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Polyvinyl Chloride (PVC) Waste Plastic Treatment Using Zinc Oxide (Zno) With Activated Carbon And Produced Hydrocarbon Fuel For Petroleum Refinery

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Abstract: *The increase of waste PVC (code 3) plastic productions is serious environmental problem issue for today. PVC plastic consumption is increasing day by day all over the world. Out of 100% plastics 6% PVC plastic used from total all types of plastic use. PVC plastic can serve as a potential resource with the correct treatment and its converting as hydrocarbon raw materials or as a useful fuel. PVC plastic has high chlorine (Cl) content and percentage is 56% by total weight. PVC plastic incineration process needs highly energy demand and during incineration time is creation toxic chloro emission and is ceating environmental, ecology and human health problem. Chlorine component need to be removed by using alkali wash before using produce fuel. Thermal degradation process with 5% Zinc Oxide (ZnO) can reduce chlorine content result in polymer chain generating product with heavy molecular weight and some uncontrolled Cl content. The thermal degradation of waste PVC produces only 35.6% of liquid product, some light gas 34.47% and rest of residue29.93%. Thermal degradation temperature was use 75-400 ºC. This produced fuel can be used for feedstock refinery for potential energy generation.*

Keywords: *Waste PVC, Fuel, thermal degradation, ZnO, catalyst, activated carbon*

I. Introduction

The conversion of waste plastics into fuel represents a sustainable way for the recovery of the organic content of polymeric waste and also preserves valuable petroleum resources in addition to protecting the environment. [1]. The worlds limited reserve of coal, crude oil and natural gas places a great pressure on mankind to preserve its existing non-renewable materials. Among the various recycling methods for the waste plastics, the feedstock recycling has been found to be promising technique. There are a lot of research [1-11] in progress on the pyrolysis and utilization of pyrolysis products for various applications one of them being thermal degradation. Municipal waste plastics is a mixture of non-halogenated and halogenated thermoplastics such as polyethylene, polypropylene, polystyrene, polyvinyl chloride, and polyethylene terephthalate. The waste from electric and electronic equipment mostly consists of high impact polystyrene (HIPS), acrylonitrile-butadiene-styrene copolymer (ABS) and these plastics contain various additives, e.g. flame retardants. More than half of the computer housings analyzed was made of HIPS with the next biggest fraction being ABS [2]. Kaminsky and Hartmann reported on the pathways in plastic recycling and the current status of plastic recycling as a source of raw materials [3]. There is an abundance of literature on the recovery of fuel and chemicals through catalytic pyrolysis of waste plastics [4-10]. Chemical recycling of plastics into useful organic compounds by oxidative degradation and oxidative chemical recycling of polyethylene has been reported in Pifer and Sen [11].

The main problem posses during the recycling of waste plastics are associated with polyvinyl chloride (PVC). The municipal waste plastics contain all kinds of plastics including PVC. The pyrolysis of these municipal waste plastic leads to the production of chloroorganic compounds. It is well known that during the thermal degradation of PVC, elimination of HCL occurs and leads to the formation of conjugated double bonds [12]. The other plastics like polystyrene (PS) also produces double bond such as styrene during degradation. The polar HCL molecule when liberated from PVC attacks the double bond compounds leading to the production of chlorinated organic compounds [13]. If the produced fuel using PVC is used directly as fuel oil, the chlorinated compound creates problem. It is necessary to remove chloroorganic compound from the fuel oil before refinement is done. Catalytic de-chlorination is one of the preferred methods for the removal of organic chlorine compounds compare to other methods such as incineration because it excludes the formation of toxic compounds. Various metal oxide catalysts are used in the de-chlorination reaction [14].

Thermal degradation of mixed plastics is currently receiving renewed interest as a route for disposal of the large quantities of waste plastics collected by different collecting system. The pyrolytic route is favorable because of the rates of conversion into oil which can be obtained. The advantage of thermal degradation of macromolecules in the absence of air (pyrolysis) compared to combustion is a reduction in the volume of product gases by a factor of 5-20 which leads to considerable saving in the gas conditioning equipment. Furthermore, it is possible to obtain valuable hydrocarbon compounds. The pyrolysis is complicated by the fact that plastics show poor thermal conductivity while the degradation of macromolecules requires large amount of energy. Compare to pyrolysis, the thermal degradation process described in this paper is much simpler and cost effective because we do not use any gas to purge the reactor, and the degradation process is conducted in the presence of atmospheric pressure. The temperature range selected for the conversion process was in the range of 75 to 400 ^{0}C. Also in this presented process we are going to remove the chlorine compounds from the chloroorganic compound by applying the 5% Zinc Oxide (ZnO) Catalyst and 1% activated carbon.

I. Experimental Section

2.1 Raw materials collection

Polyvinyl chloride (PVC) waste plastic is collect from fence store at Stamford, CT. After collect the PVC fence we washed with liquid soap and water to removed dust particle from PVC fence. PVC waste plastic is place on table for room air dry.

2.2 Raw materials preparation

After finished dry PVC waste plastic is cut into small pieces by using manually with scissor for fit into the reactor chamber. Before put into reactor inside PVC waste plastic analysis by using Perkin Elmer GC/MS clarus 500 models with CDS-500 series pyroprobe, FT-IR Perkin Elmer model number is spectrum 100 and TGA (Pyris 1) equipment. By using GC/MS with pyroprobe we check the compound structure for PVC waste plastic with different retention time, FT-IR is given us functional group structure with different wave number and at the end we used for onset melting temperature measurement TGA equipment. Table 1 is shown PVC plastic properties for visual understanding.

Table 1: PVC Plastic Properties

Mechanical Properties

Quantity	Value	Units
Specific Gravity	1.3~1.7	
Elongation	%	24~145
Tensile Strength	7,300	psi
Flexural Strength	4,060~14,100	psi
Compressive Strength	7,250~8,120	
Tensile Elastic Modulus (Young's Modulus)	3.5~10	(10~5) psi
Flexural Modulus	3~8	(10~5) psi
Hardness Durometer	107~113	Rockwell R
Impact Strength IZOD 73°F/23°C	0.4~20	notched ft/lbs/in

Thermal Properties

Quantity	Value	Units
Melting Point	182	°C
	(360)	(°F)
Upper Service	°C	60
Temperature(20,000h)	(°F)	(140)
Flame Rating**	UL94	VO
Thermal Conductivity	3.0~5.0	10~4 cal/sec/cm^2,ºC/cm

Electrical Properties

Quantity	Value	Units
Dielectric Constant	3.0~8.0	1kHz
Dissipation Factor	0.009~0.16	1kHz
Dielectric Strength	300~500	125 v/mil
Volume Resistivity	5.4 x 10^{13}	ohm-cm at 73^0F, 50% RH

