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Research Article

Catalytic Degradation of PVC and PETE Mixture of Waste Plastic into Petrochemicals using Al_2O_3 & Activated Carbon

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Abstract

Waste plastics are creating environmental problems and occupying large amount of landfill. PVC waste is generating ~10 % and PET ~8% from total waste plastics. Catalytic degradation of polyvinyl chloride and polyethylene terephthalate mixture to petrochemical recovery at temperature ranges from 120-420 ºC using aluminum oxide and activated carbon. PET sample of 75 g and PVC sample of 25 g, total raw materials of 100 g was used in this experiment. Aluminum oxide of 5% (5g) as a catalyst and activated carbon of 5% (5g) was used. Laboratory batch process experiment was conducted under laboratory fume hood without vacuum system. Product fuel density is 0.85 g/ml. PVC and PET mixture to fuel production conversion rate is 42.9 % including liquid product and gas product. Product fuel was analyzed by using Perkin Elmer Gas Chromatography and Mass Spectrometer (GC/MS) and carbon chain detected C_2 to C_{28}. Present technology can convert all PVC and PET to valuable fuel energy using catalytic degradation process. This process can remove PVC and PET waste plastic problems from environment and convert them into valuable petrochemical energy.

Keywords: polyvinyl chloride, degradation, petrochemicals, activated carbon, waste plastic, PETE, aluminum oxide

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Introduction

Nowadays plastic consumption is more than ever increasing. Annual consumption of plastics in Occidental Europe is about 60 million tons, of which about 40% are used in packing and packaging applications, which in a very short period are converted into wastes, yielding about 15 million tons of such wastes per year [1]. At present, in Europe, about 50% of the annually generated plastic wastes are valorized, 60% by incineration with energy recovery and about 40% by recycling. Most of the recycled plastics are mechanically recycled, while less than 1% is chemically recycled [1]. Municipal waste plastic represents about 8 wt% of the municipal solid waste and it generally consists of mixture of different kind of plastics: 40.5 wt% HDPE and L/LDPE, 19.6 wt% PP, 11.9 wt% PS/EPS, 10.7 wt% PVC, 8.1 wt% PET, and about 5 wt% ABS and 4.2 wt% other polymers [2]. This waste is difficult to be treated or recycled due to its complex nature and compositions, structural deterioration of the polymeric components and the contamination with various organic and inorganic or biological residues [3].

Thermal degradation of polymer mixtures is more complex than the degradation of single polymers. Interactions can appear at high temperatures during decomposition in the polymer bulk, between the components of the mixture and the low molecular weight products and free radicals that are formed by the scission of the polymeric chains. PVC and PET are heteroatom containing polymers that create problems during thermal decomposition because bromine, chlorine, and nitrogen can remain as organic compounds in pyrolysis oils or can produce acid or toxic gases such as HCl, HBr, HCN, NH_3 or polyhalogenated dibenzodioxins and dibenzofurans [4, 5]. Therefore, the amount of these compounds has to be decreased as much as possible. In an industrialized society a sizeable amount of waste materials is produced that has to be disposed. Possible ways to achieve this is through landfilling or incineration. Less space is available for landfilling, especially in highly populated areas where most of the waste occurs. A further disadvantage is the fact that landfilling emits harmful CO_2 and methane (CH_4) to the atmosphere on decomposition. CH_4 has a greenhouse warming potential, 21 times greater than CO_2. This has led to policy statements and legislation worldwide to restrict landfilling. With new legislation coming into effect in many countries, landfilling is becoming a less attractive option from an economic point of view [6].

The Packing and Packaging Waste Directive (2004/12/CE) obliges to valorize (energy recovery + recycling) 60% of the packing and packaging wastes, with at least 55–85 % of recycling. For this to be possible, in many European countries, municipal (yellow) containers for municipal plastic and metallic packing wastes have been set out and for industrial separation and classification plants, which receive the yellow containers contents as raw materials, are being operated on an industrial scale. In such plants the wastes are separated in different fractions (steel, tetra-brick, aluminum cans, different plastics, etc.) and then sent to recycling companies. However, a significant amount of the incoming materials (>25 wt %) cannot be properly classified or separated and is rejected. The rejected fractions are composed of many different materials (PE, PP, PS, PVC, PET, ABS, aluminum, film, etc.), which are very much intermingled; consequently it is not technically or economically viable as an ulterior separation, and therefore they can only be incinerated or landfilled [7]. There are many references in the literature about the thermal decomposition of plastics. Different experimental procedures have been used including thermogravimetric analyzers [8, 9], fixed bed reactors [10, 11], fluidized bed pyrolysis units [12, 13], vacuum pyrolysis units [14, 15], spouted bed reactors [16], and etc.

