

Research article

Production of Valuable Hydrocarbons by Catalytic Degradation of a Mixture of Polyvinyl Chloride and Polystyrene Waste

Moinuddin Sarker*, Mohammad Mamunor Rashid

Natural State Research, Inc., Department of Research and Development, 37 Brown House Road (2nd Fl), Stamford, CT 06902, USA, Phone: 203-406-0675, Fax: 203-406-9852,

*E-mail: msarker@naturalstateresearch.com; mamun_sarker2002@yahoo.com

Abstract

Plastics using demand all over the world due to plastics lightweight and durability its practice is very efficient in all sectors of the world. Plastics have many advantages and disadvantages. However, once plastics are discarded after use, they end up in land and ocean creating many sorts of environmental and health related problems because the waste plastics do not bio-degrade and its can remain long period into the environment. Thermal and catalytic degradation process applied with PVC and PS waste plastics mixture using ZnO catalyst at temperature range 200-430 °C. ZnO was use 5% and initial feed was use PS 50 gm and PVC 25 gm for this experiment. Product fuel density is 0.86 g/ml and liquid conversion rate is 50.08%. Product was analysis by using GC/MS and obtain carbon chain detected C₃ –C₃₂. **Copyright © IJEATR, all rights reserved.**

Keywords: polystyrene, polyvinyl chloride, hydrocarbon, waste plastics, catalytic, GC/MS

1. Introduction

The substantial increase on energy demand and consumptions of natural resources and goods, caused by continuous growth of world population, has led to enormous amounts of wastes. These wastes need to be treated adequately to prevent environmental problems and make possible a sustained development of modern society. On the other hand,

with the decrease on the availability of energy resources, there is a renewed interest on innovative ways to convert the existing reserves with improved technologies that may lead to a lower impact on environment. Both these two targets may be reached with the application of gasification technology to co-process coal mixed with wastes, like biomass, plastics or municipal solid wastes. Wastes are generally more difficult to process, because they are heterogeneous which gives rise to fluctuations in quality, availability and composition [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 composition, structural deterioration of the polymeric components and the contamination with various organic, inorganic or biological residues [3].

Plastic waste can be regarded as a potentially cheap source of chemicals and energy. The destruction of waste plastics by incineration is prevalent, but is expensive and often generates problems with unacceptable emissions. It is also undesirable to dispose of waste plastics by landfill due to high costs and poor biodegradability [4]. An alternative strategy is that of chemical recycling, known as feedstock recycling or tertiary recycling, which has attracted much interest recently with the aim of converting waste plastics into basic petrochemicals to be used as chemical feedstock or fuels for a variety of downstream processes. Two main chemical recycling routes are the thermal and catalytic degradation of waste plastics [5]. Thermal cracking or pyrolysis is a well-known technique and is often used in petrochemical processing. The pyrolysis of waste plastics is the thermal decomposition in the absence of oxygen and is carried out in vessels, shaft kilns, autoclaves, rotary kilns, screw conveyors or fluidized beds [6–8]. However, the thermal degradation of plastics to low molecular weight materials has a major drawback in that a very broad product range is obtained. In addition, these processes require high temperatures typically more than 500 °C and even up to 900 °C [9]. There have been many reports on the pyrolysis of PVC alone [10–13] or mixed with other polymers [14, 15]. Inorganic and organic compounds are formed during the initial stages of the process [16, 17] but the amount of chlorine in pyrolysis oil can be decreased by catalytic procedures [18].

2. Materials

For experimental purpose raw waste materials was collected from local plastics recycling facility. A collected waste plastic was cut into small pieces fit for reactor chamber. PVC waste plastic was fence and white color, polystyrene waste plastics was food container and black color. Zinc Oxide (ZnO), NaHCO₃ and AgNO₃ was collected from VWR.COM Company. Zinc Oxide was use for catalyst with mixture of polystyrene (PS) and polyvinyl chloride (PVC) waste plastics. Sodium Bicarbonate and Silver nitrate was used for light gas cleaning purpose.

3. Process Description

Polystyrene waste plastics and polyvinyl chloride waste plastics mixture to fuel production process shown in to figure 1. For experimental setup was need reactor with temperature controller, condensation unit, fuel collection tank, fuel purification unit, fuel sediment collection tank, final fuel collection tank, 0.5 (N) sodium bicarbonate solution, 0.25 (N) AgNO₃ solution, water container, small pump, residue collection container and Teflon bag. In process structure shown PVC and PS mixture placed into reactor inside with zinc oxide catalyst. Pyrex glass reactor was use for the experiment and temperature range was 200 - 430 °C. PVC and PS waste plastics to fuel recovery purpose Zinc Oxide catalyst was use 5% (3.75 gm). An initial raw material was PS 50 gm and PVC was 25 gm by weight. Starting temperature was use 200 °C because PS melting point temperature up 200 °C. If start temperature less than 200 °C its take time longer to finish experiment for that reason starting temperature was 200 °C.