General Properties

Quantity	Value	Units
Chemical/Solvent Resistance	Excellent	
Water Absorption, 24h	0.1~1.5	%
Refractive Index	1.539	

2.3 Process Description

Waste plastic PVC to liquid hydrocarbon fuel production process into laboratory scale was use thermal degradation process with 5% Zinc Oxide (ZnO) catalyst with 1% activated carbon and at temperature 75 - 400 ºC under atmospheric pressure in present of oxygen and under Labconco fume hood. Sample was using only polyvinyl chloride (PVC-3) and experiment was performing fully close system. Experimental purpose sample was use 75 gm and glass reactor was use. Reactor temperature range can go up to 450 ºC. Grinded waste plastic (PVC) fence sample put into reactor chamber with 5% Zinc Oxide catalyst and 1% activated carbon then heat start from 75 ºC temperature to up to 400 ºC. When PVC waste plastic start to melt due to temperature increase from melted PVC waste plastic turn into liquid phase and liquid phase to turn into vapor, vapor passing through condenser unit its becomes liquid form and it's called plastic fuel (shown Figure1). This PVC waste plastic to fuel conversion rate is 35.6%. This produced fuel density is 0.81 g. /ml. 5% Zinc Oxide catalyst was use for remove chlorine content from this experiment and no extra chemical used in this conversion process. During plastic converting to liquid fuel all vapor is not turn into fuel some vapor portion is come out as a light gas because that gas boiling point is minus temperature. Light gas cleaning purpose was use as an $AgNO_3$ and NaOH/ $NaHCO_3$ solution and after wash light gases passing through also water wash and at the end we put light gas into gas storage tank. Alkali wash and water wash was cleaning chorine contain and is formation Sodium Chloride or Silver Chloride and light gas is removing chlorine by this type wash. This light gas percentage is 34.47%. From PVC waste plastic to fuel production total conversion rate is 70.07%. The produced PVC plastic to fuel passes through filter paper to remove fuel sediment to making fuel clean and water and sediment come out separately its call fuel sediment, this sediment and water we can retreat. When we collected fuels some chlorine contains are came out with fuel, this fuel we pass though again Zinc Oxide solution to remove all chlorine contain by precipitation method. PVC waste plastic to fuel production period we are getting some black solid residue and this residue percentage is 29.93%. Because PVC plastic has 56% chlorine contains and additives. Experimental run time was 5.45 hours. In mass balance calculation showed 75 gm PVC to liquid fuel 26.7gm, light gas 25.85 gm and black solid residue 22.45 gm.

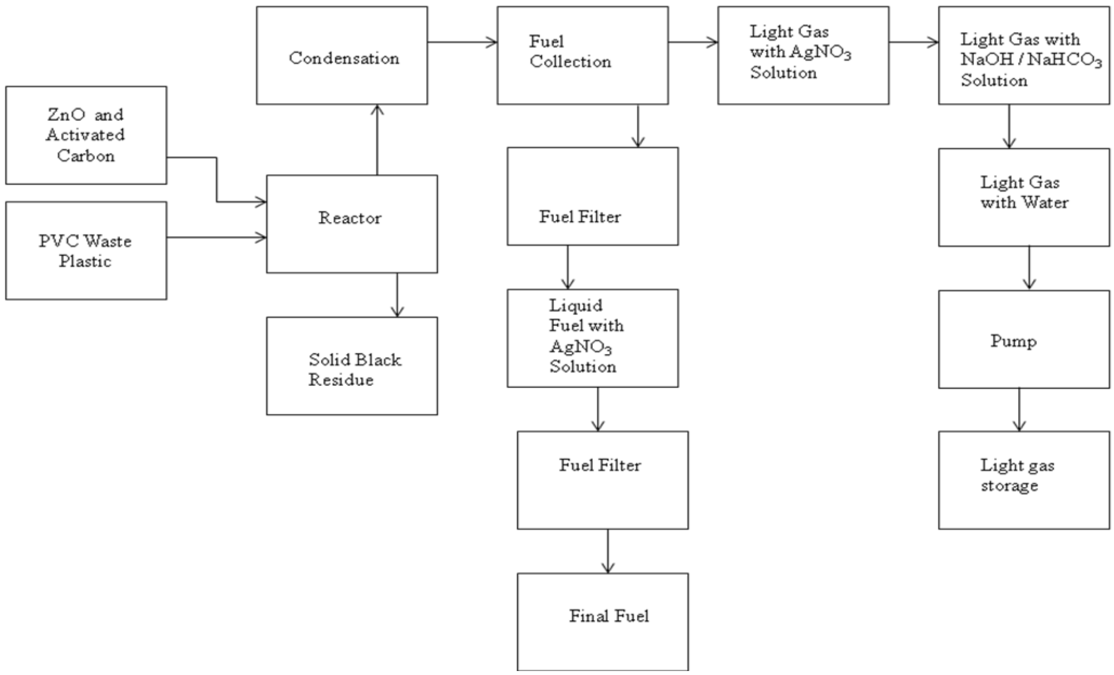

Figure 1: PVC Waste Plastic to Fuel Production Process with 5% ZnO and 1% Activated Carbon

II. Result and Discussion

3.1. Analysis Technique

Perkin Elmer GC/MS with pyroprobe was use for PVC raw sample analysis, TGA was use for raw sample analysis. Liquid sample was analysis by FT-IR and GC/MS with auto sampler system. Raw material analysis purposed TGA was use and temperature profile was 50-800 ºC and rate was 20ºC. Carrier gas was Helium. FT-IR was use for liquid sample analysis and NaCl cell was use for sample holder. FT-IR program was 4000-400 cm^{-1}, Resolution 4 and scan number 32. GC/MS was use for initial raw material and liquid sample analysis and carrier gas was helium. For analysis purpose a GC column was use (Perkin Elmer) with a elite-5MS length 30 meter, 0.25 mm ID, 0.5um df, maximum program temperature 350 ºC and minimum bleed at 330 ºC [cat.# N9316284] and also it can be used -60 ºC. Capillary column internal silica coating of viscous liquid such as carbowax or wall bonded organic materials. GC/MS operational purpose we used carrier gas as Helium gas. For GC method setup initial temperature 40 ºC and initial hold for 1 minute. Final temperature setup is 330 ºC. Temperature ramping rate is 10ºC/minutes up to 325 ºC and hold for 15 minutes 325 ºC. Total experiment runs time 44.50 minutes. MS method setup for sample analysis MS scan time 1 to 44.50 minutes and mass detection 35- 528 EI^+ centroid. Internal scan time used 0.15 second. Mass detection is creating m/z ratio.

