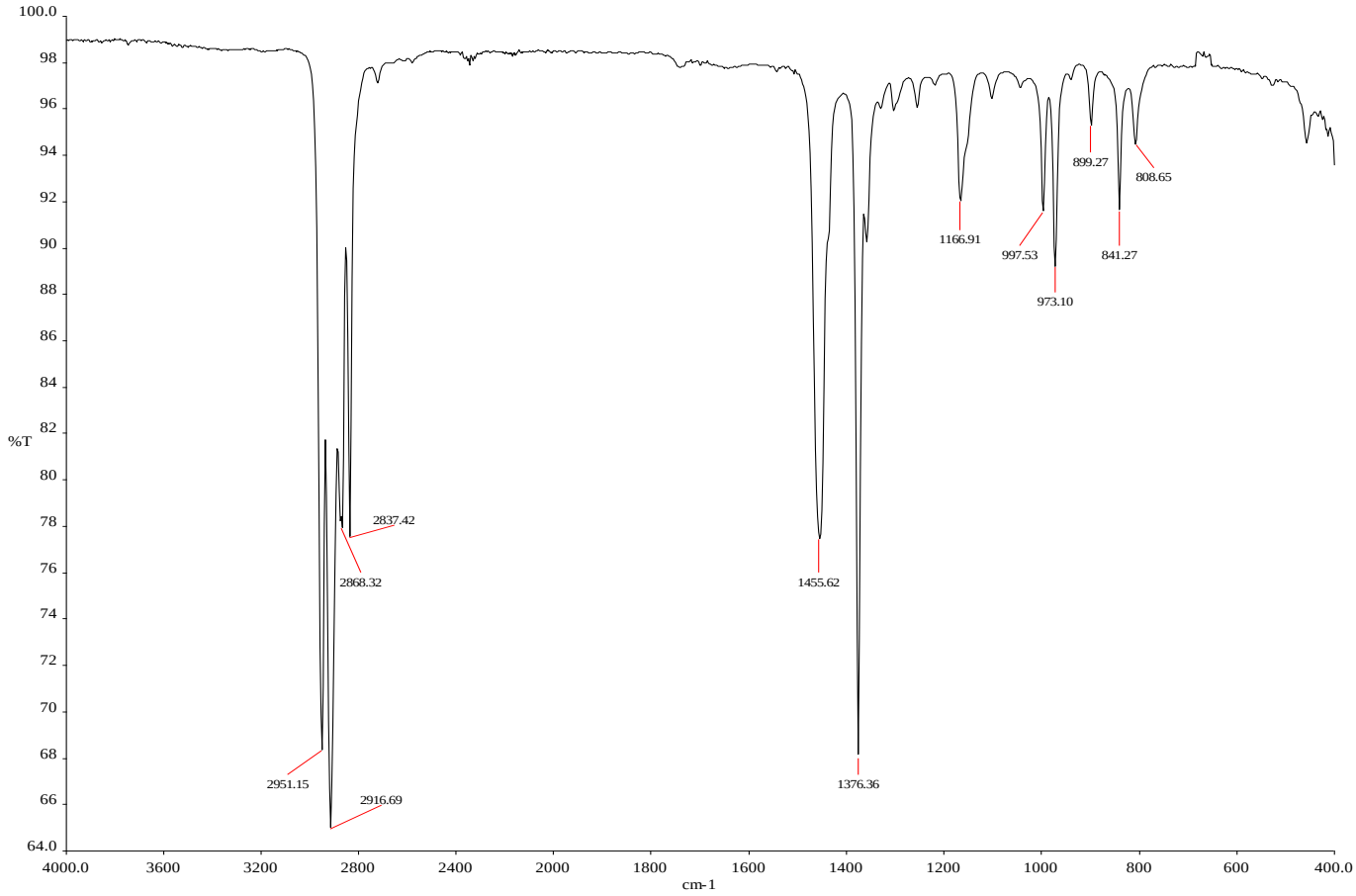

Figure 3: FT-IR spectrum of polypropylene raw standard plastic

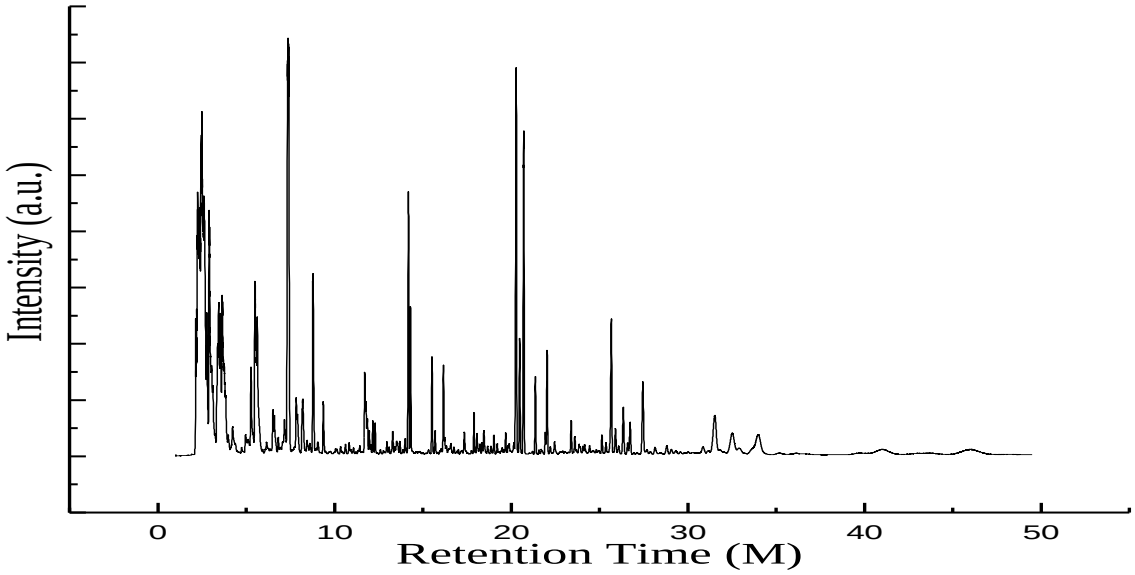

Figure 4: GC/MS chromatogram of polypropylene raw waste plastic

Table 7: Polypropylene raw waste plastic GC/MS chromatogram compound list

Peak Number	Retention Time (M)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	NIST Library Number
1	2.14	38	Cyclopropane	C_3H_6	42	23.5	18854
2	2.16	37	1-Pentanol, 4-amino-	$C_5H_{13}NO$	103	44.8	214253
3	2.20	43	2-Propyn-1-ol, acetate	$C_5H_6O_2$	98	51.9	983
4	2.25	50	1,2-Butadiene	C_4H_6	54	17.2	61939
5	2.26	39	1-Butyne	C_4H_6	54	29.3	114493
6	2.34	42	1-Butene, 3-methyl-	C_5H_{10}	70	12.6	160477
7	2.36	41	Borane, ethyldimethyl-	$C_4H_{11}B$	70	12.9	151493
8	2.39	39	3-Butyn-1-ol	C_4H_6O	70	15.1	118179
9	2.43	55	2-Pentene, (E)-	C_5H_{10}	70	14.2	291780
10	2.45	39	2-Buten-1-ol, (E)-	C_4H_8O	72	24.1	53333
11	2.48	43	7-Oxabicyclo[4.1.0]heptan-2-ol	$C_6H_{10}O_2$	114	7.07	221547
12	2.53	70	2-Butene, 2-methyl-	C_5H_{10}	70	13.1	233774
13	2.61	55	Cyclopropane, 1,2-dimethyl-, trans-	C_5H_{10}	70	8.27	19071
14	2.77	43	3-Penten-2-ol	$C_5H_{10}O$	86	18.7	61717
15	2.91	41	1-Pentene, 3-methyl-	C_6H_{12}	84	10.8	156570
16	2.92	41	Pentane, 3-methylene-	C_6H_{12}	84	13.4	19323
17	3.38	67	2,4-Hexadiene, (Z,Z)-	C_6H_{10}	82	11.8	113646
18	3.45	79	2,4-Hexadien-1-ol	$C_6H_{10}O$	98	43.6	194037
19	3.54	81	2,4-Dimethyl 1,4-pentadiene	C_7H_{12}	96	24.1	114468
20	3.64	77	Benzene	C_6H_6	78	49.3	291514
21	3.98	56	1,3-Benzodioxole, 2-ethenylhexahydro-	$C_9H_{14}O_2$	154	6.75	26846
22	4.23	81	1,4-Hexadiene, 4-methyl-	C_7H_{12}	96	12.5	113135
23	4.97	79	2,4-Heptadien-1-ol, (E,E)-	$C_7H_{12}O$	112	15.1	1645
24	5.28	69	2-Hexene, 3,5-dimethyl-	C_8H_{16}	112	22.4	149385
25	5.49	92	Benzene, (2-ethylbutyl)-	$C_{12}H_{18}$	162	17.0	5845
26	5.49	91	1,3,5-Cycloheptatriene	C_7H_8	92	13.4	230230
27	5.55	91	Toluene	C_7H_8	92	52.5	19585
28	5.63	91	trans-3,5-Dimethylcyclohexene	C_8H_{14}	110	8.49	113432
29	6.15	95	5,5-Dimethyl-1,3-hexadiene	C_8H_{14}	110	13.8	113453
30	6.36	91	Bicyclo[2.2.1]hept-2-en-7-ol	$C_7H_{10}O$	110	10.0	20149
31	6.52	69	3-Heptene, 2,6-dimethyl-	C_9H_{18}	126	15.9	113946
32	6.59	69	2,3-Dimethyl-3-heptene, (Z)-	C_9H_{18}	126	22.6	232149
33	6.82	43	Hexane, 3-ethyl-	C_8H_{18}	114	14.4	113940
34	7.17	69	Cyclohexane, 1,3,5-trimethyl-	C_9H_{18}	126	24.0	114702
35	7.35	55	Ethanone, 1-cyclohexyl-	$C_8H_{14}O$	126	13.9	238054

36	7.41	40	2-Heptenal, 2-methyl-	$C_8H_{14}O$	126	8.30	2490
37	7.83	69	Cyclohexane, 1,3,5-trimethyl-	C_9H_{18}	126	37.0	114702
38	8.21	91	p-Xylene	C_8H_{10}	106	44.6	113952
39	8.45	109	Cyclohexene, 3,3,5-trimethyl-	C_9H_{16}	124	35.0	114765
40	8.60	56	Pentadecane, 8-methylene-	$C_{16}H_{32}$	224	7.88	60985
41	8.79	83	3-Octene, 2,2-dimethyl-	$C_{10}H_{20}$	140	10.8	186136
42	9.06	83	Bicyclo[3.1.1]heptan-2-one, 6,6-dimethyl-, (1R)-	$C_9H_{14}O$	138	13.4	108460
43	9.37	82	1,6-Octadiene, 2,5-dimethyl-, (E)-	$C_{10}H_{18}$	138	6.51	62075
44	10.06	43	Hexadecane, 1,1-bis(dodecyloxy)-	$C_{40}H_{82}O_2$	594	3.49	36104
45	10.35	56	Pentadecane, 8-methylene-	$C_{16}H_{32}$	224	8.91	60985
46	10.62	91	3-Chloropropanoic acid, 6-ethyl-3-octyl ester	$C_{13}H_{25}ClO_2$	248	5.80	282658
47	10.83	105	Benzene, 1-ethyl-3-methyl-	C_9H_{12}	120	24.7	228743
48	11.71	69	Nonane, 2-methyl-3-methylene-	$C_{11}H_{22}$	154	11.0	61011
49	11.79	69	1-Ethyl-2,2,6-trimethylcyclohexane	$C_{11}H_{22}$	154	6.98	69815
50	11.97	71	Hexanoic acid, octadecyl ester	$C_{24}H_{48}O_2$	368	4.87	279270
51	12.17	71	Nonane, 2,6-dimethyl-	$C_{11}H_{24}$	156	12.2	61438
52	12.30	71	Decane, 4-methyl-	$C_{11}H_{24}$	156	9.79	5261
53	12.97	69	2-Undecanethiol, 2-methyl-	$C_{12}H_{26}S$	202	5.63	9094
54	13.09	69	1-Nonadecanol	$C_{19}H_{40}O$	284	3.98	232931
55	13.30	115	1H-Indene, 1-chloro-2,3-dihydro-	C_9H_9Cl	152	35.2	4882
56	13.41	71	1-Docosanol	$C_{22}H_{46}O$	326	6.46	23377
57	13.52	69	9-Eicosyne	$C_{20}H_{38}$	278	5.64	62817
58	14.01	69	(2,4,6-Trimethylcyclohexyl) methanol	$C_{10}H_{20}O$	156	6.73	113757
59	14.19	57	2-Dodecene, (E)-	$C_{12}H_{24}$	168	4.44	142605
60	14.30	69	2-Dodecene, (E)-	$C_{12}H_{24}$	168	3.39	142605
61	15.52	69	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	5.39	114065
62	15.70	83	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	10.8	114065
63	16.17	69	(2,4,6-Trimethylcyclohexyl) methanol	$C_{10}H_{20}O$	156	30.9	113757
64	16.69	69	1-Isopropyl-1,4,5-trimethylcyclohexane	$C_{12}H_{24}$	168	7.62	113584
65	17.01	69	Cyclohexane, 1,3,5-	$C_{27}H_{54}$	378	14.8	16569