Experiment was monitor continuously because reactor chamber inside gas generation has to be controlled because if reactor inside gas generation higher then vapor is not condense properly. Temperature was increased slowly because experimental main goal was good quality fuel collection. In this experiment main goal was waste PVC and PS to fuel recovery by using ZnO catalyst because PVC waste plastic has chlorine content and percentage is 56% by weight. PVC waste plastic chlorine content and ZnO can react and produce zinc chloride salt and chlorine content can remove from hydrocarbon fuel. NaHCO₃ and AgNO₃ solution was use for chlorinated gas cleaning purpose, because some light gas cannot be condense due to negative boiling point temperature. Produce light gas passed through liquid sodium bicarbonate solution and liquid silver nitrate solution then light gas can clean from chlorine content. Finally light gas was passed through clean water for remove other contamination. This process was fully batch process and light gas was collected by Teflon bag for analysis purpose. Product fuel was filtered by purification system and filtered fuel was collected another collection container for analysis purpose. Fuel sediment was collected another container and this sediment can be reuse for another batch process waste plastic to fuel production purpose. PVC and PS waste plastic to fuel production process can be generated hydrochloric acid because chlorine content and hydrocarbon hydrogen can produce HCl acid and fuel acidic limit can decrease because of ZnO catalyst. By using sodium bicarbonate and silver nitrate solution can remove chlorine content from light gas and chlorinated gas cannot come into environment. Product fuel density is 0.86 gm/ml and conversion rate including liquid fuel and light gas was 58.94%. In percentage calculation liquid fuel is 50.8%, light gas is 8.14% and left over residue is 41.06%. In mass balance calculation from 75 gm waste materials (PVC and PS) to liquid fuel is 38.1 gm; light gas generated 6.1 gm and left over residue 30.8 gm. In this experiment residue percentage are shown little high because of PVC and PS both raw materials has high percentage of additives. PVC has more than 50% chlorine that chlorine cannot convert as liquid fuel. Total experiment finished was 3.35 hours and input electricity was required 0.433KWh. Product fuel is ignited and color is light yellow. Light gas and solid black residue analysis under consideration.

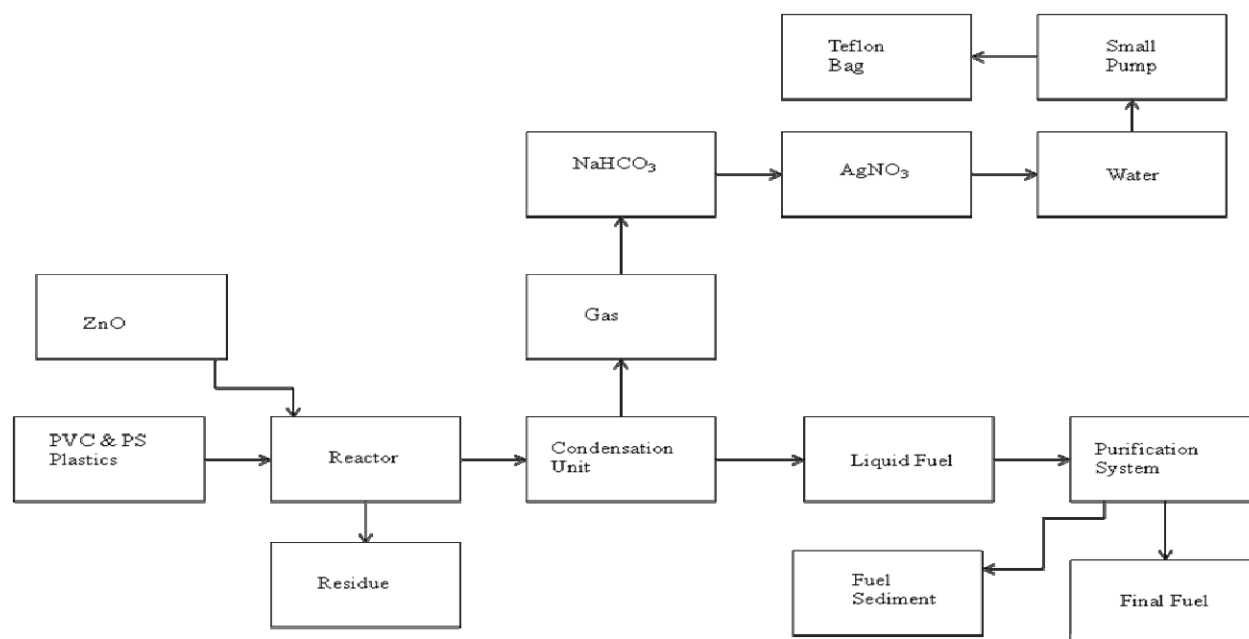


Figure 1: Polyvinyl chloride and polystyrene mixture to fuel production process using Zinc Oxide