Process Description

Initial raw materials were collected from Stamford local city, PET was a drinking bottle and PVC was a transparent pipe. Both of these waste plastics were cut into small pieces for reactor setup. Aluminum oxide catalyst and activated carbon was collected from VWR.Com. PET waste plastics took 75 g and PVC waste plastic took 25 g, as initial raw materials. PVC has ~56% chlorine and PET has ~33% oxygen in their structure and rest of the materials was hydrocarbons. For experimental purpose, extra two types of chemical were used because an initial raw material has chlorine content. $NaHCO_3$ and $AgNO_3$ were provided from VWR.com. For the thermal catalytic degradation process purpose, aluminum oxide was used as catalyst. For experiment purpose, temperature range from 120- 420 ºC and reactor chamber made by Pyrex glass. Experimental temperature control was under variac meter. Experimental setup procedure shown into figure 1 and accessories and materials was required such as reactor with temperature controller, condensation unit, fuel collection tank, purification unit, sediment collection tank, residue collection container, final fuel collection tank, liquid $NaHCO_3$ solution, $AgNO_3$ solution, clean water tank, small pump and Teflon bag. PET structure has benzene, oxygen, carbon, and hydrogen; on the other hand PVC structure has carbon, hydrogen, and chlorine content. Chlorine content and oxygen content are not convertible. Both compounds created problems during fuel production because chlorine content generates toxic gas and oxygen generates phenol group or wax. In laboratory scale batch process starting temperature was 120 ºC and final temperature was 420 ºC until the end of the experiment. During PVC and PET waste plastics to fuel production period, the waxy materials try to block the condenser unit. When heated PET and PVC a mixture waste plastic inside a glass reactor, some portion was made again solidify and it was not properly melt or liquid. From PVC and PET waste plastics hydrocarbon portion came out after breakdown when heat was continually starting to end the experiment. Temperature was controlled with variac meter and temperature was increased gradually from start time to the end of experiment. PVC has chlorine content, for that reason two types of chemical solutions were placed into condensation side and cleaning chlorinated gas and finally gas passed with clean water. Cleaner gas was collected into Teflon bag using small pump. Whole process was under labconco fume hood and experiment was run cautiously. In this process none of gas comes out in the environment; whole process was close system and it was batch process. Product fuel density is 0.85 g/ml and conversion rate from 100 g of initial materials was liquid fuel 27.2 %, Light gas 15.7 % and 57.1% was wax and solid residue. In mass balance calculation give us from 100 g PVC and PET mixture to liquid fuel is 27.2 g (volume 32 ml), sample as light gas generated during production period 15.7 g, and residue and wax generated 26.9 +30.2 = 57.1 g. Full experiment took about 4.25 hours and input electricity was 0.497 KWh.