66	17.35	128	trimethyl-2-octadecyl-Naphthalene	$C_{10}H_8$	128	51.2	114935
67	17.90	69	3-Tetradecene, (E)-	$C_{14}H_{28}$	196	6.97	139981
68	18.07	69	5-Tetradecene, (Z)-	$C_{14}H_{28}$	196	4.11	142626
69	18.24	69	Phytol	$C_{20}H_{40}O$	296	5.24	157813
70	18.36	69	2-Hexyl-1-octanol	$C_{14}H_{30}O$	214	7.54	113807
71	18.45	71	2-Hexyl-1-octanol	$C_{14}H_{30}O$	214	7.24	113807
72	18.67	71	Tetradecane, 2,6,10-trimethyl-	$C_{17}H_{36}$	240	12.9	11556
73	19.02	69	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	3.40	114065
74	20.29	69	Trichloroacetic acid, pentadecyl ester	$C_{17}H_{31}Cl_3O_2$	372	5.41	280517
75	20.71	69	1-Decanol, 2-methyl-	$C_{11}H_{24}O$	172	5.77	185011
76	21.38	69	3-Hexadecene, (Z)-	$C_{16}H_{32}$	224	4.32	62797
77	21.93	69	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242	4.13	114709
78	22.04	69	Cyclododecanemethanol	$C_{13}H_{26}O$	198	5.29	108275
79	22.46	69	11-Dodecen-1-ol difluoroacetate	$C_{14}H_{24}F_2O_2$	262	5.46	130724
80	23.40	69	3-Heptadecene, (Z)-	$C_{17}H_{34}$	238	6.57	141673
81	24.44	69	1-Octadecanol	$C_{18}H_{38}O$	270	4.47	221125
82	25.14	69	Cyclododecanemethanol	$C_{13}H_{26}O$	198	4.73	108275
83	25.67	69	1-Octadecene	$C_{18}H_{36}$	252	4.94	229404
84	25.91	69	Acetic acid, 3,7,11,15-tetramethyl-hexadecyl ester	$C_{22}H_{44}O_2$	340	4.30	193630
85	26.35	69	1-Hexadecanol, 3,7,11,15-tetramethyl-	$C_{20}H_{42}O$	298	4.33	194527
86	27.46	69	Cyclododecanemethanol	$C_{13}H_{26}O$	198	5.29	108275
87	28.15	69	18-Nonadecen-1-ol	$C_{19}H_{38}O$	282	6.13	142892
88	30.88	69	Oxirane, hexadecyl-	$C_{18}H_{36}O$	268	7.42	291026
89	31.53	69	1-Heneicosyl formate	$C_{22}H_{44}O_2$	340	5.19	72853
90	32.52	69	1-Heneicosyl formate	$C_{22}H_{44}O_2$	340	4.58	72853
91	33.98	69	1,22-Docosanediol	$C_{22}H_{46}O_2$	342	7.99	156101

GC/MS analysis of polypropylene (PP) raw plastic (**figure 4 and table 7**) in accordance with the various retention time and trace masses different types of hydrocarbon compound and benzene derivatives compounds are appeared in the analysis result index. Many compounds are emerged on the analysis carbon range C_3 to C_{27}. Three types of plastics fuel are mixed together in order to fuel produced and in produced fuel different types of blended hydrocarbon compound are available. 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 2.14 and trace mass 38, compound is Cyclopropane (C_3H_6), retention time 2.16 and trace mass 37, compound is 1-Pentanol,4-Amino- ($C_5H_{13}NO$), retention time 2.20 and trace mass 43, compound is 2-Propyn-1-ol, acetate ($C_5H_6O_2$), retention time 2.25 and trace mass 50,compound is 1,2-Butadiene (C_4H_6), retention time 2.39 and trace mass 39, compound is 3-Butyn-1-ol (C_7H_6O), retention time 2.43 and trace mass 55, compound is 2-Pentene, (E)- (C_5H_{10}), retention time 2.92 and trace mass 41,compound is Pentane, 3-methylene- (C_6H_{12}), retention time 3.38 and trace mass 67,compound name is 2,4-

Hexadiene, (Z,Z)-, (C_6H_{10}), retention time 3.98 and trace mass 56,compound name is 1,3-Benzodioxole, 2-ethenylhexahydro-, ($C_9H_{14}O_2$), retention time 4.97 and trace mass 79, compound is 2,4-Heptadien-1-ol, (E,E)-($C_7H_{12}O$), retention time 5.63 and trace mass 91, compound is trans-3,5-Dimethylcyclohexene (C_8H_{14}), retention time 6.82 and trace mass 43, compound is Hexane, 3-ethyl- (C_8H_{18}), retention time 7.83 and trace mass 69, compound is Cyclohexane, 1,3,5-trimethyl- (C_9H_{18}), retention time 8.79 and trace mass 83 compound is 3-Octene, 2,2-dimethyl- ($C_{10}H_{20}$), retention time 10.83 and trace mass 105, compound is Benzene, 1-ethyl-3-methyl- (C_9H_{12}), retention time 11.97 and trace mass 71, compound is Hexanoic acid, octadecyl ester ($C_{24}H_{48}O_2$), retention time 12.97 and trace mass 69, compound is 2-Undecanethiol, 2-methyl- ($C_{12}H_{26}S$), retention time 13.52 and trace mass 69, compound is 9-Eicosyne ($C_{20}H_{38}$), benzene compounds are formed because when raw polystyrene are made styrene are added into the as a reactants. Also at retention time 14.30 and trace mass 69, compound is 2-Dodecene, (E)- ($C_{12}H_{24}$), retention time 15.70 and trace mass 83, compound is 1-Dodecanol, 3,7,11-trimethyl- ($C_{15}H_{32}O$), polypropylene hydrocarbon its burns and as its characteristic of materials containing aliphatic rings. More hydrocarbon single bond, double bond and conjugated compound are appeared. Retention time 16.69 and trace mass 69, compound is 1-Isopropyl-1, 4, 5-trimethylcyclohexane, ($C_{12}H_{24}$) 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 17.90 and trace mass 69, compound is Eicosane ($C_{14}H_{28}$), retention time 18.67 and trace mass 71, compound is Tetradecane, 2,6,10-trimethyl- ($C_{17}H_{36}$) . Retention time 20.71 and trace mass 69, compound is 1-Decanol, 2-methyl- ($C_{11}H_{24}O$), retention time 22.46 and trace mass 69, compound is 11-Dodecen-1-ol difluoroacetate ($C_{14}H_{24}F_2O_2$), retention time 23.46 and trace mass 57, compound is Eicosane, ($C_{20}H_{42}$), at retention time 24.44 and trace mass 69, compound is 1-Octadecanol ($C_{18}H_{58}O$), retention time 26.35 and trace mass 69, compound is 1-Hexadecanol, 3,7,11,15-tetramethyl- ($C_{20}H_{42}O$) 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 27.46 and trace mass 69, compound is Cyclododecanemethanol ($C_{13}H_{26}O$), retention time 30.88 and trace mass 69, compound is Oxirane, hexadecyl- ($C_{18}H_{36}O$), and ultimately retention time 33.98 and trace mass 69, compound is 1, 22-Docosanediol ($C_{26}H_{46}O_2$) as well.

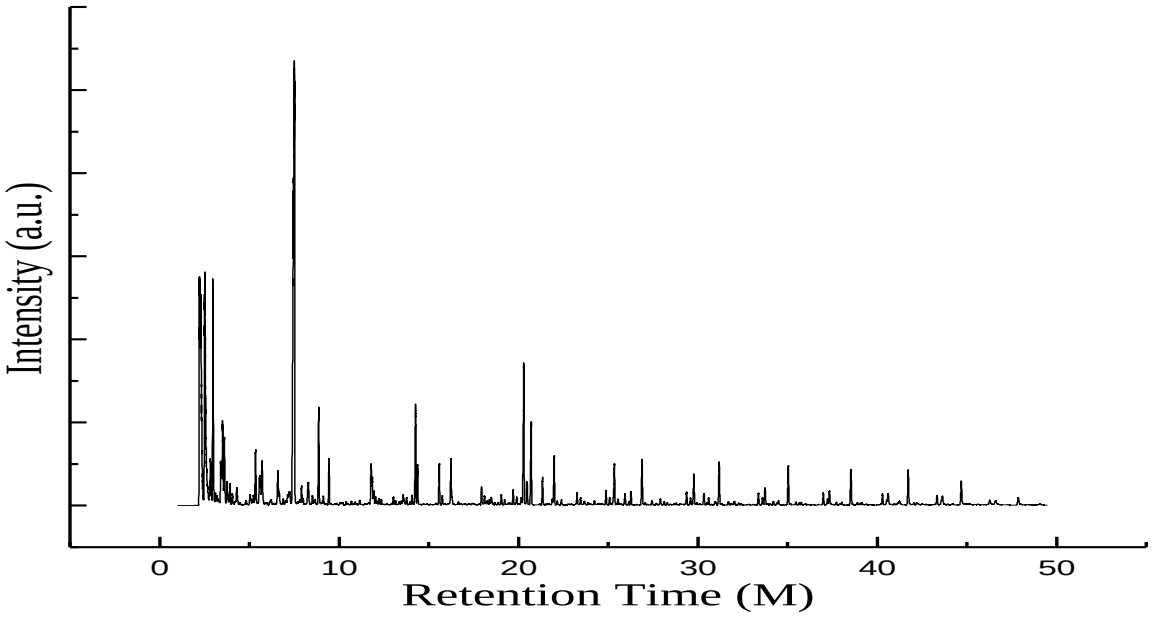

Figure 5: GC/MS chromatogram of polypropylene raw standard plastic

Table 8: Polypropylene raw standard plastic GC/MS chromatogram compound list

Peak Number	Retention Time (M)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	NIST Library Number
1	2.20	42	Cyclopropane	C_3H_6	42	60.1	18854
2	2.29	41	2-Butene, (E)-	C_4H_8	56	13.5	105
3	2.30	56	Cyclobutane	C_4H_8	56	18.8	107
4	2.34	41	1-Propene, 2-methyl-	C_4H_8	56	20.4	61293
5	2.50	43	Pentane	C_5H_{12}	72	23.0	114462
6	2.83	43	1-Pentanol, 2-methyl-	$C_6H_{14}O$	102	17.3	19924
7	2.96	41	1-Pentene, 2-methyl-	C_6H_{12}	84	17.3	495
8	3.40	67	1,3-Pentadiene, 2-methyl-, (E)-	C_6H_{10}	82	17.2	113652
9	3.43	67	2,4-Hexadiene, (Z,Z)-	C_6H_{10}	82	12.2	113646
10	3.51	56	1-Pentene, 2,4-dimethyl-	C_7H_{14}	98	52.6	114435
11	3.60	81	2,4-Dimethyl 1,4-pentadiene	C_7H_{12}	96	42.8	114468
12	3.75	78	Benzene	C_6H_6	78	53.4	291514
13	3.92	81	1,5-Hexadiene, 2-methyl-	C_7H_{12}	96	48.3	114394
14	4.31	81	1,3-Pentadiene, 2,3-dimethyl-	C_7H_{12}	96	21.9	150967
15	5.04	79	1-Cyclohexene-1-methanol	$C_7H_{12}O$	112	32.0	52048
16	5.23	56	3-Hexene, 2,5-dimethyl-, (E)-	C_8H_{16}	112	17.4	114264
17	5.35	69	2-Heptene, 4-methyl-, (E)-	C_8H_{16}	112	16.1	113478

18	5.57	43	Cyclohexanol, 2-methyl-, cis-	$C_7H_{14}O$	114	10.4	114160
19	5.61	91	1,3,5-Cycloheptatriene	C_7H_8	92	35.9	230230
20	5.71	67	1,5-Hexadiene, 2,5-dimethyl-	C_8H_{14}	110	13.2	162753
21	6.22	95	Cyclopentene, 1,2,3-trimethyl-	C_8H_{14}	110	20.4	113461
22	6.59	69	3-Heptene, 2,6-dimethyl-	C_9H_{18}	126	12.9	37342
23	6.66	69	Cyclopentane, 1,1,3,4-tetramethyl-, cis-	C_9H_{18}	126	9.45	27589
24	7.44	70	2,4-Dimethyl-1-heptene	C_9H_{18}	126	55.6	113516
25	7.91	69	Cyclohexane, 1,3,5-trimethyl-	C_9H_{18}	126	36.8	114702
26	7.99	91	1,3-Hexadiene, 2,5-dimethyl-	C_8H_{14}	110	9.52	61715
27	8.28	91	Cyclohexanol, 1-ethynyl-, carbamate	$C_9H_{13}NO_2$	167	39.3	313023
28	8.51	109	Cyclohexene, 3,3,5-trimethyl-	C_9H_{16}	124	27.1	114765
29	8.87	43	2,3,3-Trimethyl-1-hexene	C_9H_{18}	126	10.5	113521
30	9.12	83	Bicyclo[3.1.1]heptan-2-one, 6,6-dimethyl-, (1R)-	$C_9H_{14}O$	138	18.9	108460
31	9.44	82	1,6-Octadiene, 2,6-dimethyl-, (Z)-	$C_{10}H_{18}$	138	8.95	150614
32	10.41	56	2-Methyl-1-nonene	$C_{10}H_{20}$	140	4.66	113561
33	10.69	91	Ethanone, 1-(2,2-dimethylcyclopentyl)-	$C_9H_{16}O$	140	6.45	46578
34	10.90	105	Benzene, 1-ethyl-3-methyl-	C_9H_{12}	120	23.6	228743
35	11.15	105	2H-Indeno[1,2-b]oxirene, octahydro-, (1aα,1bβ,5aα,6aα)-	$C_9H_{14}O$	138	15.3	46570
36	11.79	69	Nonane, 2-methyl-3-methylene-	$C_{11}H_{22}$	154	12.4	61011
37	11.85	69	Nonane, 2-methyl-3-methylene-	$C_{11}H_{22}$	154	10.5	61011
38	12.03	43	1-Nonene, 4,6,8-trimethyl-	$C_{12}H_{24}$	168	7.81	6413
39	12.12	43	1-Decene, 4-methyl-	$C_{11}H_{22}$	154	5.86	150275
40	13.09	69	3-Dodecene, (E)-	$C_{12}H_{24}$	168	5.15	70642
41	13.16	69	2-Undecanethiol, 2-methyl-	$C_{12}H_{26}S$	202	6.43	9094
42	13.36	69	4-Chloro-3-n-hexyltetrahydropyran	$C_{11}H_{21}ClO$	204	7.61	216835
43	13.58	69	3-Tetradecyne	$C_{14}H_{26}$	194	5.98	62725
44	13.77	69	3-Tridecene	$C_{13}H_{24}$	180	9.46	142644
45	14.27	69	2-Undecanethiol, 2-methyl-	$C_{12}H_{26}S$	202	4.70	9094
46	14.38	69	1-Octanol, 3,7-dimethyl-	$C_{10}H_{22}O$	158	3.55	114129
47	15.59	69	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	3.86	114065
48	16.23	69	(2,4,6-Trimethylcyclohexyl)	$C_{10}H_{20}O$	156	32.9	113757