4. Result and Discussion

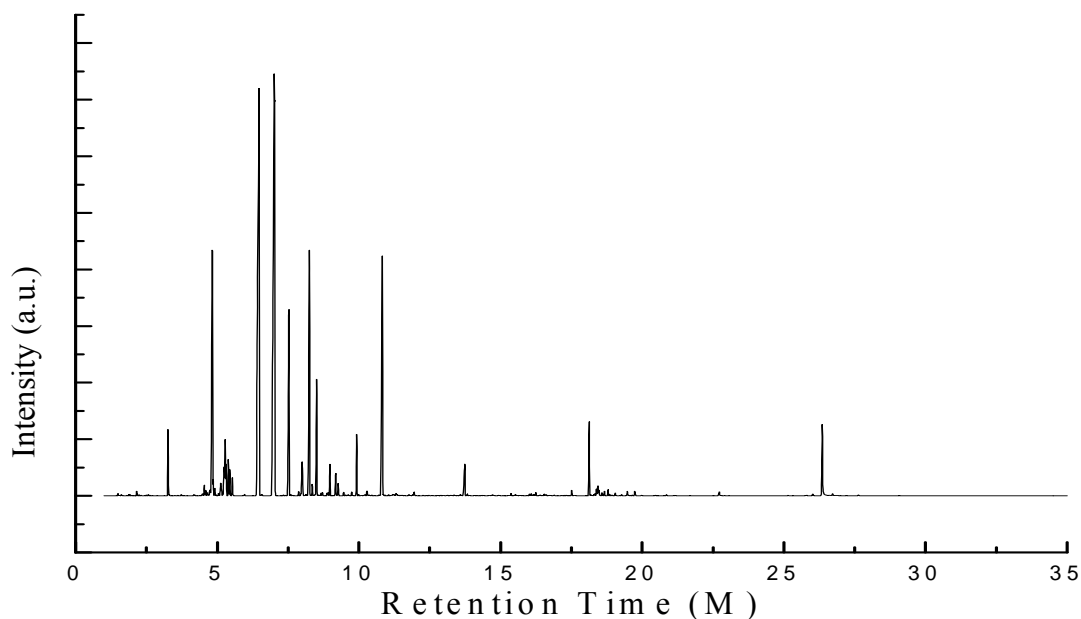


Figure 2: GC/MS chromatogram of polyvinyl chloride and polystyrene mixture to fuel

Table 1: GC/MS chromatogram compounds list of polyvinyl chloride and polystyrene 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	Cyclopropene	C ₃ H ₄	40	35.2	194058
2	1.56	43	Acetic acid, hydrazide	C ₂ H ₆ N ₂ O	74	59.8	52318
3	1.61	43	Butane	C ₄ H ₁₀	58	57.0	18940
4	1.63	41	1-Propene, 2-methyl-	C ₄ H ₈	56	27.6	61293
5	1.81	43	Butane, 2-methyl-	C ₅ H ₁₂	72	67.4	19107
6	1.87	42	Cyclopropane, ethyl-	C ₅ H ₁₀	70	40.0	114410
7	1.91	43	Pentane	C ₅ H ₁₂	72	64.3	114462
8	1.95	55	Cyclopropane, 1,1-dimethyl-	C ₅ H ₁₀	70	19.6	34618
9	1.99	55	Cyclopropane, ethyl-	C ₅ H ₁₀	70	17.7	114410
10	2.05	40	Cyclobutane, methylene-	C ₅ H ₈	68	37.2	214
11	2.18	57	Propane, 2-chloro-2-methyl-	C ₄ H ₉ Cl	92	84.8	107667
12	2.24	67	Cyclopentene	C ₅ H ₈	68	28.5	19032
13	2.32	42	Pentane, 2-methyl-	C ₆ H ₁₄	86	27.9	61279