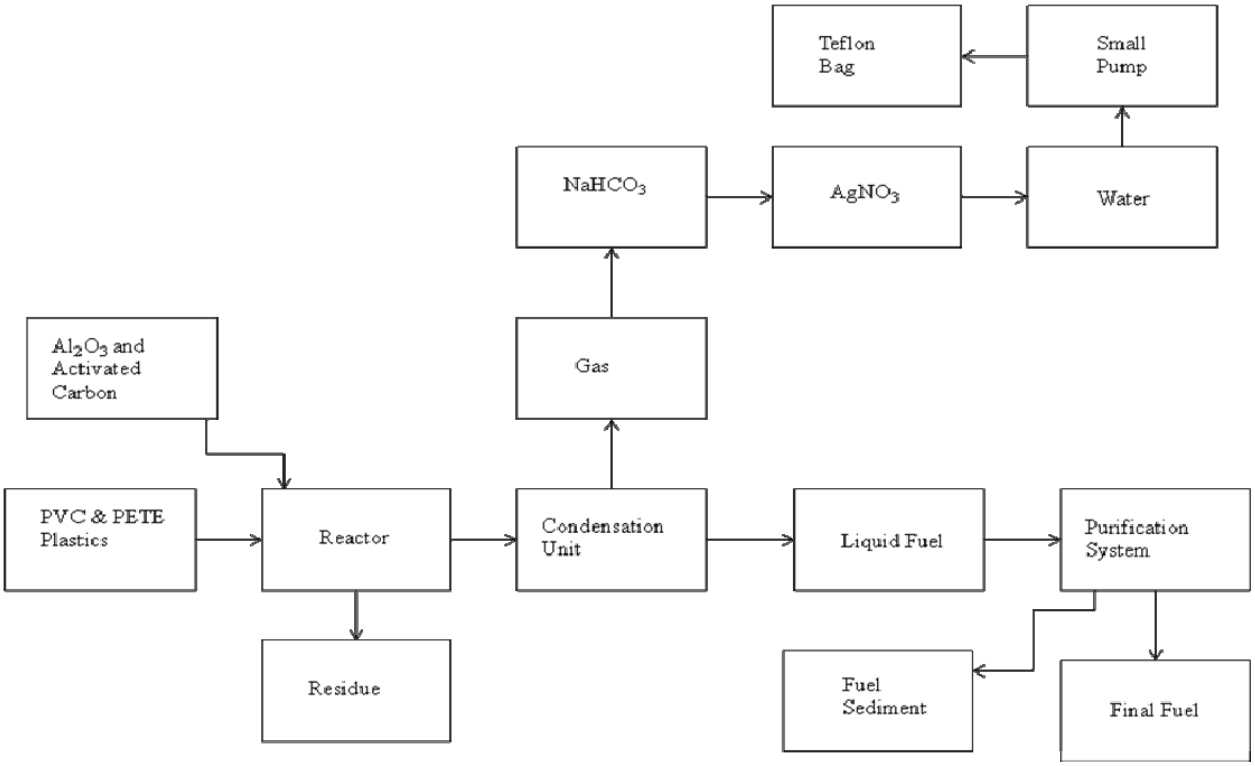

Figure 1: PVC and PETE waste plastic mixture to fuel production process using Al_2O_3 and activated carbon

Result and Discussion

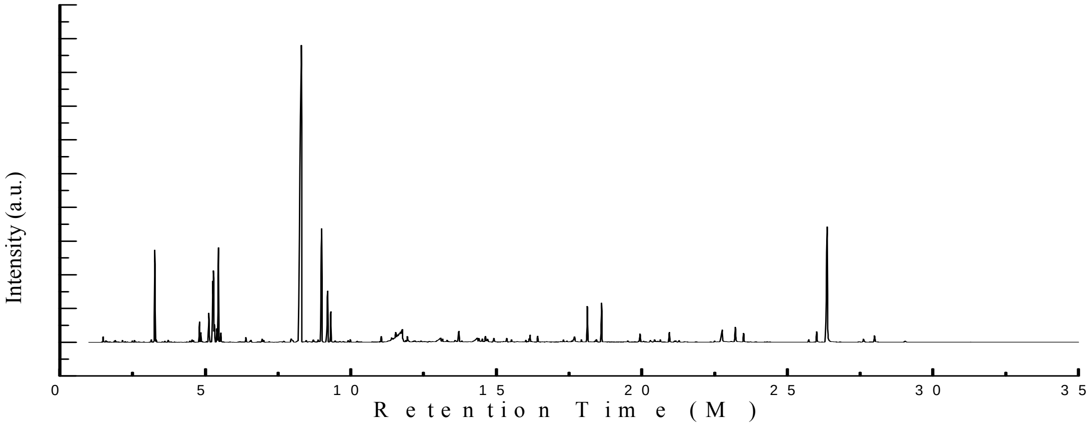

Figure 2: GC/MS chromatogram of PVC and PETE waste plastic mixture to fuel

Table 1: GC/MS chromatogram compounds list of PVC and PETE waste plastic mixture to fuel