			methanol				
49	17.94	69	3-Tetradecene, (E)-	$C_{14}H_{28}$	196	5.03	62795
50	18.11	69	Cyclohexane, 2-propyl-1,1,3-trimethyl-	$C_{12}H_{24}$	168	5.58	69818
51	18.39	71	1-Nonene, 4,6,8-trimethyl-	$C_{12}H_{24}$	168	10.5	6413
52	18.49	69	2-Hexyl-1-octanol	$C_{14}H_{30}O$	214	5.27	113807
53	18.70	43	Decane, 2,3,5,8-tetramethyl-	$C_{14}H_{30}$	198	6.79	149589
54	19.05	69	Isotridecanol-	$C_{13}H_{28}O$	200	5.51	298499
55	19.71	69	(2,4,6-Trimethylcyclohexyl) methanol	$C_{10}H_{20}O$	156	17.6	113757
56	20.30	69	Isotridecanol-	$C_{13}H_{28}O$	200	5.41	298499
57	20.48	69	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242	4.09	114709
58	20.71	69	1-Octanol, 2-butyl-	$C_{12}H_{26}O$	186	3.68	114639
59	21.35	69	1-Octanol, 2-butyl-	$C_{12}H_{26}O$	186	6.89	114639
60	22.00	55	(2,4,6-Trimethylcyclohexyl) methanol	$C_{10}H_{20}O$	156	7.80	113757
61	22.39	69	7-Octadecyne, 2-methyl-	$C_{19}H_{36}$	264	5.74	114518
62	23.27	69	2-Isopropyl-5-methyl-1-heptanol	$C_{11}H_{24}O$	172	3.37	245029
63	23.47	69	3-Eicosene, (E)-	$C_{20}H_{40}$	280	3.70	62838
64	23.69	71	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242	4.96	114709
65	24.24	69	1-Dodecanol, 3,7,11-trimethyl-	$C_{15}H_{32}O$	228	4.17	114065
66	25.35	69	1-Hexadecanol, 3,7,11,15-tetramethyl-	$C_{20}H_{42}O$	298	4.17	194527
67	26.27	69	9-Eicosene, (E)-	$C_{20}H_{40}$	280	4.67	62815
68	26.89	69	2,4,6-Trimethylcyclohexyl) methanol	$C_{10}H_{20}O$	156	9.15	113757
69	27.92	69	3-Eicosene, (E)-	$C_{20}H_{40}$	280	4.27	62838
70	29.38	69	11-Dodecen-1-ol, 2,4,6-trimethyl-, (R,R,R)-	$C_{15}H_{30}O$	226	15.4	31254
71	29.59	69	Cyclododecanemethanol	$C_{13}H_{26}O$	198	7.43	108275
72	29.78	69	1-Nonadecene	$C_{19}H_{38}$	266	3.93	107568
73	30.35	69	1-Nonadecene	$C_{19}H_{38}$	266	4.15	113626
74	31.19	69	1,22-Docosanediol	$C_{22}H_{46}O_2$	342	12.3	142886
75	32.04	69	1-Docosene	$C_{22}H_{44}$	308	4.07	113878
76	33.38	69	11-Dodecen-1-ol, 2,4,6-trimethyl-, (R,R,R)-	$C_{15}H_{30}O$	226	17.6	31254
77	33.75	69	Acetic acid, 3,7,11,15-tetramethyl-hexadecyl ester	$C_{22}H_{44}O_2$	340	6.85	193630
78	35.04	69	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	348	6.03	15853
79	35.78	69	3-Eicosene, (E)-	$C_{20}H_{40}$	280	5.18	62838
80	37.00	69	11-Dodecen-1-ol, 2,4,6-trimethyl-, (R,R,R)-	$C_{15}H_{30}O$	226	10.9	31254
81	37.33	69	Cyclotetradecane, 1,7,11-	$C_{20}H_{40}$	280	14.3	13489

			trimethyl-4-(1-methylethyl)-				
82	38.54	69	Oxirane, tetradecyl-	$C_{16}H_{32}O$	240	10.4	75831
83	40.30	69	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	348	9.87	15853
84	40.62	69	Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	$C_{20}H_{40}$	280	7.45	13489
85	41.73	69	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	348	7.67	15853
86	43.34	69	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	348	9.22	15853
87	44.68	69	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	348	8.83	15853

Perkin Elmer GC/MS analysis of polypropylene (PP) raw standard plastic (**figure 5 and table 8**) in accordance with the various retention time and trace masses different types of hydrocarbon compound and benzene derivatives compounds are appeared in the analysis result index. Many compounds are emerged in the analysis between carbon ranges C_3 to C_{25} . 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 2.20 and trace mass 42, compound is Cyclopropane (C_3H_6), retention time 2.29 and trace mass 41, compound is 2-Butene, (E)- (C_4H_8), retention time 2.50 and trace mass 43, compound is Pentane (C_5H_{12}), retention time 2.96 and trace mass 41,compound is 1-Pentene,2-methyl- (C_6H_{12}), retention time 3.75 and trace mass 78, compound is Benzene (C_6H_6), retention time 3.92 and trace mass 81, compound is 1,5-Hexadiene, 2-methyl- (C_7H_{12}), retention time 4.31 and trace mass 81,compound is 1,3-Pentadiene, 2,3-dimethyl- (C_7H_{12}), retention time 5.61 and trace mass 91,compound name is 1,3,5-Cycloheptatriene (C_7H_8), retention time 5.71 and trace mass 67,compound name is 1,5-Hexadiene, 2,5-dimethyl- (C_8H_{14}), retention time 6.66 and trace mass 69, compound is Cyclopentane, 1,1,3,4-tetramethyl-, cis- (C_9H_{18}), retention time 7.99 and trace mass 91, compound is 1,3-Hexadiene, 2,5-dimethyl- (C_8H_{14}), retention time 8.87 and trace mass 43, compound is 2,3,3-Trimethyl-1-hexene (C_9H_8), retention time 9.12 and trace mass 83, compound is Bicyclo[3.1.1]heptan-2-one, 6,6-dimethyl-, (1R)- ($C_9H_{14}O$), retention time 10.90 and trace mass 105 compound is 2H-Indeno[1,2-b]oxirene, octahydro-, (1aα,1bβ,5aα,6aα)- ($C_9H_{14}O$), retention time 11.85 and trace mass 69, compound is Nonane, 2-methyl-3-methylene- ($C_{11}H_{22}$), retention time 12.12 and trace mass 43, compound is 1-Dcene-4-methyl-($C_{11}H_{22}$), retention time 13.77 and trace mass 69, compound is 3-Tridecene ($C_{13}H_{24}$), retention time 14.38 and trace mass 69, compound is 1-Octanol, 3,7-dimethyl- ($C_{10}H_{22}O$). Also at retention time 15.59 and trace mass 69, compound is 1-Dodecanol, 3,7,11-trimethyl- ($C_{15}H_{32}O$), retention time 17.94 and trace mass 69, compound is 3-3-Tetradecene, (E)- ($C_{14}H_{28}$), polypropylene hydrocarbon its burns and as its characteristic of materials containing aliphatic rings. More hydrocarbon single bond, double bond and conjugated compound are appeared. Retention time 18.70 and trace mass 43, compound is Decane, 2, 3, 5, 8-tetramethyl- ($C_{14}H_{30}$) 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 20.30 and trace mass 69, compound is Isotridecanol- ($C_{13}H_{28}O$), retention time 21.35 and trace mass 69, compound is 1-Octanol, 2-butyl- ($C_{12}H_{26}O$) . Retention time 23.47 and trace mass 69, compound is 3-Eicosene, (E)-

($C_{20}H_{40}$), retention time 25.35 and trace mass 69, compound is 1-Hexadecanol, 3,7,11,15-tetramethyl- ($C_{20}H_{40}O$), retention time 29.38 and trace mass 69, compound is 11-Dodecen-1-ol, 2,4,6-trimethyl-, (R,R,R)- ($C_{15}H_{30}O$), at retention time 33.38 and trace mass 69, compound is 11-Dodecen-1-ol, 2,4,6-trimethyl-, (R,R,R)- ($C_{15}H_{30}O$), retention time 35.78 and trace mass 69, compound is 3-Eicosene, (E)- ($C_{20}H_{40}$) 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 37.33 and trace mass 69, compound is Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)- ($C_{20}H_{40}$), retention time 43.34 and trace mass 69, compound is Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)- ($C_{25}H_{48}$), and ultimately retention time 44.68 and trace mass 69, compound is Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)- ($C_{25}H_{48}$) as well.

3.3. Liquid Fuel Analysis

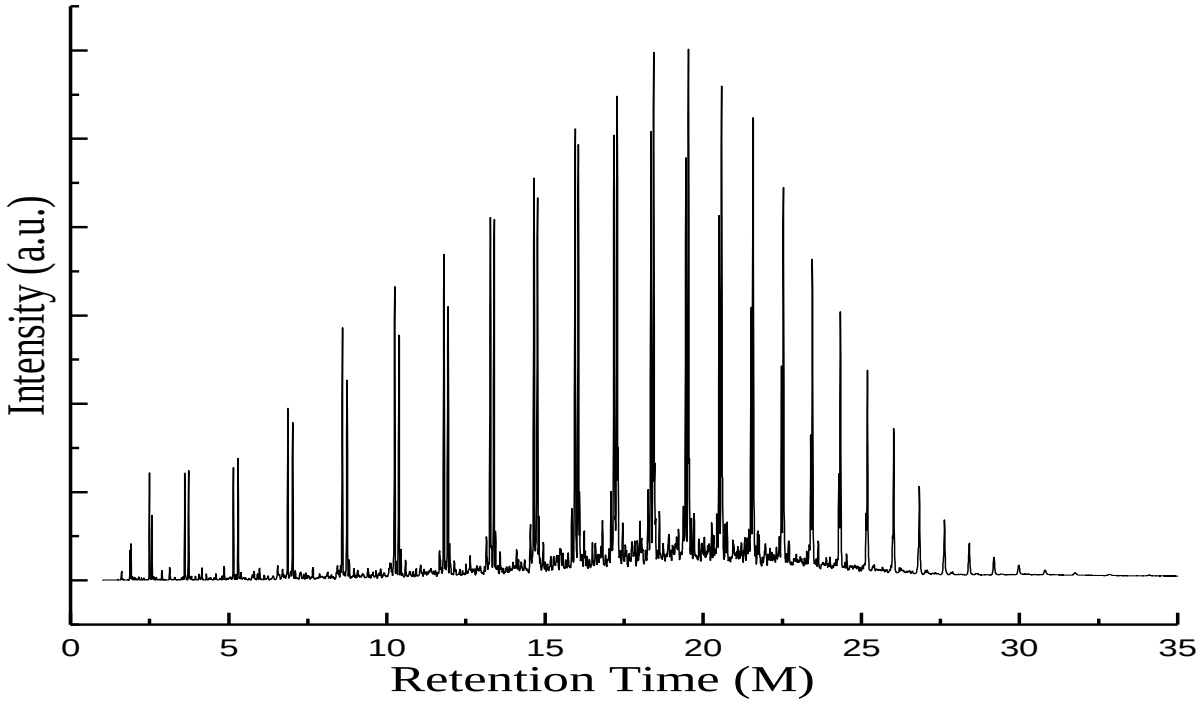

Figure 6: GC/MS chromatogram of polypropylene waste plastic to liquid fuel

Table 9: Polypropylene waste plastic to liquid fuel GC/MS chromatogram compound list

Peak Number	Retention Time (M)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	NIST Library Number
1	1.50	39	Propane	C_3H_8	44	60.0	18863
2	1.61	43	Butane	C_4H_{10}	58	58.6	123
3	1.67	41	2-Butene, (E)-	C_4H_8	56	20.9	105

4	1.87	42	Cyclopropane, ethyl-	C_5H_{10}	70	27.6	250
5	1.91	43	Pentane	C_5H_{12}	72	81.0	114462
6	1.95	55	Cyclopropane, 1,2-dimethyl-, cis-	C_5H_{10}	70	15.0	19070
7	2.01	55	1-Butene, 3-methyl-	C_5H_{10}	70	21.5	114463
8	2.06	67	1,3-Pentadiene	C_5H_8	68	15.1	291890
9	2.50	41	Cyclopropane, 1-ethyl-2-methyl-, cis-	C_6H_{12}	84	19.8	113658
10	2.57	41	Hexane	C_6H_{14}	86	80.9	291337
11	2.89	56	Cyclopentane, methyl-	C_6H_{12}	84	64.8	114428
12	3.14	67	Cyclopentene, 3-methyl-	C_6H_{10}	82	11.1	114408
13	3.61	41	1-Heptene	C_7H_{14}	98	35.8	107734
14	3.73	43	Heptane	C_7H_{16}	100	68.1	61276
15	3.94	81	1,4-Hexadiene, 2-methyl-	C_7H_{12}	96	8.47	840
16	4.06	81	Cyclopentane, 1-methyl-2-methylene-	C_7H_{12}	96	11.8	62523
17	4.16	83	Cyclohexane, methyl-	C_7H_{14}	98	67.1	118503
18	4.29	41	Cyclopentane, ethyl-	C_7H_{14}	98	32.1	940
19	4.38	81	Cyclohexene, 3-methyl-	C_7H_{12}	96	7.81	236066
20	4.54	81	Cyclobutane, (1-methylethylidene)-	C_7H_{12}	96	11.9	150272
21	4.60	67	1-Ethylcyclopentene	C_7H_{12}	96	33.0	114407
22	4.72	43	1-Hexanethiol, 2-ethyl-	$C_8H_{18}S$	146	4.47	4291
23	4.79	91	Toluene	C_7H_8	92	28.3	227551
24	4.85	81	Cyclohexene, 3-methyl-	C_7H_{12}	96	9.18	236066
25	5.15	41	1-Octene	C_8H_{16}	112	25.5	1604
26	5.23	55	Cyclopentane, 1-ethyl-2-methyl-, cis-	C_8H_{16}	112	12.4	118884
27	5.30	43	Octane	C_8H_{18}	114	30.9	229407
28	5.39	55	2-Octene	C_8H_{16}	112	14.5	118191
29	5.76	67	Bicyclo[5.1.0]octane	C_8H_{14}	110	7.82	46292
30	5.80	67	1-Methyl-2-methylenecyclohexane	C_8H_{14}	110	24.2	113437
31	5.91	41	Cyclopentane, butyl-	C_9H_{18}	126	7.80	114172
32	5.97	83	Cyclohexane, ethyl-	C_8H_{16}	112	50.0	113476
33	6.12	67	3-Octyne	C_8H_{14}	110	12.0	118185
34	6.40	91	Bicyclo[2.1.1]hexan-2-ol, 2-ethenyl-	$C_8H_{12}O$	124	11.6	221372
35	6.55	81	Cyclohexanol, 1-ethynyl-, carbamate	$C_9H_{13}NO_2$	167	22.7	313023
36	6.61	67	1-Methyl-2-methylenecyclohexane	C_8H_{14}	110	4.63	113437
37	6.87	41	1-Nonene	C_9H_{18}	126	10.8	107756
38	7.02	43	Nonane	C_9H_{20}	128	32.5	228006
39	7.10	55	2-Nonene, (E)-	C_9H_{18}	126	16.6	113510
40	7.28	55	2,4-Pentadien-1-ol, 3-propyl-, (2Z)-	$C_8H_{14}O$	126	18.0	142179
41	7.44	67	trans-1-Butenylcyclopentane	C_9H_{16}	124	20.4	113509