14	2.43	57	Heptane, 2,2-dimethyl-	C ₉ H ₂₀	128	18.5	114054
15	2.49	41	Cyclopropane, 1-ethyl-2-methyl-, cis-	C ₆ H ₁₂	84	33.5	113658
16	2.57	57	Hexane	C ₆ H ₁₄	86	82.5	19379
17	2.62	55	3-Hexene, (E)-	C ₆ H ₁₂	84	22.5	114481
18	2.72	55	Cyclopropane, 1-ethyl-2-methyl-, cis-	C ₆ H ₁₂	84	30.6	113658
19	2.89	56	Cyclopentane, methyl-	C ₆ H ₁₂	84	38.0	114428
20	3.26	78	Benzene	C ₆ H ₆	78	68.7	114388
21	3.40	43	Hexane, 3-methyl-	C ₇ H ₁₆	100	68.9	113081
22	3.51	67	Ethylidenecyclobutane	C ₆ H ₁₀	82	7.35	215135
23	3.60	41	1-Heptene	C ₇ H ₁₄	98	25.2	19704
24	3.72	43	Heptane	C ₇ H ₁₆	100	39.1	61276
25	3.77	41	(Z)-4-Methyl-2-hexene	C ₇ H ₁₄	98	22.4	113641
26	3.82	55	(Z)-3-Heptene	C ₇ H ₁₄	98	40.2	113674
27	3.88	41	3-Hexene, 2,5-dimethyl-, (E)-	C ₈ H ₁₆	112	20.6	114264
28	3.94	41	2-Heptene, (E)-	C ₇ H ₁₄	98	17.5	932
29	4.00	41	3-Methyl-3-chloro-1-butene	C ₅ H ₉ Cl	104	15.4	113113
30	4.09	67	Cyclopentene, 3-ethyl-	C ₇ H ₁₂	96	19.7	139431
31	4.17	43	Hexane, 2,5-dimethyl-	C ₈ H ₁₈	114	71.5	113944
32	4.21	43	Hexane, 2,4-dimethyl-	C ₈ H ₁₈	114	26.9	61782
33	4.29	69	Cyclopentane, ethyl-	C ₇ H ₁₄	98	36.4	940
34	4.38	55	2-Hexene, 2,3-dimethyl-	C ₈ H ₁₆	112	18.5	149376
35	4.42	41	2-Hexene, 3,5-dimethyl-	C ₈ H ₁₆	112	5.48	149385
36	4.47	55	1-Hexene, 3,5-dimethyl-	C ₈ H ₁₆	112	9.23	113470
37	4.59	69	2-Heptene, 4-methyl-, (E)-	C ₈ H ₁₆	112	18.4	113478
38	4.82	91	Toluene	C ₇ H ₈	92	65.5	291301
39	4.91	56	2-Heptene, 5-methyl-	C ₈ H ₁₆	112	57.2	113480
40	5.04	55	3-Heptene, 4-methyl-	C ₈ H ₁₆	112	29.3	149383
41	5.12	55	3-Heptene, 3-methyl-	C ₈ H ₁₆	112	37.7	113088
42	5.28	55	4-Octene, (E)-	C ₈ H ₁₆	112	19.6	227616
43	5.31	55	3-Octene, (Z)-	C ₈ H ₁₆	112	14.4	113895
44	5.39	55	2-Octene, (E)-	C ₈ H ₁₆	112	23.7	107269
45	5.44	70	2-Heptene, 3-methyl-	C ₈ H ₁₆	112	33.3	149374
46	5.53	55	2-Octene, (Z)-	C ₈ H ₁₆	112	25.9	113889
47	5.91	81	4-Methyl-1,4-heptadiene	C ₈ H ₁₄	110	17.0	113473
48	5.96	54	1,5-Cyclooctadiene, (E,Z)-	C ₈ H ₁₂	108	35.0	1407
49	6.26	81	1-Undecyne	C ₁₁ H ₂₀	152	16.6	113280
50	6.47	106	Ethylbenzene	C ₈ H ₁₀	106	52.5	158804
51	7.02	103	Styrene	C ₈ H ₈	104	34.4	291542
52	7.53	105	Benzene, (1-methylethyl)-	C ₉ H ₁₂	120	34.5	228742
53	7.99	69	Hexane, 2-chloro-2,5-dimethyl-	C ₈ H ₁₇ Cl	148	44.4	114683