Number of Peak	Retention Time (min.)	Trace Mass (m/z)	Compound Name	Compound Formula	Molecular Weight	Probability %	NIST Library Number
1	1.49	36	Hydrogen chloride	ClH	36	94.2	18847
2	1.59	44	Acetaldehyde	C_2H_4O	44	87.8	18870
3	1.67	41	1-Propene, 2-methyl-	C_4H_8	56	23.5	61293
4	1.72	64	Ethyl Chloride	C_2H_5Cl	64	97.2	34545
5	1.87	42	Cyclopropane, ethyl-	C_5H_{10}	70	48.9	114410
6	1.91	43	Pentane	C_5H_{12}	72	86.0	114462
7	1.95	55	1-Butene, 3-methyl-	C_5H_{10}	70	14.2	114463
8	1.99	55	2-Pentene, (Z)-	C_5H_{10}	70	14.8	19080
9	2.01	55	1-Butene, 3-methyl-	C_5H_{10}	70	21.9	160477
10	2.18	57	Propane, 2-chloro-2-methyl-	C_4H_9Cl	92	65.2	228235
11	2.24	67	Cyclopentene	C_5H_8	68	31.2	19032
12	2.32	42	1-Pentene	C_5H_{10}	70	20.5	230821
13	2.43	57	Pentane, 3-methyl-	C_6H_{14}	86	33.1	19375
14	2.49	41	Cyclopropane, 1-ethyl-2-methyl-, cis-	C_6H_{12}	84	39.2	113658
15	2.56	57	Hexane	C_6H_{14}	86	80.6	61280
16	2.52	55	3-Hexene, (E)-	C_6H_{12}	84	21.4	114481
17	2.71	67	1,3-Butadiene, 2-ethyl-	C_6H_{10}	82	10.1	118159
18	2.77	41	2-Butene, 2,3-dimethyl-	C_6H_{12}	84	22.4	289588
19	2.89	56	Cyclopentane, methyl-	C_6H_{12}	84	59.7	114428
20	3.14	62	Ethane, 1,2-dichloro-	$C_2H_4Cl_2$	98	98.4	114952
21	3.26	78	Benzene	C_6H_6	78	62.0	291514
22	3.40	43	Hexane, 3-methyl-	C_7H_{16}	100	40.3	113081
23	3.52	45	5-[2-(Trimethylsilyl)cycloprop-	$C_{11}H_{16}Si$	176	15.3	139176