42	7.66	55	Cyclopentane, butyl-	C_9H_{18}	126	31.9	114172
43	8.13	105	1-Hepten-5-yne, 2-methyl-3-methylene-	C_9H_{12}	120	13.2	149826
44	8.25	57	2-Decen-1-ol	$C_{10}H_{20}O$	156	19.9	136260
45	4.41	55	4,5-Nonadiene, 2-methyl-	$C_{10}H_{18}$	138	5.62	26999
46	8.44	55	Cyclodecene, (E)-	$C_{10}H_{18}$	138	13.1	37628
47	8.60	41	1-Decene	$C_{10}H_{20}$	140	27.6	118883
48	8.74	43	Decane	$C_{10}H_{22}$	142	61.4	114147
49	8.81	55	2-Decene, (Z)-	$C_{10}H_{20}$	140	13.6	114151
50	8.96	55	3-Decyn-2-ol	$C_{10}H_{18}O$	154	6.37	53449
51	9.40	55	Cyclodecane	$C_{10}H_{20}$	140	6.85	113565
52	9.56	67	Cyclopentene, 1-pentyl-	$C_{10}H_{18}$	138	8.42	139585
53	9.65	41	1,5,7-Octatrien-3-ol, 2,6-dimethyl-	$C_{10}H_{16}O$	152	10.7	31915
54	9.75	91	Bicyclo[3.1.1]heptan-3-ol, 6,6-dimethyl-2-methylene-, [1S-(1α,3α,5α)]-	$C_{10}H_{16}O$	152	13.3	151861
55	9.80	41	Cyclohexene, 3-(2-methylpropyl)-	$C_{10}H_{18}$	138	5.71	27008
56	9.91	41	7-Hexadecenal, (Z)-	$C_{16}H_{30}O$	238	12.0	293051
57	10.10	41	1,10-Undecadiene	$C_{11}H_{20}$	152	20.0	113574
58	10.25	41	1-Undecene	$C_{11}H_{22}$	154	9.77	34717
59	10.38	43	Undecane	$C_{11}H_{24}$	156	50.3	114185
60	10.44	55	5-Undecene, (E)-	$C_{11}H_{22}$	154	10.5	114227
61	11.07	41	3-Undecene, (E)-	$C_{11}H_{22}$	154	8.58	60565
62	11.17	67	1-Undecyne	$C_{11}H_{20}$	152	5.49	36306
63	11.66	41	1,11-Dodecadiene	$C_{12}H_{22}$	166	8.24	113595
64	11.80	41	3-Dodecene, (E)-	$C_{12}H_{24}$	168	7.81	113960
65	11.92	71	Dodecane	$C_{12}H_{26}$	170	35.0	291499
66	11.98	41	3-Dodecene, (E)-	$C_{12}H_{24}$	168	12.6	70642
67	12.12	41	6-Dodecene, (Z)-	$C_{12}H_{24}$	168	13.4	142611
68	12.50	41	1-Octadecyne	$C_{18}H_{34}$	250	5.65	233010
69	12.63	41	Cyclododecane	$C_{12}H_{24}$	168	9.88	60982
70	12.84	41	7-Hexadecenal, (Z)-	$C_{16}H_{30}O$	238	5.87	293051
71	12.95	41	Tetradecane, 2,6,10-trimethyl-	$C_{17}H_{36}$	240	12.2	11556
72	13.15	41	Z-10-Pentadecen-1-ol	$C_{15}H_{30}O$	226	7.37	245485
73	13.26	41	1-Tridecene	$C_{13}H_{26}$	182	8.27	107768
74	13.38	57	Tridecane	$C_{13}H_{28}$	184	35.3	114282
75	13.43	41	5-Tridecene, (E)-	$C_{13}H_{26}$	182	8.57	142619
76	13.57	41	2-Tridecene, (Z)-	$C_{13}H_{26}$	182	7.85	142613
77	14.09	41	1-Nonadecanol	$C_{19}H_{40}O$	284	4.75	13666
78	14.15	67	1,12-Tridecadiene	$C_{13}H_{24}$	180	7.16	7380
79	14.24	43	Tetradecane, 2,6,10-trimethyl-	$C_{17}H_{36}$	240	13.6	11556
80	14.35	41	7-Hexadecenal, (Z)-	$C_{16}H_{30}O$	238	6.03	293051
81	14.54	41	3-Tetradecene, (E)-	$C_{14}H_{28}$	196	5.91	139981
82	14.64	41	1-Tetradecene	$C_{14}H_{28}$	196	6.76	34720

83	14.76	57	Tetradecane	$C_{14}H_{30}$	198	35.1	113925
84	14.80	41	3-Tetradecene, (E)-	$C_{14}H_{28}$	196	7.84	139981
85	14.94	41	7-Tetradecene	$C_{14}H_{28}$	196	7.25	70643
86	15.48	41	1-Nonadecanol	$C_{19}H_{40}O$	284	5.25	13666
87	15.56	43	Octadecane, 6-methyl-	$C_{19}H_{40}$	268	6.19	35803
88	15.84	41	Z-10-Pentadecen-1-ol	$C_{15}H_{30}O$	226	16.0	245485
89	15.94	41	1-Pentadecene	$C_{15}H_{30}$	210	6.54	69726
90	16.05	43	Pentadecane	$C_{15}H_{32}$	212	30.7	107761
91	16.08	41	E-2-Hexadecacen-1-ol	$C_{16}H_{32}O$	240	12.0	131101
92	16.59	41	1-Hexadecanol, 2-methyl-	$C_{17}H_{36}O$	256	8.96	36540
93	16.81	41	1-Nonadecanol	$C_{19}H_{40}O$	284	7.36	13666
94	16.91	41	Octadecane, 6-methyl-	$C_{19}H_{40}$	268	10.7	35803
95	17.09	41	Cyclohexadecane	$C_{16}H_{32}$	224	4.93	258206
96	17.18	43	1-Hexadecene	$C_{16}H_{32}$	224	8.05	118882
97	17.27	71	Hexadecane	$C_{16}H_{34}$	226	34.9	114191
98	17.31	41	1-Hexadecene	$C_{16}H_{32}$	224	5.59	118882
99	17.45	41	10-Heneicosene (c,t)	$C_{21}H_{42}$	294	3.34	113073
100	17.99	43	1-Hexadecanol, 2-methyl-	$C_{17}H_{36}O$	256	4.80	36540
101	18.25	41	E-2-Octadecadecen-1-ol	$C_{18}H_{36}O$	268	18.1	131102
102	18.38	55	1-Heptadecanol	$C_{17}H_{36}O$	256	7.36	113250
103	18.44	56	Heptadecane	$C_{17}H_{36}$	240	31.5	107308
104	18.46	41	2-Methyl-E-7-hexadecene	$C_{17}H_{34}$	238	8.32	130870
105	18.62	41	2-Methyl-E-7-hexadecene	$C_{17}H_{34}$	238	13.3	130870
106	18.90	43	1-Hexadecanol, 2-methyl-	$C_{17}H_{36}O$	256	6.78	36540
107	19.12	43	Tetradecane, 2,6,10-trimethyl-	$C_{17}H_{36}$	240	6.93	11556
108	19.21	41	Heptadecane, 2,3-dimethyl-	$C_{19}H_{40}$	268	6.42	68909
109	19.38	41	1-Tetracosanol	$C_{24}H_{50}O$	354	4.50	16001
110	19.45	55	9-Nonadecene	$C_{19}H_{38}$	266	4.76	113627
111	19.54	85	Eicosane	$C_{20}H_{42}$	282	15.7	290513
112	19.62	41	1-Docosanol	$C_{22}H_{46}O$	326	6.39	23377
113	19.71	43	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242	4.60	114709
114	19.86	55	1-Docosanol	$C_{22}H_{46}O$	326	9.93	23377
115	20.51	55	9-Nonadecene	$C_{19}H_{38}$	266	11.1	113627
116	20.59	57	Eicosane	$C_{20}H_{42}$	282	20.9	290513
117	21.51	43	1-Docosene	$C_{22}H_{44}$	308	7.92	113878
118	21.58	55	Eicosane	$C_{20}H_{42}$	282	45.4	290513
119	22.54	56	Heneicosane	$C_{21}H_{44}$	296	18.6	107569
120	23.40	43	1-Docosene	$C_{22}H_{44}$	308	9.50	113878
121	23.46	57	Heneicosane	$C_{21}H_{44}$	296	17.4	107569
122	24.29	83	1-Eicosanol	$C_{20}H_{42}O$	298	7.72	113075
123	24.34	85	Heneicosane	$C_{21}H_{44}$	296	14.6	107569
124	25.20	57	Octacosane	$C_{28}H_{58}$	394	11.3	134306
125	26.03	57	Heneicosane	$C_{21}H_{44}$	296	10.6	107569
126	26.85	57	Heneicosane	$C_{21}H_{44}$	296	9.32	107569
127	27.65	57	Tetratetracontane	$C_{44}H_{90}$	618	9.27	23773

128	28.45	57	Heptacosane	$C_{27}H_{56}$	380	13.3	79427

Gas Chromatography and Mass Spectrometer analysis of polypropylene (PP) waste plastic to liquid fuel (**figure 6 and table 9**) in accordance with the various retention time and trace masses different types of hydrocarbon compound and benzene derivatives compounds are appeared in the analysis result index. Many compounds are emerged in the analysis between carbon ranges C_3 to $C_{44.}$ 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 1.50 and trace mass 39, compound is Propane (C_3H_8), retention time 1.95 and trace mass 55, compound is Cyclopropane, 1,2-dimethyl-, cis- (C_5H_{10}), retention time 2.57 and trace mass 41, compound is Hexane (C_6H_{14}), retention time 2.89 and trace mass 56,compound is Cyclopentane, methyl- (C_6H_{12}), retention time 3.73 and trace mass 43, compound is Heptane (C_7H_{16}), retention time 4.54 and trace mass 81, compound is Cyclobutane, (1-methylethylidene)- (C_7H_{12}), retention time 4.85 and trace mass 81,compound is Cyclohexene, 3-methyl- (C_7H_{12}), retention time 5.91 and trace mass 41,compound name is Cyclopentane, butyl- (C_9H_{18}), retention time 5.97 and trace mass 83,compound name is Cyclohexane, ethyl- (C_8H_{16}), retention time 6.87 and trace mass 41, compound is 1-Nonene (C_9H_{18}), retention time 7.66 and trace mass 55, compound is Cyclopentane, butyl- (C_8H_{18}), retention time 8.96 and trace mass 55, compound is 3-Decyn-2-ol ($C_{10}H_{18}O$), retention time 9.91 and trace mass 41, compound is 7-Hexadecenal, (Z)- ($C_{16}H_{30}O$), retention time 10.44 and trace mass 55 compound is 5-Undecene, (E) ($C_{11}H_{22}$), retention time 11.98 and trace mass 41, compound is 3-Dodecene,(E)-($C_{11}H_{24}$), retention time 12.12 and trace mass 41, compound is 6-Dodecene, (Z)-($C_{11}H_{24}$), retention time 12.95 and trace mass 41, compound is Tetradecane, 2,6,10-trimethyl- ($C_{17}H_{36}$), retention time 13.57 and trace mass 41, compound is 2-Tridecene (Z), ($C_{13}H_{26}$) etc. Also at retention time 14.94 and trace mass 41, compound is 7-Tetradecene ($C_{14}H_{28}$), retention time 15.94 and trace mass 41, compound is 1-Pentadecene ($C_{15}H_{30}$), polypropylene hydrocarbon its burns and as its characteristic of materials containing aliphatic rings. More hydrocarbon single bond, double bond and conjugated compound are appeared. Retention time 18.90 and trace mass 43, compound is 1-Hexadecanol, 2-methyl- ($C_{17}H_{36}O$) 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 20.51 and trace mass 55, compound is 9-Nonadecene ($C_{19}H_{38}$), retention time 21.51 and trace mass 43, compound is 1-Docosene ($C_{22}H_{44}$). Retention time 23.46 and trace mass 57, compound is Heneicosane ($C_{21}H_{44}$), retention time 24.29 and trace mass 83, compound is 1-Eicosanol ($C_{20}H_{42}O$), retention time 25.20 and trace mass 57, compound is Octacosane ($C_{28}H_{58}$), at retention time 26.03 and trace mass 57, compound is Heneicosane ($C_{21}H_{44}$), retention time 26.85 and trace mass 57, compound is Heneicosane ($C_{21}H_{44}$) 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 27.65 and trace mass 57, compound is Tetratetracontane ($C_{44}H_{90}$) and ultimately retention time 28.45 and trace mass 57, compound is Heptacosane ($C_{27}H_{56}$) as well.