54	8.25	55	Heptane, 3-chloro-3-methyl-	C ₈ H ₁₇ Cl	148	73.4	114670
55	8.35	55	3-Chloro-3-ethylhexane	C ₈ H ₁₇ Cl	148	87.8	113216
56	8.51	118	α -Methylstyrene	C ₉ H ₁₀	118	34.5	2021
57	8.67	117	Benzene, 2-propenyl-	C ₉ H ₁₀	118	12.9	114744
58	8.71	41	Octane, 2-chloro-	C ₈ H ₁₇ Cl	148	40.3	4499
59	8.88	41	Octane, 3-chloro-	C ₈ H ₁₇ Cl	148	28.6	114636
60	8.91	41	Octane, 2-chloro-	C ₈ H ₁₇ Cl	148	36.9	114638
61	8.97	57	Heptane, 3-(chloromethyl)-	C ₈ H ₁₇ Cl	148	67.4	35077
62	9.18	57	1-Hexanol, 2-ethyl-	C ₈ H ₁₈ O	130	69.5	114109
63	9.27	117	Benzene, 2-propenyl-	C ₉ H ₁₀	118	20.6	114744
64	9.46	117	Indane	C ₉ H ₁₀	118	13.5	118485
65	9.53	91	Benzene, 3-butenyl-	C ₁₀ H ₁₂	132	78.7	113933
66	9.75	91	Benzene, butyl-	C ₁₀ H ₁₄	134	60.6	228741
67	9.92	105	Benzene, (1-chloroethyl)-	C ₈ H ₉ Cl	140	42.0	3716
68	10.29	117	Indan, 1-methyl-	C ₁₀ H ₁₂	132	18.5	150963
69	10.36	57	Undecane	C ₁₁ H ₂₄	156	22.4	249213
70	10.46	105	Benzene, (1-methylbutyl)-	C ₁₁ H ₁₆	148	32.9	34703
71	10.56	131	Benzene, 1-methyl-4-(1-methyl-2-propenyl)-	C ₁₁ H ₁₄	146	12.0	155401
72	10.83	119	Benzene, (1-azido-1-methylethyl)-	C ₉ H ₁₁ N ₃	161	50.2	31549
73	11.05	43	Acetic acid, 2-ethylhexyl ester	C ₁₀ H ₂₀ O ₂	172	62.5	6786
74	11.20	131	Bicyclo[4.2.0]octa-1,3,5-triene, 7-isopropyl-	C ₁₁ H ₁₄	146	11.0	161767
75	11.32	115	Benzene, (1-methylene-2-propenyl)-	C ₁₀ H ₁₀	130	10.7	54280
76	11.54	104	Naphthalene, 1,2,3,4-tetrahydro-	C ₁₀ H ₁₂	132	70.3	113929
77	11.61	119	Benzene, (cyclopropylidenemethyl)-	C ₁₀ H ₁₀	130	19.8	37790
78	11.76	129	(1-Methylenebut-2-enyl)benzene	C ₁₁ H ₁₂	144	18.3	210059
79	11.90	57	1H-Indene, 1-ethyl-2,3-dihydro-1-methyl-	C ₁₂ H ₁₆	160	12.6	34632
80	11.94	128	Naphthalene	C ₁₀ H ₈	128	34.2	114935
81	12.27	91	Benzene, 1-methyl-4-(2-propenyl)-	C ₁₀ H ₁₂	132	9.65	113549
82	12.47	117	Benzocycloheptene	C ₁₁ H ₁₄	146	25.4	281556
83	12.57	117	2-Ethyl-2,3-dihydro-1H-indene	C ₁₁ H ₁₄	146	39.1	214919
84	12.81	131	Naphthalene, 2-ethyl-1,2,3,4-tetrahydro-	C ₁₂ H ₁₆	160	13.7	151403
85	12.89	91	Benzene, hexyl-	C ₁₂ H ₁₈	162	66.8	113954
86	13.01	129	(1-Benzyl-cyclopropyl)-	C ₁₁ H ₁₄ O	162	11.7	193386