3.2. Pre-analysis of raw materials

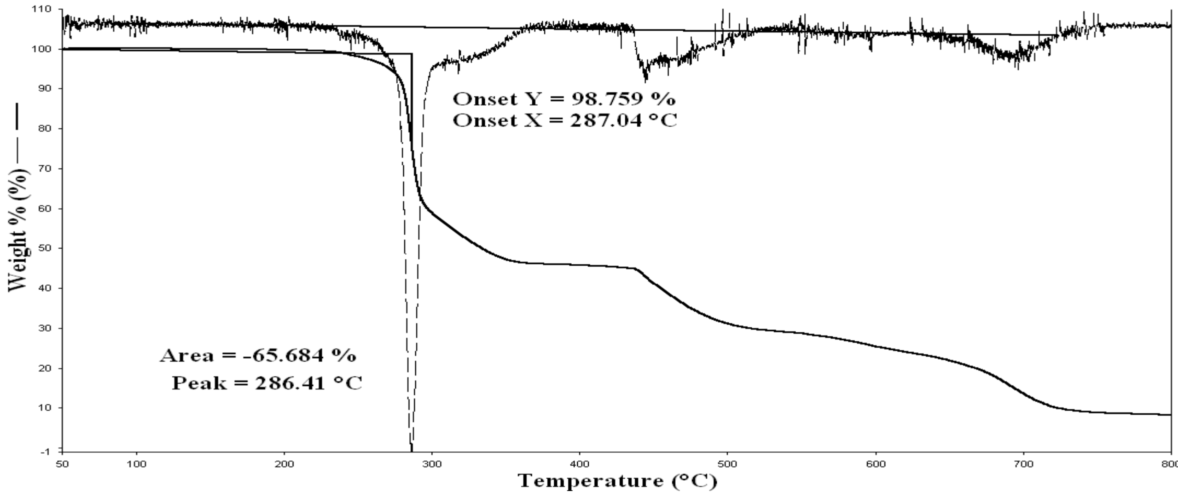

Figure 2: TGA (Pyris-1) Graph of PVC raw waste plastic

PVC waste plastic was per-analyzed by TGA for onset temperature measurement (figure 2). After analysis sample TGA analysis graph showed onset temperature 287.04 ºC, peak temperature was 286.41 ºC. Pre-analysis purposed raw sample was use 2.27 gm and after sample run by TGA left over residue was 0.57 gm. TGA analysis result showed PVC conversion rate 74.89% and after sample run finished left over was into crucible 0.57 gm and rate was 25.11%.

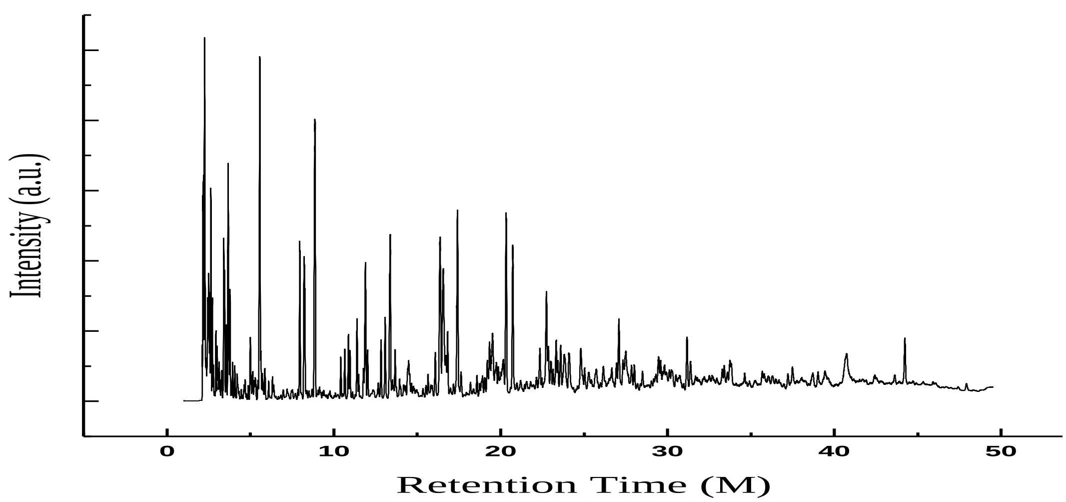

Figure 3: GC/MS Chromatogram of PVC raw waste plastic

Table 2: GC/MS Chromatogram Compound list of raw PVC waste plastic

Retention Time (min.)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight
2.12	44	Ethyne, fluoro-	C_2HF	44
2.25	56	3-Pentyn-1-ol	C_5H_8O	84
2.63	66	3-Penten-1-yne, (E)-	C_5H_6	66