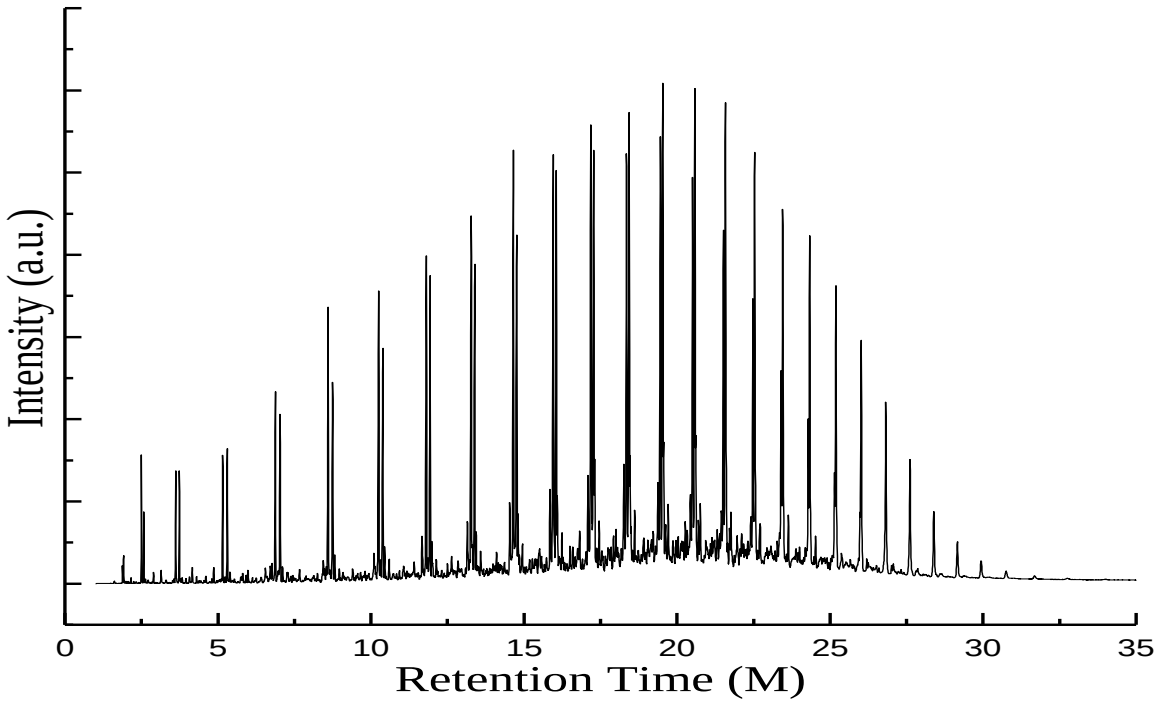

Figure 7: GC/MS chromatogram of polypropylene standard plastic to liquid fuel

Table 10: Polypropylene standard plastic to liquid fuel GC/MS chromatogram compound list

Peak Number	Retention Time (M)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	NIST Library Number
1	1.62	43	Butane	C_4H_{10}	58	63.1	123
2	1.64	41	1-Propene, 2-methyl-	C_4H_8	56	13.2	61293
3	1.88	42	Cyclopropane, ethyl-	C_5H_{10}	70	18.5	250
4	1.92	43	Pentane	C_5H_{12}	72	89.8	114462
5	1.95	55	Cyclopropane, 1,2-dimethyl-, trans-	C_5H_{10}	70	16.4	19071
6	2.06	67	1,4-Pentadiene	C_5H_8	68	18.6	114494
7	2.25	67	Cyclopentene	C_5H_8	68	19.5	19032
8	2.32	42	1-Pentanol, 2-methyl-	$C_6H_{14}O$	102	10.1	19924
9	2.50	41	Cyclopropane, 1-ethyl-2-methyl-, cis-	C_6H_{12}	84	19.2	113658
10	2.58	57	Hexane	C_6H_{14}	86	79.2	61280
11	2.84	67	Cyclopentene, 3-methyl-	C_6H_{10}	82	8.72	114408
12	2.90	56	Cyclopentane, methyl-	C_6H_{12}	84	62.9	114428
13	3.00	67	2,4-Hexadiene, (Z,Z)-	C_6H_{10}	82	7.75	113646
14	3.14	67	Cyclopentene, 3-methyl-	C_6H_{10}	82	17.1	114408
15	3.57	56	1-Hexene, 2-methyl-	C_7H_{14}	98	36.0	114433
16	3.62	41	Cyclopentane, 1,2-dimethyl-, cis-	C_7H_{14}	98	26.5	114027

17	3.74	43	Heptane	C_7H_{16}	100	59.7	61276
18	3.83	55	2-Heptene	C_7H_{14}	98	22.2	113119
19	3.96	81	Cyclopropane, trimethylmethylene-	C_7H_{12}	96	7.96	63085
20	4.07	81	Cyclopentane, 1-methyl-2-methylene-	C_7H_{12}	96	11.2	62523
21	4.17	83	Cyclohexane, methyl-	C_7H_{14}	98	63.8	118503
22	4.31	69	Cyclopentane, ethyl-	C_7H_{14}	98	38.3	940
23	4.44	81	Cycloheptene	C_7H_{12}	96	9.58	231486
24	4.55	81	Cyclopentene, 4,4-dimethyl-	C_7H_{12}	96	13.2	38642
25	4.61	67	1-Ethylcyclopentene	C_7H_{12}	96	35.8	114407
26	4.73	43	1-Hexanethiol, 2-ethyl-	$C_8H_{18}S$	146	6.45	4291
27	4.80	91	Toluene	C_7H_8	92	32.6	291301
28	4.86	81	Cyclohexene, 1-methyl-	C_7H_{12}	96	10.4	139432
29	5.15	41	1-Octene	C_8H_{16}	112	16.5	1604
30	5.23	55	Cyclopentane, 1-ethyl-2-methyl-, cis-	C_8H_{16}	112	15.6	118884
31	5.31	43	Octane	C_8H_{18}	114	43.8	229407
32	5.39	55	2-Octene	C_8H_{16}	112	16.0	118191
33	5.77	67	1-Methyl-2-methylenecyclohexane	C_8H_{14}	110	8.23	113437
34	5.92	41	2,4-Decadien-1-ol	$C_{10}H_{18}O$	154	7.78	136415
35	5.98	83	Cyclohexane, ethyl-	C_8H_{16}	112	58.0	113476
36	6.25	81	1-Undecyne	$C_{11}H_{20}$	152	7.52	36306
37	6.55	81	Cyclohexane, ethylidene-	C_8H_{14}	110	8.59	118885
38	6.71	41	Cyclohexane, cyclopropyl-	C_9H_{16}	124	16.7	26670
39	6.77	56	trans-7-Methyl-3-octene	C_9H_{18}	126	26.3	113528
40	6.88	41	cis-2-Nonene	C_9H_{18}	126	11.8	113508
41	7.03	43	Nonane	C_9H_{20}	128	31.0	228006
42	7.11	55	2-Nonene, (E)-	C_9H_{18}	126	17.1	113510
43	7.28	55	2,4-Pentadien-1-ol, 3-propyl-, (2Z)-	$C_8H_{14}O$	126	18.9	142179
44	7.66	55	Cyclopentane, butyl-	C_9H_{18}	126	17.7	114172
45	8.25	56	2-Decen-1-ol	$C_{10}H_{20}O$	156	6.62	136260
46	8.45	41	Z-1,6-Undecadiene	$C_{11}H_{20}$	152	9.16	245711
47	8.55	55	Cyclodecane	$C_{10}H_{20}$	140	10.4	113565
48	8.60	39	1-Decene	$C_{10}H_{20}$	140	17.2	118883
49	8.75	43	Decane	$C_{10}H_{22}$	142	60.7	114147
50	8.81	41	2-Decene, (Z)-	$C_{10}H_{20}$	140	18.2	114151
51	8.97	41	2-Decene, (Z)-	$C_{10}H_{20}$	140	7.15	114151
52	9.40	41	Cyclodecane	$C_{10}H_{20}$	140	6.71	237923
53	9.56	67	Cyclopentene, 1-pentyl-	$C_{10}H_{18}$	138	8.43	139585
54	9.66	41	3-Decyn-2-ol	$C_{10}H_{18}O$	154	6.45	53449
55	9.81	41	1-Undecyne	$C_{11}H_{20}$	152	5.27	36306
56	9.87	56	2,4-Decadien-1-ol	$C_{10}H_{18}O$	154	5.03	136415
57	9.93	41	Z-10-Pentadecen-1-ol	$C_{15}H_{30}O$	226	7.88	245485
58	10.10	41	1,10-Undecadiene	$C_{11}H_{20}$	152	25.6	113574

59	10.26	55	1-Undecene	$C_{11}H_{22}$	154	10.9	5022
60	10.31	41	1,4-Undecadiene, (E)-	$C_{11}H_{20}$	152	4.53	27003
61	10.39	41	Undecane	$C_{11}H_{24}$	156	52.1	114185
62	10.45	41	5-Undecene, (E)-	$C_{11}H_{22}$	154	18.2	114227
63	11.07	41	Cyclopentane, hexyl-	$C_{11}H_{22}$	154	5.09	142657
64	11.18	67	1-Undecyne	$C_{11}H_{20}$	152	7.04	36306
65	11.41	56	Tridecane, 7-methylene-	$C_{14}H_{28}$	196	6.52	113992
66	11.67	41	1,11-Dodecadiene	$C_{12}H_{22}$	166	9.36	113595
67	11.80	41	3-Dodecene, (E)-	$C_{12}H_{24}$	168	6.98	113960
68	11.45	41	Z-10-Pentadecen-1-ol	$C_{15}H_{30}O$	226	6.88	245485
69	11.94	43	Dodecane	$C_{12}H_{26}$	170	31.4	291499
70	11.98	41	3-Dodecene, (E)-	$C_{12}H_{24}$	168	16.8	113960
71	12.50	41	1-Octadecyne	$C_{18}H_{34}$	250	5.83	233010
72	12.63	41	Cyclododecane	$C_{12}H_{24}$	168	8.61	60982
73	12.85	41	4-Tridecene, (Z)-	$C_{13}H_{26}$	182	4.09	142617
74	13.15	41	1,12-Tridecadiene	$C_{13}H_{24}$	180	5.69	7380
75	13.27	55	1-Tridecene	$C_{13}H_{26}$	182	8.59	107768
76	13.39	41	Tridecane	$C_{13}H_{28}$	184	35.1	114282
77	13.43	41	5-Tridecene, (E)-	$C_{13}H_{26}$	182	10.4	142619
78	14.10	41	4-Tridecene, (Z)-	$C_{13}H_{26}$	182	6.65	142617
79	14.54	41	Z-1,9-Tetradecadiene	$C_{14}H_{26}$	194	6.67	245709
80	14.66	41	1-Hexadecene	$C_{16}H_{32}$	224	6.99	118882
81	14.76	57	Tetradecane	$C_{14}H_{30}$	198	28.9	113925
82	14.80	41	4-Tetradecene, (E)-	$C_{14}H_{28}$	196	7.97	142625
83	14.95	41	7-Tetradecene	$C_{14}H_{28}$	196	9.31	70643
84	15.51	41	Z-10-Pentadecen-1-ol	$C_{15}H_{30}O$	226	9.67	245485
85	15.96	55	1-Pentadecene	$C_{15}H_{30}$	210	7.22	232902
86	16.06	43	Pentadecane	$C_{15}H_{32}$	212	23.9	107761
87	16.09	41	E-2-Hexadecacen-1-ol	$C_{16}H_{32}O$	240	12.9	131101
88	16.82	41	1-Nonadecanol	$C_{19}H_{40}O$	284	7.01	13666
89	17.09	41	Z-10-Pentadecen-1-ol	$C_{15}H_{30}O$	226	22.4	245485
90	17.19	83	1-Hexadecene	$C_{16}H_{32}$	224	10.9	118882
91	17.28	43	Hexadecane	$C_{16}H_{34}$	226	32.2	114191
92	17.31	41	1-Hexadecene	$C_{16}H_{32}$	224	7.95	118882
93	17.46	41	Cyclohexadecane	$C_{16}H_{32}$	224	5.54	258206
94	18.35	41	1-Heptadecanol	$C_{17}H_{36}O$	256	6.89	113250
95	18.44	56	Heptadecane	$C_{17}H_{36}$	240	27.4	107308
96	18.47	41	8-Heptadecene	$C_{17}H_{34}$	238	7.67	113620
97	18.62	55	2-Methyl-E-7-hexadecene	$C_{17}H_{34}$	238	7.84	130870
98	19.46	43	1-Octadecene	$C_{18}H_{36}$	252	6.22	229404
99	19.54	43	Eicosane	$C_{20}H_{42}$	282	15.6	290513
100	19.63	55	1-Eicosanol	$C_{20}H_{42}O$	298	6.86	113075
101	19.72	41	10-Heneicosene (c,t)	$C_{21}H_{42}$	294	5.43	113073
102	20.44	55	E-2-Octadecadecen-1-ol	$C_{18}H_{36}O$	268	12.0	131102
103	20.51	55	9-Nonadecene	$C_{19}H_{38}$	266	7.58	113627
104	20.58	57	Eicosane	$C_{20}H_{42}$	282	21.2	290513
105	20.70	41	1-Eicosanol	$C_{20}H_{42}O$	298	7.00	113075

106	21.51	55	1-Docosene	$C_{22}H_{44}$	308	7.70	113878
107	21.58	57	Eicosane	$C_{20}H_{42}$	282	27.4	290513
108	21.76	55	1-Eicosene	$C_{20}H_{40}$	280	6.88	13488
109	22.42	55	1-Docosanol	$C_{22}H_{46}O$	326	7.29	23377
110	22.48	55	1-Docosene	$C_{22}H_{44}$	308	10.3	113878
111	22.54	56	Heneicosane	$C_{21}H_{44}$	296	18.6	107569
112	22.72	55	1-Eicosanol	$C_{20}H_{42}O$	298	8.76	113075
113	23.40	55	1-Docosene	$C_{22}H_{44}$	308	11.1	113878
114	23.45	56	Eicosane	$C_{20}H_{42}$	282	15.5	290513
115	23.64	55	1-Docosene	$C_{22}H_{44}$	308	8.61	113878
116	24.28	55	1-Docosene	$C_{22}H_{44}$	308	14.0	113878
117	24.34	71	Eicosane	$C_{20}H_{42}$	282	13.7	290513
118	24.53	55	1-Docosene	$C_{22}H_{44}$	308	5.77	113878
119	25.15	43	1-Docosene	$C_{22}H_{44}$	308	10.1	113878
120	25.19	71	Eicosane	$C_{20}H_{42}$	282	6.76	290513
121	26.01	57	Heneicosane	$C_{21}H_{44}$	296	9.09	107569
122	26.82	57	Heneicosane	$C_{21}H_{44}$	296	7.21	107569
123	27.61	57	Tetratetracontane	$C_{44}H_{90}$	618	7.13	23773
124	28.39	57	Heneicosane	$C_{21}H_{44}$	296	6.90	107569
125	29.16	57	Heptacosane	$C_{27}H_{56}$	380	6.56	79427
126	29.93	57	Heptacosane	$C_{27}H_{56}$	380	25.1	79427
127	30.75	57	Heptacosane	$C_{27}H_{56}$	380	23.6	79427