			methanol				
87	13.13	129	Naphthalene, 1,2-dihydro-4-methyl-	C ₁₁ H ₁₂	144	32.8	214935
88	13.25	41	7-Tetradecene	C ₁₄ H ₂₈	196	4.61	70643
89	13.36	57	Tridecane	C ₁₃ H ₂₈	184	10.2	114282
90	13.58	142	1H-Indene, 1-ethylidene-	C ₁₁ H ₁₀	142	36.0	55614
91	13.73	104	Phthalic anhydride	C ₈ H ₄ O ₃	148	47.7	133911
92	14.10	129	Pentacyclo[6.4.0.0(2,10).0(3,6).0(9,11)]dodec-6(7)-ene	C ₁₂ H ₁₄	158	15.6	223175
93	13.35	91	Benzene, heptyl-	C ₁₃ H ₂₀	176	51.5	118464
94	14.40	105	1,8-Cyclotetradecadiyne	C ₁₄ H ₂₀	188	4.37	155380
95	14.57	131	1H-Indene, 1-ethyl-2,3-dihydro-1-methyl-	C ₁₂ H ₁₆	160	29.8	34632
96	14.62	41	1-Octene, 3,7-dimethyl-	C ₁₀ H ₂₀	140	4.91	3653
97	14.72	154	Benzene, (2,4-cyclopentadien-1-ylidenemethyl)-	C ₁₂ H ₁₀	154	34.2	5015
98	14.78	105	(1,4-Dimethylpent-2-enyl)benzene	C ₁₃ H ₁₈	174	8.61	184979
99	14.94	141	Naphthalene, 2-ethyl-	C ₁₂ H ₁₂	156	27.4	151404
100	15.37	167	Diphenylmethane	C ₁₃ H ₁₂	168	63.3	21969
101	15.48	59	1-Decanol, 5,9-dimethyl-	C ₁₂ H ₂₆ O	186	5.37	70658
102	15.52	73	3-Hexanol, 3,5-dimethyl-	C ₈ H ₁₈ O	130	28.5	237007
103	15.68	159	4-Methyl-4-phenyl-2,3:5,6-diepoxyhexanone	C ₁₃ H ₁₂ O ₃	216	11.0	103239
104	16.02	57	Tetradecane	C ₁₄ H ₃₀	198	13.7	113925
105	16.08	167	Benzene, 1,1'-ethylidenebis-	C ₁₄ H ₁₄	182	53.0	22224
106	16.13	70	Hexanoic acid, 2-ethylhexyl ester	C ₁₄ H ₂₈ O ₂	228	48.1	279277
107	16.25	159	Naphthalene, 1,2,3,4-tetrahydro-1,6-dimethyl-4-(1-methylethyl)-, (1S-cis)-	C ₁₅ H ₂₂	202	20.0	63794
108	16.40	187	Cycloisolongifolene, 9,10-dehydro-	C ₁₅ H ₂₂	202	34.8	156816
109	16.54	91	Benzene, 1,1'-(1,2-ethanediyl)bis-	C ₁₄ H ₁₄	182	85.6	187213
110	16.61	145	Neoisolongifolene, 8,9-dehydro-	C ₁₅ H ₂₂	202	16.9	151635
111	16.64	105	Hexane, 2-phenyl-3-propyl-	C ₁₅ H ₂₄	204	14.8	161015
112	16.79	159	Benzene, 1-(1-formylethyl)-4-(1-buten-3-yl)-	C ₁₃ H ₁₆ O	188	24.8	161466
113	16.89	105	Benzene, 1,1'-(1-methyl-1,2-ethanediyl)bis-	C ₁₅ H ₁₆	196	41.3	151418
114	17.25	57	Eicosane	C ₂₀ H ₄₂	282	7.95	53470
115	17.31	43	Heptanoic acid, 4-octyl ester	C ₁₅ H ₃₀ O ₂	242	11.7	160117

116	11.51	119	Benzene, (1,1-dimethyldecyl)-	C ₁₈ H ₃₀	246	11.7	11893
117	17.63	91	Benzene, 1,1'-(3-methylbutylidene)bis-	C ₁₇ H ₂₀	224	13.2	10579
118	18.13	92	Benzene, 1,1'-(1,3-propanediyl)bis-	C ₁₅ H ₁₆	196	91.6	133399
119	18.39	193	1,1-di-o-Tolyethylene	C ₁₆ H ₁₆	208	32.2	135181
120	18.44	105	Benzene, 1,1'-(1-methyl-1,3-propanediyl)bis-	C ₁₆ H ₁₈	210	89.9	149665
121	18.58	207	1-Propene, 3-(2-cyclopentenyl)-2-methyl-1,1-diphenyl-	C ₂₁ H ₂₂	274	46.2	154233
122	19.05	194	1,2-Diphenylcyclopropane	C ₁₅ H ₁₄	194	35.0	135351
123	20.56	43	Oxalic acid, 2-ethylhexyl hexyl ester	C ₁₆ H ₃₀ O ₄	286	5.16	309389
124	20.77	91	Benzene, 1,1'-(3-methyl-1-propene-1,3-diyl)bis-	C ₁₆ H ₁₆	208	25.8	9505
125	20.86	119	3-Cyclohexen-1-amine, 2,5,6-triphenyl-, (1 α ,2 β ,5 β ,6 β)-	C ₂₄ H ₂₃ N	325	12.1	33786
126	21.11	43	n-Hexadecanoic acid	C ₁₆ H ₃₂ O ₂	256	50.1	251929
127	22.52	57	Nonane, 4-methyl-5-propyl-	C ₁₃ H ₂₈	184	11.7	61476
128	22.72	149	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	C ₁₆ H ₂₂ O ₄	278	62.6	75949
129	25.77	91	6-Phenyl-n-hexanol	C ₁₂ H ₁₈ O	178	8.59	136513
130	25.81	91	(2,3-Diphenylcyclopropyl)methyl phenyl sulfoxide, trans-	C ₂₂ H ₂₀ OS	332	24.2	142947
131	25.95	44	Didodecyl phthalate	C ₃₂ H ₅₄ O ₄	502	17.6	117553
132	26.02	57	Oxalic acid, bis(2-ethylhexyl) ester	C ₁₈ H ₃₄ O ₄	314	10.2	309390
133	26.36	149	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	C ₁₆ H ₂₂ O ₄	278	38.1	291384
134	27.21	44	Phthalic acid, octyl 2-phenylethyl ester	C ₂₄ H ₃₀ O ₄	382	20.5	309038