3.41	80	1,4-Cyclohexadiene	C_6H_8	80
3.66	52	1,5-Hexadiyne	C_6H_6	78
4.99	79	1,4-Cyclohexadiene, 1-methyl-	C_7H_{10}	94
5.57	65	1,5-Heptadien-3-yne	C_7H_8	92
7.96	91	Ethylbenzene	C_8H_{10}	106
8.87	91	p-Xylene	C_8H_{10}	106
10.42	117	Benzene, 1-ethenyl-2-methyl-	C_9H_{10}	118
10.66	91	Benzene, propyl-	C_9H_{12}	120
10.87	105	Benzene, 1-ethyl-3-methyl-	C_9H_{12}	120
11.40	105	Benzene, 1-ethyl-4-methyl-	C_9H_{12}	120
11.89	117	Benzene, 1-ethenyl-2-methyl-	C_9H_{10}	118
12.83	117	Benzene, 2-propenyl-	C_9H_{10}	118
13.07	117	Indane	C_9H_{10}	118
13.38	115	1-Propyne, 3-phenyl-	C_9H_8	116
13.67	91	1,2,3,4,5,8-Hexahydronaphthalene	$C_{10}H_{14}$	134
14.48	119	2,4-Dimethylstyrene	$C_{10}H_{12}$	132
15.65	117	Benzene, 1-methyl-4-(2-propenyl)-	$C_{10}H_{12}$	132
16.08	117	1H-Indene, 2,3-dihydro-5-methyl-	$C_{10}H_{12}$	132
16.55	130	Naphthalene, 1,2-dihydro-	$C_{10}H_{10}$	130
17.41	128	Naphthalene	$C_{10}H_8$	128
19.33	129	Naphthalene, 1,2-dihydro-6-methyl-	$C_{11}H_{12}$	144
19.52	129	Naphthalene, 1,2-dihydro-3-methyl-	$C_{11}H_{12}$	144
20.33	141	Benzocycloheptatriene	$C_{11}H_{10}$	142
20.73	141	Naphthalene, 1-methyl-	$C_{11}H_{10}$	142
22.35	154	Biphenyl	$C_{12}H_{10}$	154
22.75	141	Naphthalene, 1-ethyl-	$C_{12}H_{12}$	156
23.33	156	Naphthalene, 2,6-dimethyl-	$C_{12}H_{12}$	156
23.60	154	1,3-Cyclohexadien-5-ol, 1-phenyl-	$C_{12}H_{12}O$	172
24.08	152	Acenaphthylene	$C_{12}H_8$	152
24.80	168	Naphthalene, 1-(2-propenyl)-	$C_{13}H_{12}$	168
26.15	153	Naphthalene, 1,6,7-trimethyl-	$C_{13}H_{14}$	170
27.09	165	Fluorene	$C_{13}H_{10}$	166
29.46	165	(3H)Benzo[c]pyrrole, 3-methyl-3-phenyl-	$C_{14}H_{12}N_2$	208
31.17	178	Phenanthrene	$C_{14}H_{10}$	178
33.74	192	1H-Cyclopropa[l]phenanthrene,1a,9b-dihydro-	$C_{15}H_{12}$	192
35.67	206	[14]Annulene, 1,6:8,13-bis(methano)-, syn	$C_{16}H_{14}$	206
37.49	166	Carbonic acid, bis(4-nitrophenyl) ester	$C_{13}H_8N_2O_7$	304
39.44	215	Acetic acid, α-(1-naphthyl)benzyl ester	$C_{19}H_{16}O_2$	276
40.69	104	1-Aza-2-sila-5-boracyclopent-3-ene, 4,5-diethyl-2,2,3-trimethyl-1-[2-(trifluoromethyl)phenyl]-	$C_{16}H_{23}BF_3NSi$	325
44.23	297	5-(p-Aminophenyl)-4-(p-methoxyphenyl)-2-thiazolamine	$C_{16}H_{15}N_3OS$	297

Polyvinyl Chloride waste plastic was pre-analyzed before start experiment for PVC waste plastic to fuel conversion process (Figure 3 and Table 2). PVC raw material was analyzed using GC/MS with pyroprobe. Pyroprobe was use for raw sample volatile purpose the transfer into GC/MS column. Pyroprobe sample volatile purpose temperature was use 1200 ºC. After finished GC/ MS sample run raw material chromatogram was analysis with turbo mass software and compounds detected from chromatogram with different retention time and based on trace mass (t vs. m/z). PVC raw materials chromatogram compounds showed hydrocarbon with other different type of compounds. PVC raw material has halogenated compound, hydrocarbon compounds, alcoholic group compounds, benzene derivatives, oxygen content compounds, nitrogen content compounds, ester group compounds and sulfur group compounds. A PVC raw material compound was detected based on trace mass (m/z) with retention time (t) (min.) some traced compounds are elaborated in this section. Initial compounds is Fluoro-ethyne (C_2HF) (t=2.12, m/z=44) compound molecular weight is 44, 3-Pentyn-1-ol (C_5H_8O) (t=2.25, m/z=56) compound molecular weight is 84, 1,4-Cyclohexadiene (C_6H_8) (t=3.41, m/z=80) compound molecular weight is 80, Ethylbenzene (C_8H_{10}) (t=7.96, m/z=91) compound molecular weight is 106, Propyl-Benzene (C_9H_{12}) (t=10.66, m/z=91) compound molecular weight is 120, Indane (C_9H_{10}) (t=13.07, m/z=117) compound molecular weight is 118, Naphthalene ($C_{10}H_8$) (t=17.41, m/z=128) compound molecular weight is 128, 1-methyl-Naphthalene ($C_{11}H_{10}$) (t=20.73, m/z=141) compound molecular weight is 142, 1-phenyl-1,3-Cyclohexadien-5-ol ($C_{12}H_{12}O$) (t=23.60, m/z=154) compound molecular weight is 172, 3-methyl-3-phenyl-(3H)Benzo[c]pyrrole ($C_{14}H_{12}N_2$) compound molecular weight is 208, Carbonic acid, bis(4-nitrophenyl) ester ($C_{13}H_8N_2O_7$) compound molecular weight is 304, 1-Aza-2-sila-5-boracyclopent-3-ene, 4,5-diethyl-2,2,3-trimethyl-1-[2-(trifluoromethyl)phenyl]- ($C_{16}H_{23}BF_3NSi$) compound molecular weight is 325, 5-(p-Aminophenyl)-4-(p-methoxyphenyl)-2-thiazolamine ($C_{16}H_{15}N_3OS$) compound molecular weight is 297 respectively. In this analysis result gives to compound structure and compound types look for understand. In raw material analysis showed PVC waste plastic has chlorine compounds and percentage is 56% by weight.

3.3. Analysis of Liquid Fuel

Table 3: FT-IR spectra functional group name of PVC waste plastic to fuel

Number of Wave	Wave Number (cm^{-1})	Name of Functional Group
1	2958.49	$C-CH_3$
2	2924.92	$C-CH_3$
3	2857.99	CH_2
4	1722.28	Non-Conjugated
6	1462.82	CH_2
7	1426.36	CH_2
8	1380.37	CH_3
12	1039.58	Acetates
14	742.29	-CH=CH- (cis)
15	704.21	-CH=CH- (cis)

FT-IR spectrum 100 analysis of liquid fuel functional group are appeared in table 3 and figure 4 for visual understanding. $C-CH_3$ group compounds detected 2958.49 and 2924.92 cm^{-1} wave number. CH_2 functional group appeared 2857.99, 1462.82 and 1426.36 cm^{-1} wave number. Methyl group compound detected 1380.37 cm^{-1} wave number. Cis group compounds traced in wave numbers 742.29 cm^{-1} and 704.21 cm^{-1}. Non –conjugated and acetates compound showed 1722.28 cm^{-1} and 1039.58 cm^{-1}.