Polypropylene (PP) waste plastic to liquid fuel (**figure7 and table 10**) was analyzed by Gas Chromatography and Mass Spectrometer (GC/MS) in accordance with the various retention time and trace masses different types of hydrocarbon compounds and benzene derivatives compounds are appeared in the analysis result index. Many compounds are emerged in the analysis between carbon ranges C_4 to $C_{44.}$ 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 1.62 , trace mass 43, compound is Butane (C_4H_{10}), compound molecular weight 58 and probability 63.1%. Retention time 1.88, trace mass 42, compound is Cyclopropane, ethyl- (C_5H_{10}), compound molecular weight 70 and probability percentage is 18.5%. Retention time 2.06 (M), trace mass 67, compound is 1, 4-Pentadiene (C_5H_8), compound molecular weight is 68 and probability percentage is 18.6%. Retention time is 2.58, trace mass 57, compound is Hexane (C_6H_{14}), compound molecular weight 86 and compound probability percentage is 79.2%. Retention time 3.83, trace mass is 55, compound name is 2-Heptene (C_7H_{14}), compound molecular weight is 98 and compound probability percentage is 22.2%. Retention time 4.17, trace mass 83, traced compound is Cyclohexane, methyl- (C_7H_{14}), compound molecular weight is 98 and compound probability percentage is 63.8%. GC/MS analysis result showed aliphatic group compound such as alkane and alkene group compound. Analysis results indicate also alcoholic and oxygenate group compounds. Retention time 4.80, trace mass 91, compound is Toluene (C_7H_8), compound molecular weight is 92 and compound probability percentage is 32.6%. Retention time 5.31, trace mass 43, compound name is Octane (C_8H_{18}), compound molecular weight is 114 and probability percentage is 43.8%.

Hydroxyl compound detect retention time 5.92, trace mass 41, compound name is 2, 4-Decadien-1-ol ($C_{10}H_{18}O$), compound molecular weight is 154 and probability is 7.78%. Retention time 5.98, trace mass 83, compound name is Cyclohexane, ethyl- (C_8H_{16}), compound molecular weight is 112 and probability is 58.0%. Retention time 6.77, trace mass 56, compound name is trans-7-Methyl-3-octene (C_9H_{18}), compound molecular weight 126 and probability is 26.3%. Retention time 8.55, trace mass 55, compound name is Cyclodecane ($C_{10}H_{20}$), molecular weight 140 and probability percentage is 10.4%. Retention time 9.56, trace mass 67, compound name is Cyclopentene, 1-pentyl- ($C_{10}H_{18}$), compound molecular weight is 138 and compound probability percentage is 8.43%. Retention time 10.26, trace mass 55, compound name is 1-Undecene ($C_{11}H_{22}$), compound molecular weight 154 and probability percentage is 10.9%. Retention time 11.41, trace mass 56, compound name is Tridecane, 7-methylene- ($C_{14}H_{28}$), compound molecular weight 196 and probability percentage is 6.52%. Retention time 11.45, trace mass 41, compound name is Z-10-Pentadecen-1-ol ($C_{15}H_{30}O$), compound molecular weight is 226 and probability percentage is 6.88%. Retention time 12.85, trace mass 41, compound name is 4-Tridecene, (Z)- ($C_{13}H_{26}$), molecular weight 182 and probability percentage is 4.09%. Retention time 14.66, trace mass 41, compound name is 1-Hexadecene ($C_{16}H_{32}$), molecular weight is 224 and probability percentage is 6.99%. Retention time 16.06, trace mass 43, compound name is Pentadecane ($C_{15}H_{32}$), molecular weight is 212 and probability 23.9%. Retention time 17.28, trace mass 43, compound name is Hexadecane ($C_{16}H_{34}$), molecular weight is 226 and compound probability percentage is 32.2%. Retention time 18.47, trace mass 41, compound name is 8-Heptadecene ($C_{17}H_{34}$), compound molecular weight is 238 and compound probability percentage is 7.67%. Retention time 19.54, trace mass 43, compound name is Eicosane ($C_{20}H_{42}$), compound molecular weight 282 and probability percentage is 15.6%. Retention time 20.44, trace mass 55, compound name is E-2-Octadecadecen-1-ol ($C_{18}H_{36}O$), molecular weight 268 and compound probability percentage is 12.0%. Retention time 21.58, trace mass 57, compound name is Eicosane ($C_{20}H_{42}$), compound molecular weight 282 and probability 27.4%. Retention time 22.54, trace mass 56, compound name Heneicosane ($C_{21}H_{44}$), compound molecular weight 296 and probability 18.6%. Retention time 23.40, trace mass 55, compound name is 1-Docosene ($C_{22}H_{44}$), compound molecular weight is 308 and probability percentage is 11.1%. Retention time 26.01, trace mass 57, compound name is Heneicosane ($C_{21}H_{44}$),l compound molecular weight 296 and probability percentage 9.09%. Retention time 27.61, trace mass 57, compound name is Tetratetracontane ($C_{44}H_{90}$), molecular weight is 618 and probability percentage is 7.13%. Retention time is 30.75, trace mass 57, compound name is Heptacosane ($C_{27}H_{56}$), molecular weight 380 and probability percentage is 23.6% as well.

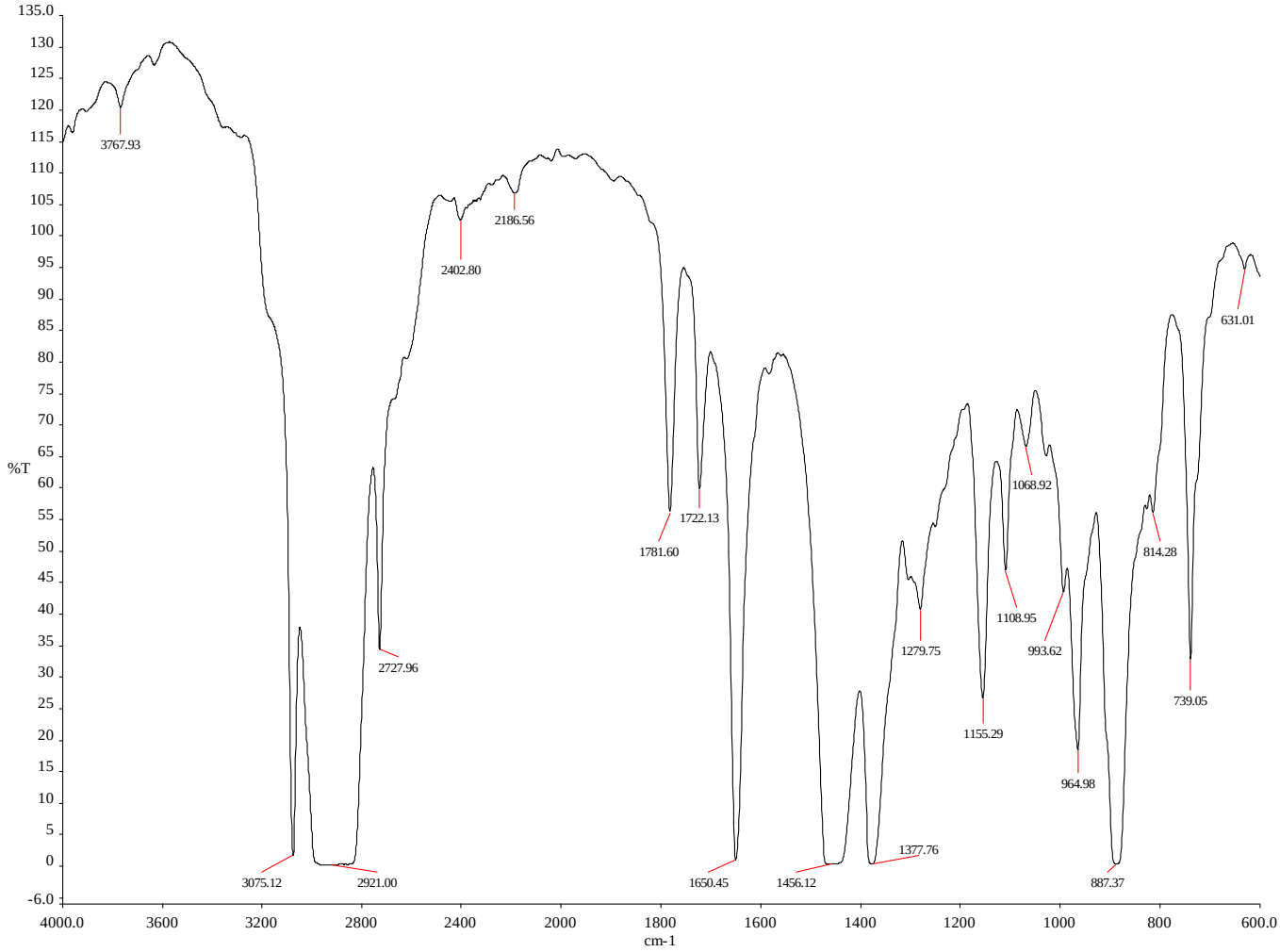

Figure 8: FT-IR spectrum of polypropylene waste plastic to liquid fuel

Table 11: FT-IR spectrum of polypropylene waste plastic to liquid fuel functional group

Number of Peak	Wave Number (cm^{-1})	Functional Group Name	Number of Peak	Wave Number (cm^{-1})	Functional Group Name
1	3767.93		12	1279.75	
2	3075.12	H Boded NH	13	1155.29	
3	2921.00	$C-CH_3$	14	1108.95	
4	2727.96	$C-CH_3$	15	1068.92	
5	2402.80		16	993.62	$-CH=CH_2$
6	2186.56	C-C=-C-C=-CH	17	964.98	-CH=CH-(trans)
7	1781.60	Non-Conjugated	18	887.37	$C=CH_2$
8	1722.13	Non-Cocjugated	19	814.28	
9	1650.45	Amides	20	739.05	
10	1456.12	CH_2	21	631.01	
11	1377.76	CH_3			

Perkin Elmer FT-IR (Spectrum 100) analysis of polypropylene waste plastic to fuel (**figure 8 and table 11**) 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 and 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 3075.12 cm^{-1} functional group is H Bonded NH, wave number 2921.00 cm^{-1}, functional group is C-CH_3, wave number 2727.96 cm^{-1}, functional group is C-CH_3, wave number 2186.56 cm^{-1} functional group is C-C=-C-C=-CH, wave number 1781.60 cm^{-1} functional group is Non-Conjugated, wave number 1456.12 cm^{-1}, functional group is CH_2 , wave number 1377.76 cm^{-1} functional group is CH_3,wave number 993.62 cm^{-1} functional group is -CH=CH_2, wave number 964.98 cm^{-1} functional group is -CH=CH-(trans) and ultimately wave number 887.37 cm^{-1} functional group is C=CH_2 as well. Energy values are calculated, using formula is E=hυ, Where h=Planks Constant, h =6.626x10^{-34} J, υ=Frequency in Hertz (sec^{-1}), Where υ=c/λ, c=Speed of light, where, c=3x10^{10} m/s, W=1/λ, where λ is wave length and W is wave number in cm^{-1}. Therefore the equation E=hυ, can substitute by the following equation, E=hcW. According to their wave number several energy values are calculated such as for wave number 2921.00 (cm^{-1}) calculated energy, E=5.80x10^{-20} J, wave number 2727.96 (cm^{-1}) calculated energy, E=5.41x10^{-20} J, wave number 1456.12 (cm^{-1}), calculated energy, E=2.89x10^{-20} J, wave number 1377.76 (cm^{-1}), calculated energy, E=2.73x10^{-20} J, wave number 993.62 (cm^{-1}), calculated energy, E=1.97x10^{-20} J and ultimately wave number 887.37 (cm^{-1}), calculated energy, E=1.76x10^{-20} J respectively .