Polyvinyl chloride and polystyrene waste plastic mixture to recovery fuel was analysis using Perkin Elmer Gas Chromatography and Mass Spectrometer (GC/MS) and model number Clarus 500 (Figure 2 and table 1). Product fuel GC/MS chromatogram analysis result showed carbon chain start C₃ to C₃₂. Table 1 compounds was detected based on retention time and trace mass and starting compounds retention time 1.49 (m) and trace mass is 36 and compound name is Cyclopropene (C₃H₄). Fuel analysis data showed fuel has hydrocarbon compounds including halogenated compounds, nitrogen content compounds, oxygen content compounds, alcoholic, aromatics and ester group. Some compounds are elaborated based on retention time and trace mass such as Hydrazide Acetic acid (C₂H₆N₂O) (t=1.56, m/z=43), 2-methyl-Butane (C₅H₁₂) (t=1.81, m/z=43), 2-chloro-2-methyl- Propane (C₄H₉Cl)

($t=2.18$, $m/z=57$), cis-1-ethyl-2-methyl- Cyclopropane (C_6H_{12}) ($t=2.49$, $m/z=41$), Benzene (C_6H_6) ($t=3.26$, $m/z=78$), (Z)-4-Methyl-2-hexene (C_7H_{14}) ($t=3.77$, $m/z=41$), 3-Methyl-3-chloro-1-butene (C_5H_9Cl) ($t=4.00$, $m/z=41$), ethyl-Cyclopentane (C_7H_{14}) ($t=4.29$, $m/z=69$), Toluene (C_7H_8) ($t=4.82$, $m/z=91$), 3-methyl-2-Heptene (C_8H_{16}) ($t=5.44$, $m/z=70$), Ethylbenzene (C_8H_{10}) ($t=6.47$, $m/z=106$), 3-Chloro-3-ethylhexane ($C_8H_{17}Cl$) ($t=8.35$, $m/z=55$), 2-ethyl-1-Hexanol ($C_8H_{18}O$) ($t=9.18$, $m/z=57$), butyl- Benzene ($C_{10}H_{14}$) ($t=9.75$, $m/z=91$), Undecane ($C_{11}H_{24}$) ($t=10.36$, $m/z=57$), (1-azido-1-methylethyl)- Benzene ($C_9H_{11}N_3$) ($t=10.83$, $m/z=119$), 1,2,3,4-tetrahydro- Naphthalene ($C_{10}H_{12}$) ($t=11.54$, $m/z=104$), 1-methyl-4-(2-propenyl)- Benzene ($C_{10}H_{12}$) ($t=12.27$, $m/z=91$), Hexyl-Benzene ($C_{12}H_{18}$) ($t=12.89$, $m/z=91$), Tridecane ($C_{13}H_{28}$) ($t=13.36$, $m/z=57$), (2,4-cyclopentadien-1-ylidenemethyl)- Benzene ($C_{12}H_{10}$) ($t=14.72$, $m/z=154$), 3,5-dimethyl-3-Hexanol ($C_8H_{18}O$) ($t=15.52$, $m/z=73$), 1,1'-ethylidenebis- Benzene ($C_{14}H_{14}$) ($t=16.08$, $m/z=167$), bis-1,1'-(1,2-ethanediyl) Benzene ($C_{14}H_{14}$) ($t=16.54$, $m/z=91$), Eicosane ($C_{20}H_{42}$) ($t=17.25$, $m/z=57$), bis-1,1'-(3-methylbutylidene) Benzene ($C_{17}H_{20}$) ($t=17.63$, $m/z=91$), 3-(2-cyclopentenyl)-2-methyl-1,1-diphenyl-1-Propene ($C_{21}H_{22}$) ($t=18.58$, $m/z=207$), 2,5,6-triphenyl-(1 α ,2 β ,5 β ,6 β)-3-Cyclohexen-1-amine ($C_{24}H_{23}N$) ($t=20.86$, $m/z=119$), trans-(2,3-Diphenylcyclopropyl) methyl phenyl sulfoxide ($C_{22}H_{20}OS$) ($t=25.81$, $m/z=91$), Didodecylphthalate ($C_{32}H_{54}O_4$) ($t=25.95$, $m/z=44$), Octyl 2-phenylethyl ester Phthalic acid ($C_{24}H_{30}O_4$) ($C_{24}H_{30}O_4$). In this analysis result showed lots of aromatics groups and all compounds detected from product fuel because of initial raw materials were PVC and PS. PS and PVC raw materials has aromatic compounds when heated up both plastics mixture its breakdown and combined aromatics derivatives. Hydrocarbon related aromatics compounds were detected based on retention time and trace mass wise. Fuel analysis compounds has come chlorinated compounds and before use any internal combustion that have to remove further refinery process. Fuel can be use internal combustion engine and electricity generation.