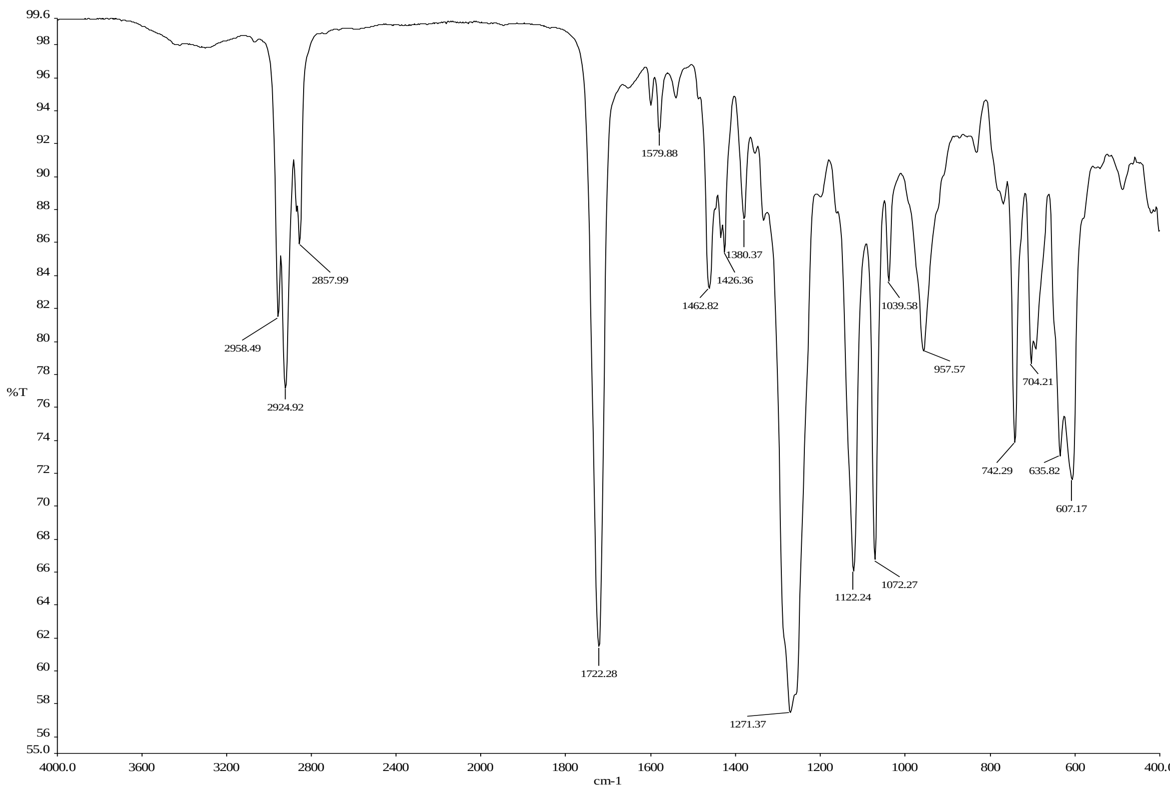

Figure 4: FT-IR Spectra of PVC waste plastic to fuel

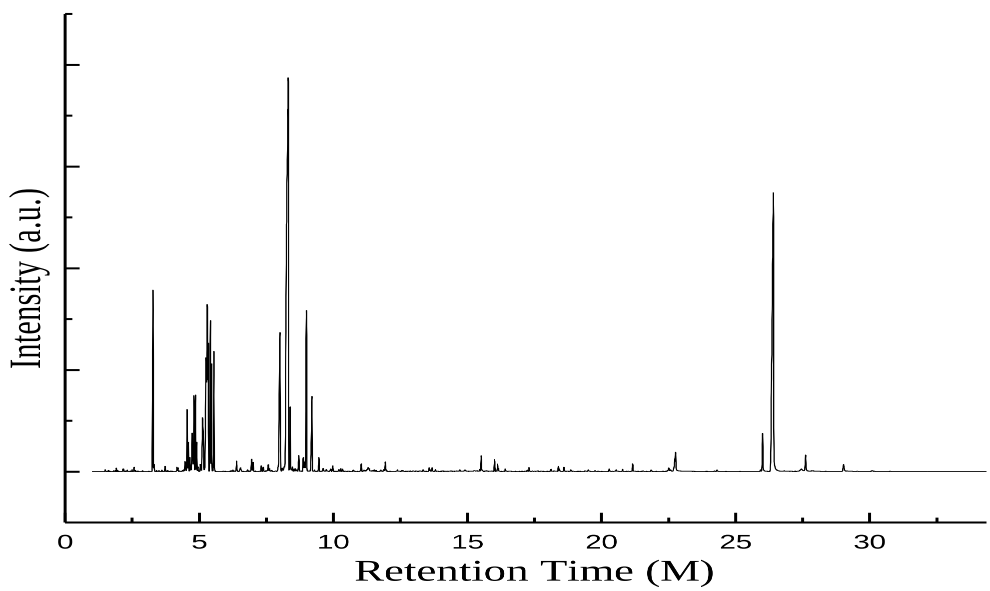

Figure 5: GC/MS Chromatogram of PVC waste plastic to produced fuel

Table 4: GC/MS Chromatogram compound list of PVC waste plastic to produced fuel

Number of Peak	Retention Time (min.)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	NIST Library Number
1	1.56	43	Isobutane	C_4H_{10}	58	49.9	121
2	1.61	43	Butane	C_4H_{10}	58	75.8	18940
3	1.63	41	2-Butene, (E)-	C_4H_8	56	29.1	105
4	1.67	41	1-Butene	C_4H_8	56	23.2	18920
5	1.81	43	Butane, 2-methyl-	C_5H_{12}	72	81.2	61287
6	1.87	42	Cyclopropane, ethyl-	C_5H_{10}	70	38.2	114410
7	1.91	43	Pentane	C_5H_{12}	72	87.2	61286
8	1.95	55	Cyclopropane, 1,1-dimethyl-	C_5H_{10}	70	18.6	34618
9	1.99	55	2-Pentene, (E)-	C_5H_{10}	70	16.9	291780
10	2.10	41	1-Propene, 2-chloro-	C_3H_5Cl	76	40.1	376
11	2.18	57	Propane, 2-chloro-2-methyl-	C_4H_9Cl	92	74.5	107667
12	2.24	67	Cyclopentene	C_5H_8	68	33.0	19032
13	2.32	43	Pentane, 2-methyl-	C_6H_{14}	86	39.1	61279
14	2.44	57	Pentane, 3-methyl-	C_6H_{14}	86	48.7	19375
15	2.50	41	Cyclopropane, 1-ethyl-2-methyl-, cis-	C_6H_{12}	84	24.9	113658
16	2.57	57	Hexane	C_6H_{14}	86	81.1	61280
17	2.62	55	3-Hexene, (E)-	C_6H_{12}	84	41.8	19325
18	2.72	55	3-Hexene, (E)-	C_6H_{12}	84	30.9	19325
19	2.89	56	Cyclopentane, methyl-	C_6H_{12}	84	41.1	114428
20	3.28	78	Benzene	C_6H_6	78	39.1	291514
21	3.41	43	Hexane, 3-methyl-	C_7H_{16}	100	66.2	113081
22	3.50	43	2-Propanone, 1-chloro-	C_3H_5ClO	92	94.4	250272
23	3.61	41	1-Heptene	C_7H_{14}	98	30.6	19704
24	3.72	43	Heptane	C_7H_{16}	100	44.1	61276
25	3.77	41	(Z)-3-Heptene	C_7H_{14}	98	17.8	113674
26	3.88	69	3-Hexene, 2,5-dimethyl-, (E)-	C_8H_{16}	112	36.7	114264
27	3.94	41	2-Heptene	C_7H_{14}	98	22.3	231709
28	4.00	57	2-Hexene, 5,5-dimethyl-, (Z)-	C_8H_{16}	112	46.1	114220
29	4.17	57	Hexane, 2,5-dimethyl-	C_8H_{18}	114	72.3	113944
30	4.20	43	Hexane, 2,4-dimethyl-	C_8H_{18}	114	49.1	118871
31	4.26	55	2-Hexene, 2,4-dimethyl-	C_8H_{16}	112	12.3	149377
32	4.38	55	4-Ethyl-2-hexene	C_8H_{16}	112	9.99	113483
33	4.42	41	3-Heptene, 4-methyl-	C_8H_{16}	112	8.06	149383
34	4.47	55	1-Heptene, 3-methyl-	C_8H_{16}	112	9.88	60730
35	4.55	55	2-Hexene, 2,3-dimethyl-	C_8H_{16}	112	15.4	149376
36	4.59	69	3-Heptene, 4-methyl-	C_8H_{16}	112	19.9	149383
37	4.65	41	2-Hexene, 3,5-dimethyl-	C_8H_{16}	112	9.95	149385
38	4.43	57	Heptane, 2-methyl-	C_8H_{18}	114	48.1	107748
39	4.81	91	Toluene	C_7H_8	92	61.9	291301
40	4.86	43	Heptane, 3-methyl-	C_8H_{18}	114	21.9	34428
41	4.91	56	2-Heptene, 5-methyl-	C_8H_{16}	112	56.3	113480
42	4.91	56	2-Heptene, 6-methyl-	C_8H_{16}	112	40.0	113464
43	5.04	55	3-Heptene, 4-methyl-	C_8H_{16}	112	33.5	149383
44	5.13	55	3-Heptene, 3-methyl-	C_8H_{16}	112	28.0	113088
45	5.25	55	4-Octene, (E)-	C_8H_{16}	112	27.3	107760
46	5.30	55	3-Octene, (E)-	C_8H_{16}	112	17.2	74040