			1-ylidene]cyclopenta-1,3-diene				
24	3.60	41	1-Heptene	C_7H_{14}	98	28.0	107734
25	3.72	43	Heptane	C_7H_{16}	100	47.7	61276
26	3.77	41	(Z)-3-Heptene	C_7H_{14}	98	9.26	113674
27	4.00	41	1-Butene, 3-chloro-2-methyl-	C_5H_9Cl	104	56.4	1296
28	4.15	55	Cyclohexane, methyl-	C_7H_{14}	98	48.8	118503
29	4.29	41	Cyclopentane, ethyl-	C_7H_{14}	98	46.5	940
30	4.36	55	2-Butenal, 2-methyl-	C_5H_8O	84	34.4	509
31	4.42	55	Cyclobutane, 1,2-diethyl-, cis-	C_8H_{16}	112	7.90	60545
32	4.47	55	1-Heptene, 3-methyl-	C_8H_{16}	112	19.1	60730
33	4.54	55	3-Heptene, 3-methyl-	C_8H_{16}	112	10.3	113088
34	4.59	69	2-Heptene, 4-methyl-, (E)-	C_8H_{16}	112	28.2	113478
35	4.79	91	Toluene	C_7H_8	92	40.7	291301
36	4.85	43	Heptane, 3-methyl-	C_8H_{18}	114	40.6	34428
37	5.13	55	3-Heptene, 3-methyl-	C_8H_{16}	112	41.8	113088
38	5.28	55	4-Octene, (E)-	C_8H_{16}	112	23.6	227616
39	5.31	41	3-Octene, (E)-	C_8H_{16}	112	17.3	113893
40	5.39	55	2-Octene, (Z)-	C_8H_{16}	112	20.3	113889
41	5.45	70	2-Heptene, 3-methyl-	C_8H_{16}	112	32.5	149374
42	5.76	41	1,4-Octadiene	C_8H_{14}	110	8.31	231549
43	5.82	55	5-Bromo-1-hexene	$C_6H_{11}Br$	162	33.0	113158
44	5.85	43	Ethanol, 2-chloro-, acetate	$C_4H_7ClO_2$	122	93.1	228222
45	5.91	41	6-Hepten-1-ol, 3-methyl-	$C_8H_{16}O$	128	8.31	60715
46	5.97	83	Cyclohexane, ethyl-	C_8H_{16}	112	47.8	1624
47	6.15	95	2,4-Hexadiene, 2,5-dimethyl-	C_8H_{14}	110	17.6	114376
48	6.19	81	1,4-Heptadiene, 3-methyl-	C_8H_{14}	110	29.2	1484
49	6.25	41	2-Chloro-2-methylhexane	$C_7H_{15}Cl$	134	29.4	113227
50	6.32	67	1,4-Heptadiene, 3-methyl-	C_8H_{14}	110	30.7	1484
51	6.39	91	Ethylbenzene	C_8H_{10}	106	63.8	114918
52	6.54	91	1,5-Decadiyne	$C_{10}H_{14}$	134	15.6	114825
53	6.57	91	p-Xylene	C_8H_{10}	106	49.5	113952
54	6.80	43	2-Heptanone	$C_7H_{14}O$	114	46.3	1767
55	6.85	41	1-Nonene	C_9H_{18}	126	8.88	107756
56	6.95	91	p-Xylene	C_8H_{10}	106	38.8	113952
57	7.00	43	2-Propanol, 1,3-dichloro-	$C_3H_6Cl_2O$	128	85.4	291412
58	7.20	63	Ethane, 1,2-bis(2-chloroethoxy)-	$C_6H_{12}Cl_2O_2$	186	65.2	8002
59	7.57	55	4-Chloro-2,4-dimethylhexane	$C_8H_{17}Cl$	148	42.6	114695
60	7.63	62	1-Propanol, 2,3-dichloro-	$C_3H_6Cl_2O$	128	97.5	20710
61	7.70	73	3-Heptanol, 3-methyl-	$C_8H_{18}O$	130	68.1	27545
62	7.86	117	Tetracyclo[3.3.1.0(2,8).0(4,6)]-non-2-ene	C_9H_{10}	118	13.7	191137
63	7.95	57	Hexanal, 2-ethyl-	$C_8H_{16}O$	128	58.7	291286