5. Conclusion

Thermal and catalytic degradation was performed with mixture of PVC and PS and using ZnO as a catalyst and temperature range was 200 - 430 °C. Fuel was collected from PVC and PS mixture and fuel density was 0.86gm/ml. Fuel color light yellow and fuel was little thick. Analysis result indicates that product fuel has hydrocarbon and aromatic related compounds. Aromatics compounds are present into liquid fuel such as Benzene, Toluene, Ethylbenzene, Styrene, α -Methylstyrene, Indane, 3-butenyl-Benzene, 1,2,3,4-tetrahydro-Naphthalene, 1-methyl-4-(2-propenyl)-Benzene, 1,2-dihydro-4-methyl-Naphthalene, 2-ethyl-Naphthalene, (1,1-dimethyldecyl)-Benzene etc.. Product fuel has also ester group and peak intensity small. By using present technology can convert PVC and PS to liquid fuel and solve PS and PVC problem same time.

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References

- [1] Filomena Pinto, Carlos Franco, Rui Neto Andre, C. Tavares, M. Dias, I. Gulyurtlu, I. Cabrita, Effect of experimental conditions on co-gasification of coal, biomass and plastics wastes with air/steam mixtures in a fluidized bed system, Fuel 82 (2003) 1967–1976

- [2] Aguado J, Serrano D. In: Clark JH, editor. RSC clean technology monographs, on feedstock recycling of waste plastic. Cambridge: Royal Society of Chemistry; 1999.
- [3] Mihai Brebu, Thallada Bhaskar, Kazuya Murai, Akinori Muto, Yusaku Sakata, Md. Azhar Uddin, The effect of PVC and/or PET on thermal degradation of polymer mixtures containing brominated ABS, Fuel 83 (2004) 2021–2028
- [4] Scott G. Polymers and the environment. London: Royal Society of Chemistry; 1999.
- [5] Brandrup J, Bittner M, Michaeli W, Menges G. Recycling and recovery of plastics. Munich, New York: Carl Hanser Verlag; 1996.
- [6] Kaminsky W, Schlesselmann B, Simon C. Olefins from polyolefins and mixed plastics by pyrolysis. J Anal Appl Pyrolysis 1995; 32:19–27.
- [7] Sodero SF, Berruti F, Behie LA. Ultraprolytic cracking of polyethylene – a high yield recycling method. Chem Eng Sci 1996; 51:2805–10.
- [8] Mastellone ML, Perugini F, Ponte M, Arena U. Fluidized bed pyrolysis of a recycled polyethylene. Polym Degrad Stab 2002; 76(3):479.
- [9] Yeuh-Hui Lin, Production of valuable hydrocarbons by catalytic degradation of a mixture of post-consumer plastic waste in a fluidized-bed reactor, Polymer Degradation and Stability 94 (2009) 1924–1931
- [10] Marcilla A, Beltran M. Polym Degrad Stab 1995; 48:219.
- [11] Troitskii BB, Yakhnov AS, Novikova MA, Ganyukhina TG, Desinova VN. Eur Polym J 1997; 33(4):505.
- [12] Troitskii BB, Troitskaya LS. Eur Polym J 1999; 35:2215.
- [13] McNeill IC, Memetea L, Cole WJ. Polym Degrad Stab 1995; 49:181.
- [14] Vasile C, Brebu M, Sakata Y, Pakdel H, Roy C, Miranda R. J Environ Prot Ecol 2002;3(1):230.
- [15] Miranda R, Pakdel H, Roy C, Vasile C. Polym Degrad Stab 2001; 73: 47.
- [16] Shiraga Y, Uddin MA, Muto A, Narazaki M, Sakata Y, Murata K. Energy Fuels 1999;13(2):428.
- [17] Uddin MA, Sakata Y, Shiraga Y, Muto A, Murata K. Ind Eng Chem Res 1999;38(4):1406.
- [18] Lingaiah N, Uddin MA, Morikawa K, Muto A, Murata K, Sakata Y. Green Chem 2001;3:74.