47	5.33	55	4-Octene, (Z)-	C_8H_{16}	112	16.1	227615

48	5.41	55	2-Octene, (E)-	C_8H_{16}	112	26.3	107269
49	5.46	70	2-Heptene, 3-methyl-	C_8H_{16}	112	35.5	149374
50	5.55	55	2-Octene, (E)-	C_8H_{16}	112	26.7	107269
51	5.89	57	Heptane, 2,5-dimethyl-	C_9H_{20}	128	17.1	114209
52	6.19	81	1,4-Heptadiene, 3-methyl-	C_8H_{14}	110	19.4	1484
53	6.25	56	2-Chloro-2-methylhexane	$C_7H_{15}Cl$	134	41.8	113227
54	6.31	67	1,4-Heptadiene, 3-methyl-	C_8H_{14}	110	12.5	1484
55	6.39	91	Ethylbenzene	C_8H_{10}	106	62.2	158804
56	6.54	91	p-Xylene	C_8H_{10}	106	35.1	150787
57	6.80	43	2-Hexanone, 4-methyl-	$C_7H_{14}O$	114	37.7	69040
58	6.85	41	1-Nonene	C_9H_{18}	126	10.3	107756
59	6.96	91	p-Xylene	C_8H_{10}	106	36.2	113952
60	7.01	79	2-Propanol, 1,3-dichloro-	$C_3H_6Cl_2O$	128	93.8	291412
61	7.09	55	cis-2-Nonene	C_9H_{18}	126	12.1	113508
62	7.24	55	cis-4-Nonene	C_9H_{18}	126	7.67	113507
63	7.32	57	Hexane, 2-chloro-2,5-dimethyl-	$C_8H_{17}Cl$	148	57.9	114683
64	7.39	56	Hexane, 2-chloro-2,5-dimethyl-	$C_8H_{17}Cl$	148	7.75	114683
65	7.48	105	Benzene, (1-methylethyl)-	C_9H_{12}	120	42.0	249348
66	7.58	55	4-Chloro-2,4-dimethylhexane	$C_8H_{17}Cl$	148	65.5	114695
67	7.62	62	1-Propanol, 2,3-dichloro-	$C_3H_6Cl_2O$	128	98.0	291278
68	7.70	73	3,4-Dimethyl-3-hexanol	$C_8H_{18}O$	130	65.9	113725
69	8.00	69	Hexane, 2-chloro-2,5-dimethyl-	$C_8H_{17}Cl$	148	35.9	114683
70	8.32	41	Heptane, 3-chloro-3-methyl-	$C_8H_{17}Cl$	148	71.9	114670
71	8.39	55	3-Chloro-3-ethylhexane	$C_8H_{17}Cl$	148	87.8	113216
72	8.71	70	Octane, 2-chloro-	$C_8H_{17}Cl$	148	28.9	114638
73	8.88	70	Octane, 3-chloro-	$C_8H_{17}Cl$	148	52.1	114636
74	9.00	57	Heptane, 3-(chloromethyl)-	$C_8H_{17}Cl$	148	71.1	35077
75	9.20	57	1-Hexanol, 2-ethyl-	$C_8H_{18}O$	130	64.2	288735
76	9.46	117	Indane	C_9H_{10}	118	19.3	118485
77	9.62	115	Benzene, 1-propynyl-	C_9H_8	116	30.1	113196
78	9.74	91	1,2,3,4,5,8-Hexahydronaphthalene	$C_{10}H_{14}$	134	12.6	113559
79	9.91	105	Benzene, (1-methylethyl)-	C_9H_{12}	120	9.06	228742
80	9.97	57	5-Chloropentanoic acid, 2-ethylhexyl ester	$C_{13}H_{25}ClO_2$	248	15.7	293489
81	10.05	119	Benzene, 1-methyl-4-(1-methylethyl)-	$C_{10}H_{14}$	134	12.9	228189
82	10.10	119	Benzene, 1-methyl-3-(1-methylethyl)-	$C_{10}H_{14}$	134	20.1	149866
83	10.21	117	2,4-Dimethylstyrene	$C_{10}H_{12}$	132	10.9	136251
84	10.28	117	Indan, 1-methyl-	$C_{10}H_{12}$	132	13.5	150963
85	10.35	57	Undecane	$C_{11}H_{24}$	156	29.4	107774
86	10.46	41	Bicyclo[3.1.1]hept-2-ene-2-ethanol, 6,6-dimethyl-	$C_{11}H_{18}O$	166	7.09	114741
87	11.04	43	Acetic acid, 2-ethylhexyl ester	$C_{10}H_{20}O_2$	172	61.0	227968
88	11.30	117	Benzene, 1-methyl-4-(2-propenyl)-	$C_{10}H_{12}$	132	17.5	113549
89	11.53	104	Naphthalene, 1,2,3,4-tetrahydro-	$C_{10}H_{12}$	132	76.6	113929
90	11.60	130	Benzene, (cyclopropylidenemethyl)-	$C_{10}H_{10}$	130	17.2	37790