64	8.30	83	Heptane, 3-chloro-3-methyl-	$C_8H_{17}Cl$	148	72.8	114670
65	8.47	105	Benzene, 1-ethyl-3-methyl-	C_9H_{12}	120	26.5	228743
66	8.71	41	Octane, 2-chloro-	$C_8H_{17}Cl$	148	26.0	114638
67	9.00	57	Heptane, 3-(chloromethyl)-	$C_8H_{17}Cl$	148	70.2	35077
68	9.20	57	1-Hexanol, 2-ethyl-	$C_8H_{18}O$	130	66.6	288735
69	9.31	57	Heptane, 3-[(ethenyloxy)methyl]-	$C_{10}H_{20}O$	156	62.2	232389
70	9.46	117	1,3-Methanopentalene, 1,2,3,5-tetrahydro-	C_9H_{10}	118	19.6	221371
71	9.54	91	1,3-Heptadiene, 3-ethyl-2-methyl-	$C_{10}H_{18}$	138	17.4	60995
72	9.62	115	Indene	C_9H_8	116	24.4	228349
73	9.74	91	Benzene, 1,4-diethyl-	$C_{10}H_{14}$	134	7.26	113892
74	9.79	105	Benzene, 1,4-diethyl-	$C_{10}H_{14}$	134	22.0	113892
75	9.91	105	Benzene, 1-ethyl-4-methyl-	C_9H_{12}	120	11.5	114034
76	9.98	57	1-Hexanol, 2-ethyl-	$C_8H_{18}O$	130	32.7	114109
77	10.11	119	1,3,5-Cycloheptatriene, 3,7,7-trimethyl-	$C_{10}H_{14}$	134	11.5	151806
78	10.28	117	Benzene, 4-ethenyl-1,2-dimethyl-	$C_{10}H_{12}$	132	14.7	2980
79	10.35	57	Undecane	$C_{11}H_{24}$	156	8.80	114185
80	10.42	41	3-Undecene, (Z)-	$C_{11}H_{22}$	154	5.00	142598
81	11.00	105	Benzoyl bromide	C_7H_5BrO	184	7.39	226735
82	11.04	43	Acetic acid, 2-ethylhexyl ester	$C_{10}H_{20}O_2$	172	62.5	6786
83	11.40	105	Cyclohexanone, 4-(benzoyloxy)-, oxime	$C_{13}H_{15}NO_3$	233	8.47	47623
84	11.54	105	Benzoic acid, ethyl ester	$C_9H_{10}O_2$	150	45.6	107716
85	11.60	105	Benzenecarboxylic acid	$C_7H_6O_2$	122	34.7	290514
86	11.89	43	trans-Z-α-Bisabolene epoxide	$C_{15}H_{24}O$	220	13.1	131711
87	11.98	128	Naphthalene	$C_{10}H_8$	128	40.4	114935
88	12.16	73	Octane, 1-(1-ethoxyethoxy)-	$C_{12}H_{26}O_2$	202	22.1	9092
89	12.42	43	5-Bromopentanoic acid, 2-octyl ester	$C_{13}H_{25}BrO_2$	292	11.3	293355
90	12.50	43	2,2,3,4-Tetramethylhex-5-en-3-ol	$C_{10}H_{20}O$	156	11.5	191069
91	13.09	91	Benzoic acid, 4-methyl-	$C_8H_8O_2$	136	45.9	21058
92	13.71	104	1,2-Benzenedicarboxylic acid	$C_8H_6O_4$	166	49.0	290999
93	13.81	142	Benzocycloheptatriene	$C_{11}H_{10}$	142	22.6	104256
94	14.34	105	4-Ethylbenzoic acid	$C_9H_{10}O_2$	150	70.3	160286
95	14.41	55	4-(2,2-Dimethyl-6-methylenecyclohexyl)butanal	$C_{13}H_{22}O$	194	12.5	196171
96	14.51	83	2(3H)-Benzofuranone, hexahydro-4,4,7a-trimethyl-	$C_{11}H_{18}O_2$	182	3.11	186836