Table 12: FT-IR spectrum of polypropylene standard plastic to liquid fuel functional group

Number of Peak	Wave Number (cm^{-1})	Functional Group Name	Number of Peak	Wave Number (cm^{-1})	Functional Group Name
1	3768.03		12	1280.20	
2	3074.42	H Boded NH	13	1260.58	
3	2897.10	C-CH_3	14	1156.44	
4	2726.39	C-CH_3	15	1107.92	
5	2402.37		16	1027.84	Acetates
6	2177.40	C-C=-C-C=-CH	17	995.89	-CH=CH_2
7	1781.05	Non-Conjugated	18	970.83	-CH=CH-(trans)
8	1721.90	Non-Conjugated	19	887.48	C=CH_2
9	1649.86	Amides	20	806.15	
10	1467.56	CH_2	21	738.76	-CH=CH-(cis)
11	1374.14	CH_3			

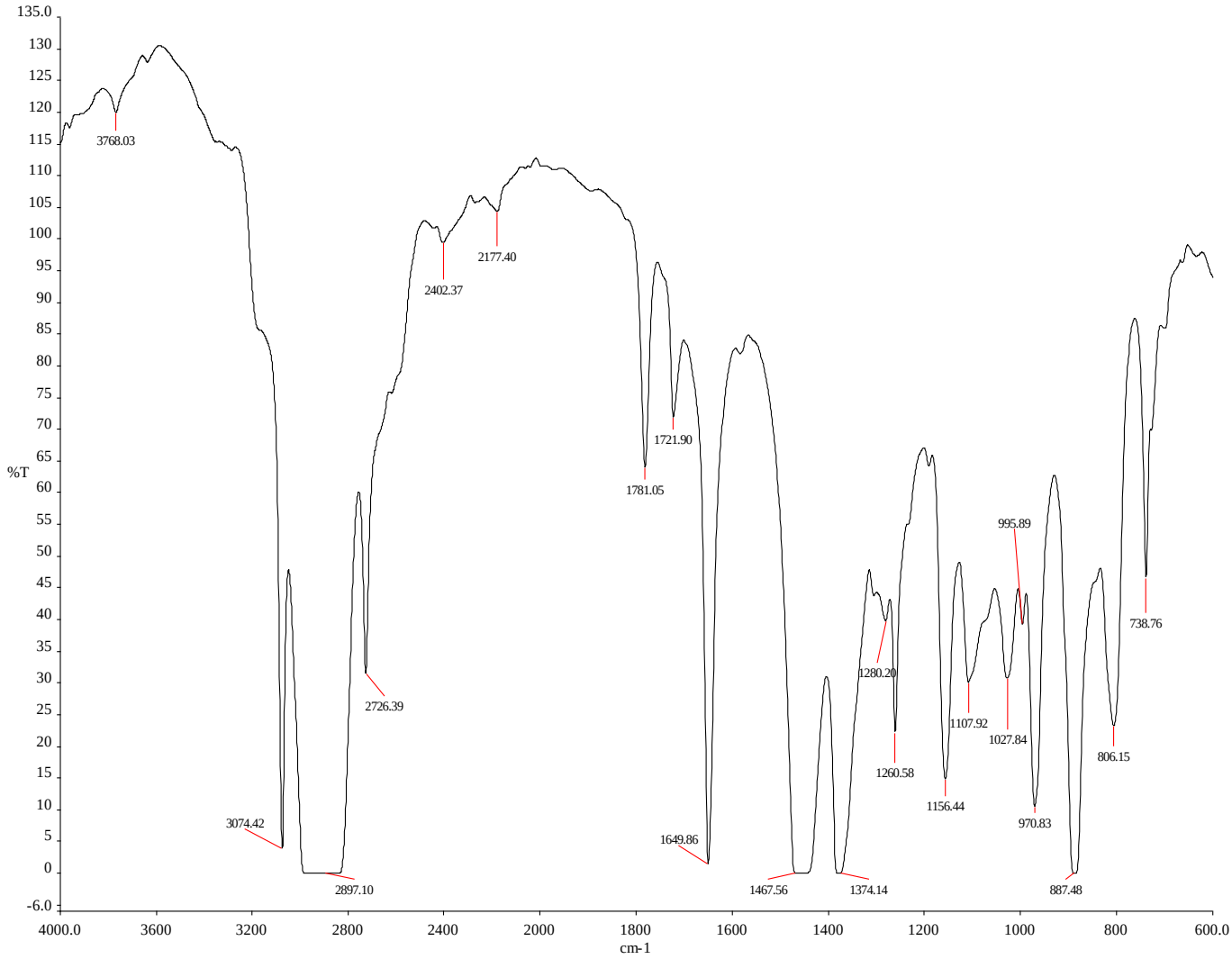

Figure 9: FT-IR spectrum of polypropylene standard plastic to liquid fuel

Perkin Elmer FT-IR (Spectrum 100) analysis of polypropylene standard plastic to fuel (**figure 9 and table 12**) 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 and 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 3074.42 cm^{-1} functional group is H Bonded NH, wave number 2897.10 cm^{-1}, functional group is C-CH_3, wave number 2726.39 cm^{-1}, functional group is C-CH_3, wave number 2177.40 cm^{-1} functional group is C-C=-C-C=-CH, wave number 1781.05 cm^{-1} functional group is Non-Conjugated, wave number 1467.56 cm^{-1}, functional group is CH_2 , wave number 1374.14 cm^{-1} functional group is CH_3,wave number 995.89 cm^{-1} functional group is -CH=CH_2, wave number 970.83 cm^{-1} functional group is -CH=CH-(trans), wave number 887.48 cm^{-1} functional group is C=CH_2 and ultimately wave number 738.76 cm^{-1} functional group is -CH=CH-(cis) as well. Energy values are calculated, using formula is E=hυ, Where h=Planks Constant, h =6.626x10^{-34} J,

υ=Frequency in Hertz (sec^{-1}), Where υ=c/λ, c=Speed of light, where, c=$3x10^{10}$ m/s, W=1/λ, where λ is wave length and W is wave number in cm^{-1}. Therefore the equation E=hυ, can substitute by the following equation, E=hcW. According to their wave number several energy values are calculated such as for wave number 2897.10 (cm^{-1}) calculated energy, E=$5.75x10^{-20}$ J, wave number 2726.09 (cm^{-1}) calculated energy, E=$5.41x10^{-20}$ J, wave number 1467.56 (cm^{-1}), calculated energy, E=$2.91x10^{-20}$ J, wave number 1374.41 (cm^{-1}), calculated energy, E=$2.73x10^{-20}$ J, wave number 995.89 (cm^{-1}), calculated energy, E=$1.97x10^{-20}$ J and ultimately wave number 887.37 (cm^{-1}), calculated energy, E=$1.76x10^{-20}$ J respectively .

Table 13: Polypropylene waste plastic to liquid fuel ASTM test results

Method Name	Test Name	PP Waste Plastic to Fuel Results	Units
ASTM D240	Gross Heat of Combustion	19514	BTU/lb
ASTM D240	Gross Heat of Combustion (Calculated)	126373	BTU/gal
ASTM D4052	API Gravity @ 60°F	50.4	°API
ASTM D86-07b	IBP Recovery	57.4	°C
ASTM D86-07b	5% Recovery	98.9	°C
ASTM D86-07b	10% Recovery	118.2	°C
ASTM D86-07b	20% Recovery	140.6	°C
ASTM D86-07b	30% Recovery	158.0	°C
ASTM D86-07b	40% Recovery	181.0	°C
ASTM D86-07b	50% Recovery	216.1	°C
ASTM D86-07b	60% Recovery	243.8	°C
ASTM D86-07b	70% Recovery	273.4	°C
ASTM D86-07b	80% Recovery	313.4	°C
ASTM D86-07b	90% Recovery	361.6	°C
ASTM D86-07b	95% Recovery	378.1	°C
ASTM D86-07b	FBP Recovery	378.2	°C
ASTM D86-07b	Recovery	97.6	Vol%
ASTM D86-07b	Residue	1.4	Vol%
ASTM D2500	Cloud point	9.8	°C
ASTM D2500	Cloud Point	49.6	°F
ASTM D97	Pour point	-7.0	°C
ASTM D97	Pour point	20.1	°F
ASTM D2386	Freezing Point	<-21.0	°C
ASTM D2386	Freezing Point	<-5.8	°F
ASTM D2624	Temperature	76.0	°C
ASTM D2624	Electrical Conductivity	<1.0	pS/M
ASTM D5453	Sulfur	8.2	Mg/kg
AST M D1500	ASTM Color	3.5	
ASTM D4176	Appearance: Clean and Bright	Fail-Hazy	
ASTM D4176	Free Water Content/Particles		Mg/kg
ASTM D4176	Haze Rating	5.0	
ASTM D4176	Special Observation		
ASTM D4737	Cetane Index by D4737 (Procedure A)	55.0	
ASTM D5708_MOD	Vanadium	<1.0	ppm
ASTM D5708_MOD	Nickel	<1.0	ppm
ASTM D5708_MOD	Iron	<1.0	ppm, or, mg/Kg
ASTM D482	Ash	<0.001	Wt%
ASTM D93	Procedure Used	A	
ASTM D93	Corrected Flash Point	Below room temperature	°C

ASTM D4530	Average Micro Method Carbon Residue 10% distillation	0.2	Wt%
ASTM D664	Procedure Used		
ASTM D664	Acid Number	0.15	mgKOH/gm
ASTM D130	Copper Corrosion @ 50°C (122°F)/3 hrs.	1a	
ASTM D2709	Sediment and Water	0.100	Vol%
ASTM D5291	Carbon Content	86.35	Wt%
ASTM D5291	Hydrogen Content	13.60	Wt%
ASTM D5291	Nitrogen Content	<0.75	Wt%

Polypropylene (PP) waste plastic to liquid fuel (**table 13**) was analyzed by 3rd party laboratory and ASTM test method followed for fuel analysis such as ASTM D240 Gross Heat of Combustion: 19514 BTU/lb, ASTM D240 Gross Heat of Combustion (Calculated): 126373 BTU/gal, ASTM D4052 API Gravity @ 60°F: 50.4 °API, ASTM D86-07b IBP Recovery: 57.4 °C, ASTM D86-07b 5% Recovery: 98.9 °C, ASTM D86-07b 10% Recovery: 118.2 °C, ASTM D86-07b 20% Recovery: 140.6 °C, ASTM D86-07b 30% Recovery: 158.0 °C, ASTM D86-07b 40% Recovery: 181.0 °C, ASTM D86-07b 50% Recovery: 216.1 °C, ASTM D86-07b 60% Recovery: 243.8 °C, ASTM D86-07b 70% Recovery: 273.4 °C, ASTM D86-07b 80% Recovery: 313.4 °C, ASTM D86-07b 90% Recovery: 361.6 °C, ASTM D86-07b 95% Recovery: 378.1 °C, ASTM D86-07b FBP Recovery: 378.2 °C, ASTM D86-07b Recovery : 97.6 Vol%, ASTM D86-07b Residue: 1.4 Vol%, ASTM D2500 Cloud point: 9.8 °C, ASTM D2500 Cloud Point: 49.6 °F, ASTM D97 Pour point: -7.0 °C, ASTM D97 Pour point: 20.1 °F, ASTM D2386 Freezing Point: <-21.0 °C, ASTM D2386 Freezing Point: <-5.8 °F, ASTM D2624 Temperature : 76.0 °C, ASTM D2624 Electrical Conductivity: <1.0 pS/M, ASTM D5453 Sulfur: 8.2 Mg/kg, ASTM D1500 ASTM Color: 3.5, ASTM D4176 Appearance Clean and Bright : Fail-Hazy, ASTM D4176 Free Water Content/Particles: Nil Mg/kg, ASTM D4176 Haze Rating: 5.0 ASTM D4176 Special Observation: none, ASTM D4737 Cetane Index by D4737 (Procedure A): 55.0, ASTM D5708_MOD Vanadium: <1.0 ppm ASTM D5708_MOD Nickel: <1.0 ppm, ASTM D5708_MOD Iron :<1.0 ppm, or, mg/Kg, ASTM D482 Ash: <0.001 Wt%, ASTM D93 Procedure Used A ASTM D93 Corrected Flash Point: Below room temperature °C, ASTM D4530 Average Micro Method Carbon Residue 10% distillation: 0.2 Wt%, ASTM D664 Procedure Used ASTM D664 Acid Number: 0.15 mgKOH/gm, ASTM D130 Copper Corrosion @ 50°C (122°F)/3 hrs.:1a, ASTM D2709 Sediment and Water: 0.100 Vol%, ASTM D5291 Carbon Content 86.35 Wt%, ASTM D5291 Hydrogen Content: 13.60 Wt% ASTM D5291 Nitrogen Content: <0.75 Wt%.

Table 14: Polypropylene standard plastic to liquid fuel ASTM test results

Method Name	Test Name	PP Standard Plastic to Fuel Results	Units
ASTM D240	Gross Heat of Combustion	20393	BTU/lb
ASTM D240	Gross Heat of Combustion (Calculated)	130699	BTU/gal
ASTM D4052	API Gravity @ 60°F	52.3	°API
ASTM D86-07b	IBP Recovery	56.2	°C
ASTM D86-07b	5% Recovery	96.4	°C
ASTM D86-07b	10% Recovery	114.7	°C
ASTM D86-07b	20% Recovery	137.0	°C

ASTM D86-07b	30% Recovery	148.8	°C
ASTM D86-07b	40% Recovery	164.6	°C
ASTM D86-07b	50% Recovery	193.4	°C
ASTM D86-07b	60% Recovery	222.6	°C
ASTM D86-07b	70% Recovery	243.0	°C
ASTM D86-07b	80% Recovery	268.4	°C
ASTM D86-07b	90% Recovery	307.2	°C
ASTM D86-07b	95% Recovery	342.5	°C
ASTM D86-07b	FBP Recovery	349.3	°C
ASTM D86-07b	Recovery	98.1	Vol%
ASTM D86-07b	Residue	1.0	Vol%
ASTM D2500	Cloud point	-2.7	°C
ASTM D2500	Cloud Point	27.1	°F
ASTM D97	Pour point	<-57	°C
ASTM D97	Pour point	<-70.6	°F
ASTM D2386	Freezing Point	<-21.0	°C
ASTM D2386	Freezing Point	<-5.8	°F
ASTM D2624	Temperature	76.0	°C
ASTM D2624	Electrical Conductivity	1.0	pS/M
ASTM D5453	Sulfur	4.2	Mg/kg
ASTM D1500	ASTM Color	3.0	
ASTM D4176	Appearance: Clean and Bright	Fail-Hazy	
ASTM D4176	Free Water Content/Particles	No water particles	Mg/kg
ASTM D4176	Haze Rating	5.0	
ASTM D4176	Special Observation		
ASTM D4737	Cetane Index by D4737 (Procedure A)	54.3	
ASTM D5708_MOD	Vanadium	<1.0	ppm
ASTM D5708_MOD	Nickel	<1.0	ppm
ASTM D5708_MOD	Iron	<1.0	ppm OR, mg/Kg
ASTM D482	Ash	<0.001	Wt%
ASTM D93	Procedure Used	A	
ASTM D93	Corrected Flash Point	Below room temperature	°C
ASTM D4530	Average Micro Method Carbon Residue 10% distillation	0.2	Wt%
ASTM D664	Procedure Used	-	
ASTM D664	Acid Number	0.15	mgKOH/gm
ASTM D130	Copper Corrosion @ 50°C (122°F)/3 hrs.	1a	
ASTM D2709	Sediment and Water	0.100	Vol%
ASTM D5291	Carbon Content	86.35	Wt%
ASTM D5291	Hydrogen Content	13.60	Wt%
ASTM D5291	Nitrogen Content	<0.75	Wt%

Polypropylene (PP) standard plastic to liquid fuel (**table 14**) was analyzed by 3rd party laboratory, Intertek , New Jersey, USA and ASTM test method followed such as ASTM D240 Gross Heat of Combustion : 20393 BTU/lb, ASTM D240 Gross Heat of Combustion (Calculated): 130699 BTU/gal, ASTM D4052 API Gravity @ 60°F : 52.3 °API, ASTM D86-07b IBP Recovery: 56.2 °C, ASTM D86-07b 5% Recovery: 96.4 °C, ASTM D86-07b 10% Recovery: 114.7 °C, ASTM D86-07b 20% Recovery: 137.0 °C, ASTM D86-07b 30% Recovery: 148.8 °C, ASTM D86-07b 40% Recovery: 164.6 °C, ASTM D86-07b 50% Recovery 193.4 °C, ASTM D86-07b 60% Recovery: 222.6 °C, ASTM D86-07b 70% Recovery: 243.0 °C, ASTM D86-07b 80% Recovery: 268.4 °C, ASTM D86-07b