91	11.76	43	3-Dodecene, (E)-	$C_{12}H_{24}$	168	8.04	113960
92	11.89	57	Dodecane	$C_{12}H_{26}$	170	9.82	291499
93	11.94	128	Naphthalene	$C_{10}H_8$	128	42.2	114935
94	12.01	131	1H-Indene,2,3-dihydro-2,2-dimethyl-	$C_{11}H_{14}$	146	32.0	214909
95	12.39	57	Oxirane, [[(2-ethylhexyl)oxy]methyl]-	$C_{11}H_{22}O_2$	186	7.68	291546
96	12.56	117	2-Ethyl-2,3-dihydro-1H-indene	$C_{11}H_{14}$	146	30.5	214919
97	12.88	91	Benzene, hexyl-	$C_{12}H_{18}$	162	37.4	113954
98	12.99	71	Cyclohexane, (1,2,2-trimethylbutyl)-	$C_{13}H_{26}$	182	16.1	45488
99	13.23	43	3-Tridecene, (E)-	$C_{13}H_{26}$	182	3.96	142616
100	13.35	57	Tridecane	$C_{13}H_{28}$	184	21.4	107767
101	13.57	142	Naphthalene, 1-methyl-	$C_{11}H_{10}$	142	33.4	291511
102	13.69	104	1,2-Benzenedicarboxylic acid	$C_8H_6O_4$	166	53.8	290999
103	13.81	142	Benzocycloheptatriene	$C_{11}H_{10}$	142	27.7	104256
104	14.72	57	Tetradecane	$C_{14}H_{30}$	198	14.8	113925
105	14.92	141	Naphthalene, 2-ethyl-	$C_{12}H_{12}$	156	36.1	151404
106	15.54	59	Heptane, 3-[(1,1-dimethylethoxy)methyl]-	$C_{12}H_{26}O$	186	16.6	164818
107	15.52	73	3-Hexanol, 3,5-dimethyl-	$C_8H_{18}O$	130	20.7	237007
108	16.01	57	Pentadecane	$C_{15}H_{32}$	212	40.2	107761
109	16.12	70	Hexanoic acid, 2-ethylhexyl ester	$C_{14}H_{28}O_2$	228	68.8	279277
110	17.30	70	Heptanoic acid, 4-octyl ester	$C_{15}H_{30}O_2$	242	52.6	160117
111	18.11	57	Octane, 1,1'-[ethylidenebis(oxy)]bis-	$C_{18}H_{38}O_2$	286	22.2	279769
112	18.39	57	Heptadecane	$C_{17}H_{36}$	240	18.3	107308
113	18.60	105	Benzoic acid, 2-ethylhexyl ester	$C_{15}H_{22}O_2$	234	84.0	236353
114	18.85	57	Octane, 2-bromo-	$C_8H_{17}Br$	192	13.0	229455
115	20.28	57	9-Octadecanone	$C_{18}H_{36}O$	268	79.4	113053
116	22.51	57	Octadecanoic acid, 3-hydroxy-, methyl ester	$C_{19}H_{38}O$	314	13.6	14855
117	22.76	149	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	$C_{16}H_{22}O_4$	278	67.9	75949
118	24.21	219	10-Methylanthracene-9-carboxaldehyde	$C_{16}H_{12}O$	220	28.0	80593
119	24.30	57	Nonane, 4-methyl-5-propyl-	$C_{13}H_{28}$	184	6.03	61476
120	26.01	57	Hexadecanoic acid, 2-methylpropyl ester	$C_{20}H_{40}O_2$	312	11.5	232982
121	26.41	149	Di-n-octyl phthalate	$C_{24}H_{38}O_4$	390	41.9	191958
122	27.61	57	Octadecanoic acid, octyl ester	$C_{26}H_{52}O_2$	396	48.3	163918
123	29.02	57	Octadecanoic acid, 9-oxo-, methyl ester	$C_{19}H_{36}O_3$	312	24.0	14761