97	14.62	83	Cyclohexanone, 2,2-dimethyl-5-(3-methyloxiranyl)-, 2α(R*),3α]-(.+-.)-	$C_{11}H_{18}O_2$	182	13.5	187190
98	14.92	105	2-Chloroethyl benzoate	$C_9H_9ClO_2$	184	34.6	231949
99	15.24	115	1-Ethyl-1-(undec-10-enyloxy)-1-silacyclohexane	$C_{18}H_{36}OSi$	296	14.0	279381
100	15.52	73	2-t-Butyl-5-propyl-[1,3]dioxolan-4-one	$C_{10}H_{18}O_3$	186	16.2	186630
101	16.01	57	Tetradecane	$C_{14}H_{30}$	198	15.4	113925
102	16.73	41	2(3H)-Benzofuranone, hexahydro-4,4,7a-trimethyl-	$C_{11}H_{18}O_2$	182	5.42	7611
103	17.31	70	Heptanoic acid, 4-octyl ester	$C_{15}H_{30}O_2$	242	42.2	160117
104	17.34	166	Fluorene	$C_{13}H_{10}$	166	59.8	228672
105	17.59	105	2-Octyl benzoate	$C_{15}H_{22}O_2$	234	34.9	190250
106	17.69	149	1,4-Benzenedicarboxylic acid	$C_8H_6O_4$	166	28.9	62113
107	17.92	177	1,4-Benzenedicarboxylic acid, diethyl ester	$C_{12}H_{14}O_4$	222	72.4	232614
108	18.13	57	Octane, 1,1'-[ethylidenebis(oxy)]bis-	$C_{18}H_{38}O_2$	286	68.1	279769
109	18.43	57	Octanoic acid, 2-ethylhexyl ester	$C_{16}H_{32}O_2$	256	82.8	279521
110	18.61	105	Benzoic acid, 2-ethylhexyl ester	$C_{15}H_{22}O_2$	234	87.8	236353
111	19.52	57	Nonanoic acid, 3-methylbutyl ester	$C_{14}H_{28}O_2$	228	8.03	132174
112	19.76	178	9H-Fluorene, 9-methylene-	$C_{14}H_{10}$	178	38.0	55617
113	19.90	126	Tetradecane, 2,6,10-trimethyl-	$C_{17}H_{36}$	240	6.51	11556
114	19.94	119	p-Toluic acid, 2-ethylhexyl ester	$C_{16}H_{24}O_2$	248	56.4	293452
115	20.29	57	9-Octadecanone	$C_{18}H_{36}O$	268	51.0	113053
116	20.55	57	Decanoic acid, 2-ethylhexyl ester	$C_{18}H_{36}O_2$	284	34.3	162293
117	20.95	133	4-Ethylbenzoic acid, 2-ethylhexyl ester	$C_{17}H_{26}O_2$	262	79.9	293499
118	21.12	43	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	256	55.0	251929
119	22.50	57	Dodecanoic acid, isooctyl ester	$C_{20}H_{40}O_2$	312	39.2	159938
120	22.76	149	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	$C_{16}H_{22}O_4$	278	67.9	75949
121	23.50	70	Phthalic acid, ethyl octadecyl ester	$C_{28}H_{46}O_4$	446	19.8	309109
122	25.73	70	Phthalic acid, 2-chloroethyl octyl ester	$C_{18}H_{25}ClO_4$	340	25.0	315773
123	26.01	57	dl-2-Ethylhexyl chloroformate	$C_9H_{17}ClO_2$	192	17.4	127697

124	26.37	149	1,2-Benzenedicarboxylic acid, diisooctyl ester	$C_{24}H_{38}O_4$	390	29.3	62126
125	27.46	57	1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	$C_{24}H_{38}O_4$	390	28.1	132344
126	28.00	70	1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	$C_{24}H_{38}O_4$	390	82.6	132344
127	29.04	57	Octadecanoic acid, 9-oxo-, methyl ester	$C_{19}H_{36}O_3$	312	6.23	14761