90% Recovery: 307.2 °C, ASTM D86-07b 95% Recovery: 342.5 °C, ASTM D86-07b FBP Recovery: 349.3 °C, ASTM D86-07b Recovery: 98.1 Vol%, ASTM D86-07b Residue: 1.0 Vol%, ASTM D2500 Cloud point: -2.7 °C, ASTM D2500 Cloud Point: 27.1 °F, ASTM D97 Pour point: <-57 °C, ASTM D97 Pour point: <-70.6 °F, ASTM D2386 Freezing Point: <-21.0 °C, ASTM D2386 Freezing Point: <-5.8 °F, ASTM D2624 Temperature: 76.0 °C, ASTM D2624 Electrical Conductivity: 1.0 pS/M, ASTM D5453 Sulfur: 4.2 Mg/kg, ASTM D1500 ASTM Color : 3.0 ASTM D4176 Appearance Clean and Bright :Fail-Hazy, ASTM D4176 Free Water Content/Particles: No water particles Mg/kg, ASTM D4176 Haze Rating: 5.0 , ASTM D4176 Special Observation: none, ASTM D4737 Cetane Index by D4737 (Procedure A): 54.3, ASTM D5708_MOD Vanadium: <1.0 ppm, ASTM D5708_MOD Nickel: <1.0 ppm, ASTM D5708_MOD Iron: <1.0 ppm OR, mg/Kg, ASTM D482 Ash: <0.001 Wt%, ASTM D93 Procedure Used _A ASTM D93 Corrected Flash Point: Below room temperature °C, ASTM D4530 Average Micro Method Carbon Residue 10% distillation: 0.2 Wt%, ASTM D664 Procedure Used - ASTM D664 Acid Number: 0.15 mgKOH/gm, ASTM D130 Copper Corrosion @ 50°C (122°F)/3 hrs.: 1a, ASTM D2709 Sediment and Water: 0.100 Vol%, ASTM D5291 Carbon Content: 86.35 Wt%, ASTM D5291 Hydrogen Content: 13.60 Wt%, ASTM D5291 Nitrogen Content: <0.75 Wt%. ASTM test result are indication PP standard plastic to fuel properties and what type of combustion engine appropriate for this fuel.

3.4. Solid Black Residue Analysis

Table 15: Polypropylene waste plastic and polypropylene standard plastic to leftover residue metal analysis result by ICP

Test Method Name	Trace Metal Name	PP Waste Plastic to Residue	PP Standard Plastic to Residue
ASTM D1976	Silver	<1.0	<1.0
	Aluminum	4570	57790
	Arsenic	<1.0	9.9
	Boron	2701	7.2
	Barium	14.2	41.9
	Beryllium	<1.0	<1.0
	Calcium	16740	3944
	Cadmium	9.1	1.1
	Chromium	269.6	24.6
	Copper	1687	23.5
	Iron	395,600	1229
	Potassium	<1.0	<1.0
	Lithium	8.7	<1.0
	Magnesium	4001	1629
	Manganese	1375	14.5
	Sodium	58290	148.6
	Nickel	379.6	85.2
	Lead	19.2	35.6
	Antimony	<1.0	<1.0
	Selenium	132.3	<1.0
	Silicon	28.2	41.3
	Tin	37520	76.0
	Titanium	2674	424.6
	Vanadium	<1.0	<1.0

Zinc	5598	774.4

Polypropylene (PP) waste plastic to solid left over residue (**table 15**) was analyzed by 3rd party laboratory and ASTM test method followed ASTM D1976 for general trace metal analysis such as Silver <1.0 ppm, Aluminum 4570 ppm, Arsenic <1.0 ppm, Boron 2701ppm, Barium 14.2 ppm, Beryllium <1.0 ppm, Calcium 16740 ppm, Cadmium 9.1ppm, Chromium 269.6 ppm, Copper 1687 ppm, Iron 395,600 ppm, Potassium <1.0 ppm, Lithium 8.7 ppm, Magnesium 4001 ppm, Manganese 1375 ppm, Sodium 58290 ppm, Nickel 379.6 ppm, Lead 19.2 ppm, Antimony <1.0 ppm, Selenium 132.3 ppm, Silicon 28.2 ppm, Tin 37520 ppm, Titanium 2674 ppm, Vanadium <1.0 ppm, Zinc 5598. Polypropylene standard plastic to left over residue ICP analysis result indicate that PP standard plastic also same type of metal traced as followed ASTM method and general metal content result showed such as Silver <1.0 ppm, Aluminum 57790 ppm, Arsenic 9.9 ppm, Boron 7.2 ppm, Barium 41.9 ppm, Beryllium <1.0 ppm, Calcium 3944 ppm, Cadmium 1.1 ppm, Chromium 24.6 ppm, Copper 23.5 ppm, Iron 1229 ppm, Potassium <1.0 ppm, Lithium <1.0 ppm, Magnesium 1629 ppm, Manganese 14.5 ppm, Sodium 148.6 ppm, Nickel 85.2 ppm, Lead 35.6 ppm, Antimony <1.0 ppm, Selenium <1.0 ppm, Silicon 41.3 ppm, Tin 76.0 ppm, Titanium 424.6 ppm, Vanadium <1.0 ppm, Zinc 774.4ppm. PP waste plastic and PP standard plastic to residue analysis result showed that PP waste plastic to residue metal content high then PP standard plastic. PP standard plastic is pure plastic and this plastic as analytical grade plastic for that reason when made this plastic for analytical that time manufacturing company may be put less additive, on the other hand PP plastic made for consumer use for that reason manufacturing company may be put more additive for making plastic hardness or softness. In this comparative study ICP analytical result showed different types of metal content amount for PP waste plastic and PP standard plastic. Both residues has good Btu value and value more than 5000 Btu/lb for that reason this residue could be use as substantial coal or could be use as road carpeting or roof carpeting.

Table 16: Polypropylene waste plastic and polypropylene standard plastic to leftover residue C, H and N % analysis by EA-2400

Test Method Name	**Plastics Residue Name**	**Carbon %**	**Hydrogen %**	**Nitrogen %**
ASTM D5291.a	PP Waste Plastic to Residue	45.77	1.14	1.30
	PP Standard Plastic to Residue	53.83	1.36	<0.30

Black solid residue was analysis by EA-2400 (CHN mode) and ASTM test method followed ASTM D5291_a for PP waste plastic and standard plastic to residue **(table 16)**. PP waste plastic to residue result indicate that carbon percentage is 45.77%, hydrogen percentage is 1.14% and nitrogen percentage is 1.30% reaming as left over. Standard plastic reaming left over residue carbon percentage is 53.83%, hydrogen percentage 1.36% and nitrogen percentage is less than <0.30. Left over residue could be using also Nanotube production because 5-6 % amount of residue was reaming from all experiment or production process.

4. Economical Benefit

Polypropylene waste plastic are generating 14% from total waste plastics. Waste plastics generations are increasing every year because every sector waste plastics are using. Waste plastics abundant everywhere and also dumping and land filling very costly. Waste plastics are creating environmental problem and waste plastics are not biodegradable it can remains long period into the landfill. Waste plastics releasing gas emission into environmental which is harmful for human body. According to environmental protection agency (EPA) data huge amount of waste plastics was landfill and dumped. By using this technology waste plastics can convert liquid hydrocarbon fuel by using thermal degradation process and remove waste plastic problem from environment. Produced fuel can be use all internal combustion engines and produce electricity by using generator or power plant and feed for feed stock refinery. In laboratory scale batch process 1 kg or 1000 gm polypropylene waste plastic generated 814.1 gm fuel, residue 4.1 gm and light gas was generated 181.8 gm, on the other hand polypropylene standard plastic to fuel generated from 1kg or 1000 gm to 854.7 gm, residue was 2.1 gm and light gas was generated 143.2 gm. Standard polypropylene plastic to fuel production yield percentage was little high because it was analytical grade pure polymer and it is costly also. Polypropylene waste plastic are available everywhere for that reason raw materials cost is zero. Polypropylene waste plastic can be collect from city or municipality or other sector easily. Polypropylene 1000 gm waste plastic to 1060 ml or 814.1 gm fuel production input electricity was 6.324 kWh and cost was based on Stamford city electricity 1kWh unit price 6.324 x $0.11 = $0.695. One gallon of fuel production cost from polypropylene waste plastic in the laboratory scale $2.49. ASTM test method showed polypropylene waste plastic to fuel Btu value for 1 gallon is 126373 Btu. Polypropylene waste plastic to one gallon of fuel production input electricity was 22.67 kWh in laboratory scale. One gallon of fuel to output electricity showed based on one gallon fuel Btu value calculation 126373Btu =37.036 kWh. Electricity output is showing more from input based on ASTM test Gross Heat of Combustion (Calculated) value. When commercial plant will start that time production cost will decrease because in large scale production always production cost decrease automatically. Using this technology from waste plastic to liquid fuel production reduce some foreign oil dependency because large amount of waste plastics are generating everywhere and those polypropylene waste plastic can convert into liquid fuel. Light gas also generated 18.18% from production and this light gas can be use for heat source during polypropylene waste plastic to fuel production then production cost will be less. Solid black residue has good Btu value that residue can be use for as substitute coal, roof carpeting, road carpeting, nano tube production or battery production.

5. Conclusion

Polypropylene waste plastic to liquid fuel production and polypropylene standard plastic to liquid fuel production comparison study was under full observation and checked their production yield percentage and mass balance. Polypropylene waste plastic to fuel yield percentage was 81.41% and standard plastic to fuel was 85.45%. From both experiments showed polypropylene standard plastic to fuel production percentage higher than polypropylene waste plastic to fuel percentage because of their present impurity. Same way light gas and leftover residue percentage also differ. Input electricity and experiment run time also different because waste polypropylene has high

percentage of additives and level is parts per million (ppm) and polypropylene standard plastic has less additives and level is parts per billion (ppb). Polypropylene waste plastic and standard plastic to fuel production difference 4.06%. in raw sample analysis results indicate that raw polypropylene waste plastic has different type of metal content and hydrocarbon compounds range is C_3 to C_{22} and standard plastic has same types of metal content but level is ppb and hydrocarbon range showed C_3 to C_{25}. Both experiments temperature was same from 150 ºC to 420 ºC and without adding catalyst experiments was performed under fume hood in presence of oxygen. Different technique was applied for liquid fuels analysis and GC/MS analysis results indicate that polypropylene waste plastic to fuel hydrocarbon range is C_3 to C_{44} and polypropylene standard plastic to fuel hydrocarbon range is C_4 to C_{44}. In ASTM test results showed polypropylene waste plastic to fuel Btu value for one gallon is 126373 Btu and polypropylene standard plastic to fuel Btu for one gallon is 130699 Btu. Polypropylene waste plastic to fuel analysis test results different from polypropylene standard plastic to fuel test results because both raw materials are different from each other. By using this technology can remove all polypropylene waste plastic to liquid fuel and save environmental problem. Produced fuel can be use all internal combustion engine by further modification or fuel can be use electricity production or feed for feed stock refinery. By using thermal degradation process polypropylene waste plastic to fuel can boost up renewable energy sector and reduce some portion of foreign oil dependency.

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References

[1] Waste to energy. Presented at the International Management Industry Conference, Global Business Network Ltd, Brussels, Belgium, December, (2000).

[2] An analysis of plastic consumption and recovery in Europe; Association of Plastics Manufacturers in Europe: Brussels, Belgium, (2004).

[3] Paula A. Costa, Filomena J. Pinto, Ana. M. Ramos, Ibrahim K. Gulyurtlu, Isabel A. Cabrita, and Maria. S. Bernardo, Kinetic Evaluation of the Pyrolysis of Polyethylene Waste. Energy & Fuels (2007), 21, 2489-2498

[4] Maria, F. D.; Pavesi, G. RDF to energy plant for a central Italian region SUW management system: Energetic and economical analysis. Appl. Therm. Eng. (2006), 26, 1291–1300.

[5] Caputo, A. C.; Palumbo, M.; Scacchia, F. Perspectives of RDF use in decentralized areas: comparing power and co-generation solutions. Appl. Therm. Eng. (2004), 24, 2171–2187.

[6] Malkow, T. Novel and innovative pyrolysis and gasification technologies for energy efficient and environmentally sound MSW disposal. Waste Manage. (2004), 24, 53–79.

[7] Wang, Z.; Huang, H.; Li, H.; Wu, C.; Chen, Y.; Li, B. Pyrolysis and combustion of refuse-derived fuels in a spouting-moving bed reactor. Energy Fuels (2002), 16, 136–142.

[8] Binlin Dou, Sanguk Park, Sungjin Lim, Tae-U Yu, and Jungho Hwang, Pyrolysis Characteristics of Refuse Derived Fuel in a Pilot-Scale Unit. Energy & Fuels (2007), 21, 3730–3734

[9] TNO Report (STB-99-55). Chemical recycling of plastic waste (PVC and other resins), (1999).

[10] Sartorius, I. Development plastics. Manufacturing industry in Europe. ICS-UNIDO Conference, Trieste, Italy, (2002).

[11] Department for Environment, Food and Rural Affairs (DEFRA). Waste Strategy 2000: England and Wales Part II; DEFRA: London, U.K., (2000); Chapter 5, pp 64-88.

[12] N. Miskolczi, L. Bartha, and A. Angyal, Pyrolysis of Polyvinyl Chloride (PVC)-Containing Mixed Plastic Wastes for Recovery of Hydrocarbons. Energy & Fuels (2009), 23, 2743–2749

[13] Tullo, A. H. Plastic additives. Chem. Eng. News (2003), 81 (46), 36-42.

[14] BERNDR T. SIMONEIT, PATRICIAM MEDEIROS, BORYSM DIDYK, Combustion Products of Plastics as Indicators for Refuse Burning in the Atmosphere, Environ. Sci. Technol. (2005), 39, 6961-6970