PVC waste plastic to fuel production process was use ZnO and activated carbon to remove chorine and additives color. PVC waste plastic has chlorine content and percentage showed in to molecular formula 56%. Chlorine gases harmful for environment and human body this gas very toxic gas. PVC waste plastic to fuel conversion period ZnO was added as catalyst to create reaction with chlorine content and form as $ZnCl_2$ precipitate and come out with residue. ZnO catalyst and PVC waste plastic to fuel production period HCl, HBr compound formed because raw materials has halogenated compounds. During production period light gas was cleaned with $AgNO_3$ solution and $NaOH/NaHCO_3$ solution to removed cholorinated compound from light gas. Liquid fuel was treated with $AgNO_3$ solution to removed chlorine compounds from liquid fuel. Filtered fuel was analyzed by GC/MS with auto sampler system (Figure 5 and Table 4). In GC/MS chromatogram analysis result showed hydrocarbon compounds present into liquid fuel and also other different types of compounds present into liquid fuel. Produced liquid fuel present are hydrocarbon compounds, halogenated compounds, alcoholic compounds, oxygen containing compounds, nitrogen containing compounds and benzene derivatives. Produced fuel GC/MS analysis result showed chlorine compound present into liquid fuel and due to chlorine compound fuel can be use as feed stock refinery to removed chlorine compound and make hydrocarbon for combustion engine useable. GC/MS chromatogram compound was detected based on compounds trace mass and retention time wise. Initial carbon chain compound traced by GC/MS Isobutane (C_4H_{10}) (t=1.56, m/z=43) compound molecular weight is 58 and compound probability percentage is 49.9% and heights carbon chain compound traced by GC/MS Octadecanoic acid, octyl ester ($C_{26}H_{52}O_2$) (t=27.61, m/z=57) compound molecular weight is 396 and compound probability percentage is 48.3%. Some compounds are elaborated in this analysis section based on retention time (t) and trace mass such as 2-methyl- Butane (C_5H_{12}) (t=1.81, m/z=43) compound molecular weight is 72 and compound probability percentage is 81.2%, 1,1-dimethyl-Cyclopropane (C_5H_{10}) (t=1.95. m/z=55) compound molecular weight is 70 and compound probability percentage is 18.6%, 2-chloro-2-methyl- Propane (C_4H_9Cl) (t=2.18, m/z=57) compound molecular weight is 92 and compound probability percentage is 74.5%, cis-1-ethyl-2-methyl-Cyclopropane (C_6H_{12}) (t=2.50, m/z=41) compound molecular weight is 84 and compound probability percentage is 24.9%, methyl-Cyclopentane (C_6H_{12}) (t=2.89, m/z=56) compound molecular weight is 84 and compound probability percentage is 41.1%, 1-chloro-2-Propanone (C_3H_5ClO) (t=3.50, m/z=43) compound molecular weight is 92 and compound probability percentage is 94.4%, 2-Heptene (C_7H_{14}) (t=3.94, m/z=41) compound molecular weight is 98 and compound probability percentage is 22.3%, 4-methyl-3-Heptene (C_8H_{16}) (t=4.42, m/z=41) compound molecular weight is 112 and compound probability percentage is 8.06%, Toluene (C_7H_8) (t=4.81, m/z=91) compound molecular weight is 92 and compound probability percentage is 61.9%, 6-methyl-2-Heptene (t=4.91, m/z=56) compound molecular weight is 112 and compound probability percentage is 40.0%, (Z)-4-Octene (C_8H_{16}) (t=5.33, m/z=55) compound molecular weight is 112 and compound probability percentage is 16.1%, 3-methyl- 1,4-Heptadiene (C_8H_{14}) (t=6.19, m/z=81) compound molecular weight is 110 and compound probability percentage is 19.4%, 4-methyl-2-Hexanone ($C_7H_{14}O$) (t=6.80, m/z=43) compound molecular weight is 114 and compound probability percentage is 37.7%, 1,3-dichloro-2-Propanol ($C_3H_6Cl_2O$) (t=7.01, m/z=79) compound molecular weight is 128 and compound probability percentage is 93.8%, 1-methylethyl- Benzene (C_9H_{12}) (t=7.48, m/z=105) compound molecular weight is 120 and compound probability percentage is 42.0%, 3,4-Dimethyl-3-hexanol ($C_8H_{18}O$) (t=7.70, m/z=73) compound molecular weight is 130 and compound probability percentage is 65.9%, 3-Chloro-3-ethylhexane ($C_8H_{17}Cl$) (t=8.39, m/z=55) compound molecular weight is 148 and compound probability percentage is 87.8%, 3-chloromethyl-Heptane ($C_8H_{17}Cl$) (t=9.00, m/z=57) compound molecular weight is 148 and compound probability percentage is 71.1%, 1,2,3,4,5,8-Hexahydronaphthalene ($C_{10}H_{14}$) (t=9.74, m/z=91) compound molecular weight is 134 and compound probability percentage is 12.6%, 1-methyl-3-(1-methylethyl)-Benzene ($C_{10}H_{14}$) (t=10.10, m/z=119) compound molecular weight is 134 and compound probability percentage is 20.1%, Acetic acid, 2-ethylhexyl ester ($C_{10}H_{20}O_2$) (t=11.04, m/z=43) compound molecular weight is 172 and compound probability percentage is 61.0%, 1,2,3,4-tetrahydro- Naphthalene ($C_{10}H_{12}$) (t=11.53, m/z=104) compound molecular weight is 132 and compound probability percentage is 76.6 %, Dodecane ($C_{12}H_{26}$) (t=11.89, m/z=57) compound molecular weight is 186 and compound probability percentage is 7.68%, 2-Ethyl-2,3-dihydro-1H-indene ($C_{11}H_{14}$) (t=12.56, m/z=117) compound molecular weight is 146 and compound probability percentage is 30.5%, Tridecane ($C_{13}H_{28}$) (t=13.35, m/z= 57) compound molecular weight is 184 and compound probability percentage is 21.4%, Tetradecane ($C_{14}H_{30}$) (t=14.72, m/z=57) compound molecular weight is 198 and compound probability percentage is 14.8%, Pentadecane ($C_{15}H_{32}$) (t=16.01, m/z=57) compound molecular weight is 212 and compound probability percentage is 40.2%, Heptadecane ($C_{17}H_{36}$) (t=18.39, m/z=57) compound molecular weight is 240 and compound probability percentage is

18.3 %, 9-Octadecanone ($C_{18}H_{36}O$) (t=20.28, m/z=57) compound molecular weight is 268 and compound probability percentage is 79.4%, 2-methylpropyl ester Hexadecanoic acid ($C_{20}H_{40}O_2$) (t=26.01, m/z=57) compound molecular weight is 312 and compound probability percentage is 11.5 %, Di-n-octyl phthalate ($C_{24}H_{38}O_4$) (t=26.41, m/z=149) compound molecular weight is 396 and compound probability percentage is 48.3% appeared respectively. Produce residue and light gas analysis under investigation and ZnO catalyst recovery also under investigation. Produce fuel has aliphatic group compound such as alkane, alkene and alkyl group present. Chlorinated compound fuel can be use only feed stock refinery for further modification and usable for any kind of internal combustion engines.

III. Conclusion

PVC waste plastic are creating big environmental problem due to chorine content present into PVC plastic. PVC waste plastic is creating problem for recycling because during recycling period toxic gas releasing and toxic gas harmful for human body. In this process PVC waste plastic converting valuable hydrocarbon compounds fuel and produced fuel conversion rate almost 71%. In thermal degradation process performed with ZnO and activated carbon to reduce some chlorine percentage and fuel was treated with silver nitrate solution to remove chlorine percentage. In GC/MS analysis result indicate that produce fuel carbon chain start C_4 to C_{26} and compounds was benzene derivatives, halogenated, alcoholic, hydrocarbon group, oxygen containing compounds and nitrogen containing compounds. Fuel has chlorine compound for that reason produce fuel can be use only feed stock refinery for further modification. The present technology can convert liquid halogenated group related hydrocarbon compound fuel and remove PVC waste plastic from environment and save environment for next generation. PVC waste plastic can remain long period into land fill and releasing toxic gas into environment. Present technology can solve PVC waste plastic problem and produce hydrocarbon fuel for petroleum refinery and boost up energy sector for near future.

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