Catalytic degradation of PVC and PET mixture to fuel product was analyzed by Perkin Elmer GC/MS (Figure 2 and Table 1). GC/MS analysis results showed product fuel has hydrocarbon mixture with halogenated compounds, alcoholic compounds, oxygen content compounds, nitrogen content compounds, aromatics group and some ester group. In produced fuel all compounds were detected based on retention time (min.) and trace mass (m/z). Produced fuel has chlorine content and the fuel is acidic. GC/MS also detected starting compound HCl because PVC has chlorine content. This produced fuel can be used only in refinery process for further modification and can make appropriate for internal combustion engines. Due to chlorine present in produced fuel before it is put into internal combustion, chlorine has to be removed from produced fuel. But using this technology we can convert all PET and PVC to liquid petrochemicals product. In this analysis result discussion some compounds are elaborated based on retention time and trace mass such as 2-methyl-1-Propene (C_4H_8) (t=1.67, m/z=47) with 23.5 % probability, Pentane (C_5H_{12}) (t=1.91, m/z=43) with 86.0 % probability, 2-chloro-2-methyl- Propane (C_4H_9Cl) (t=2.18, m/z=57) with 65.2 % probability, cis-1-ethyl-2-methyl-Cyclopropane (C_6H_{12}) (t=2.49, m/z=41) with 39.2 % probability, methyl-Cyclopentane (C_6H_{12}) (t=2.89, m/z=56) with 59.7 % probability, Heptane (C_7H_{16}) (t=3.72, m/z=43) with 47.7 % probability, ethyl-Cyclopentane (C_7H_{14}) (t=4.29, m/z=41) with 46.5 % probability, Toluene (C_7H_8) (t=4.79, m/z=91) with 40.7 % probability, (E)-4-Octene (C_8H_{16}) (t=5.28, m/z=55) with 23.6 % probability, 5-Bromo-1-hexene ($C_6H_{11}Br$) (t=5.82, m/z=55) with 33.0% probability, 3-methyl-1,4-Heptadiene (C_8H_{14}) (t=6.19, m/z=81) with 29.2% probability, p-Xylene (C_8H_{10}) (t=6.57, m/z=91) with 49.5% probability, 1-Nonene (C_9H_{18}) (t=6.85, m/z=41) with 8.88 % probability, 2-ethyl-Hexanal ($C_8H_{16}O$) (t=7.95, m/z=57) with 58.7%, probability, 3-[(ethenyloxy) methyl]-Heptane ($C_{10}H_{20}O$) (t=9.31, m/z=57) with 62.2 % probability, Undecane ($C_{11}H_{24}$) (t=10.35, m/z=57) with 8.80% probability, oxime 4-(benzoyloxy)-Cyclohexanone ($C_{13}H_{15}NO_3$) (t=11.40, m/z=105) with 8.47% probability, Naphthalene ($C_{10}H_8$) (t=11.98, m/z=128) with 40.4 % probability, 2,2,3,4-Tetramethylhex-5-en-3-ol ($C_{10}H_{20}O$) (t=12.50, m/z=43) with 11.5 % probability, 4-(2,2-Dimethyl-6-methylenecyclohexyl) butanal ($C_{13}H_{22}O$) (t=14.41, m/z=55) with 12.5 % probability, 2-Chloroethyl benzoate ($C_9H_9ClO_2$) (t=14.92, m/z=105) with 34.6 % probability, Tetradecane ($C_{14}H_{30}$) (t=16.01, m/z=57) with 15.4 % probability, Fluorene ($C_{13}H_{10}$) (t=17.34, m/z=166) with 59.8% probability, 2-ethylhexyl ester Octanoic acid ($C_{16}H_{32}O_2$) (t=18.43, m/z=57) with 82.8 % probability, 9-methylene-9H-Fluorene ($C_{14}H_{10}$) (t=19.76, m/z=178) with 38.0 % probability, 9-Octadecanone ($C_{18}H_{36}O$) (t=20.29, m/z=57) with 51.0 % probability, isooctyl ester Dodecanoic acid ($C_{20}H_{40}O_2$) (t=22.50, m/z=57) with 39.2 % probability, ethyl octadecyl ester Phthalic acid ($C_{28}H_{46}O_4$) (t=23.50, m/z=70) with 19.8 % probability, and diisooctyl ester 1,2-Benzenedicarboxylic acid ($C_{24}H_{38}O_4$) (t=26.37, m/z=149) with 29.3 % probability respectively.

Conclusion

Polyethylene Terephthalate and polyvinyl chloride mixture to fuel recovery percentage less than residue because PVC has 56% chlorine and PET has 33% Oxygen. Temperature range from 120- 420 ºC and Pyrex glass reactor was used. Aluminum oxide and activated carbon was used to remove chlorine content and fuel additives or color. Chlorine and aluminum can react and produce aluminum chloride salt. In this experiment there were some complexity because all vapor was not condensed and some vapor form as wax and tried to block the condensation pipe. Wax part was solid types and soft. Fuel odor was chlorinated and fuel is ignited. In GC/MS analysis result shows compounds structure and carbon range C_2 to C_{28} and product fuel has also some ester group compounds. In data table 1, product fuel has a lot of aromatic groups such as Benzene (C_6H_6), Toluene (C_7H_8), Ethylbenzene (C_8H_{10}), p-Xylene (C_8H_{10}), 1-ethyl-3-methyl-Benzene (C_9H_{12}), Indene (C9H8), 1,4-diethyl-Benzene ($C_{10}H_{14}$), 1-ethyl-4-methyl-Benzene (C_9H_{12}) etc. Due to aromatic group present, fuel efficiency can increase. Fuel can use refinery process because it has chlorine content and can be used for internal combustion of engine after further modification. Present technology can convert all PVC and PET waste plastic into fuel and save the world wide waste plastics problem.

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