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Characterisation of Waste plastic oil by Fourier Transform Infrared Spectroscopy and Gas Chromatography-Mass Spectrometry

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Abstract

Plastics is an essential part in today's world due to their lightweight, enduringness, faster rate of production and design flexibility. At the corresponding time, waste plastics have created very real environmental challenges due to their immense quantities and disposal problems. Pyrolysis process is an advisable method for converting waste plastics into waste plastic oil (WPO) because of their advantages such as high conversion output, independent feedstock, low pressure operation and least amount of waste produced. GC-MS of WPO contains longer hydrocarbon chains which depicts the burning quality of fuel. No formation of highly toxic poly aromatic hydrocarbon chains was found, such as carcinogens, mutagens and teratogens in the WPO. FTIR spectrum of WPO, the presence of alkenes and alkanes is detected at 3074.59 cm^{-1} & 2890.59 cm^{-1} with simple C-H stretching vibrations. The existence of ketones is noticed at 1713.78 cm^{-1} with C=O stretching vibrations. C=C stretching vibrations at 1652.06 cm^{-1} indicates the existence of alkenes. The components present in the waste plastic oil are mostly, the aliphatic hydrocarbons (alkanes and alkenes) with carbon number C_{10} - C_{25}.

Key words - waste plastics, waste plastics oil, FTIR, GC-MS and diesel engine.

1 INTRODUCTION

Expanding industrialization and modernization of the world has prompted a precarious ascent in the utilization and interest for the crude oil based fuels each and every year.**[1]**. Substitute fuels give an immense supporting channel to draining regular non-renewable energy source assets. Expedient industrialization and population impact has prompted migration of individuals from towns to urban communities, which produces a huge number of ton municipal solid waste every day.**[2]**. Plastic utilization has a critical part in this day and age, in view of their light weight, enduringness, quicker pace of creation and plan adaptability.**[3].** Disposing of the waste plastics make a huge danger to the environmental factors.**[4].** Land filling is definitely not an appropriate alternative for arranging plastic waste due to their slow degradation rates.**[5].** The utilization of incinerator produces a few toxins to the air, which likewise cause natural issues. Thusly, reusing and recuperating strategies have been utilized to limit the natural effects and to lessen the harm of plastic waste.**[6].** Convert the waste polymers into fuel with the assistance of reactor.**[7].**

The fluid WPO typically made out of hydrocarbons and aromatics, Naphthenes could likewise be created which are generally significant in the fuel scope of hydrocarbons.**[8].** Composition analyses by Gas Chromatography and Mass Spectrometry (GC/MS) of the oil products showed aliphatic hydrocarbons as the major compounds.**[9].** It was analyzed the produced hydrocarbon oil by GC-MS test is found that can range C_6 to C_{25} and Fourier Transform Infrared Spectroscopy (FTIR) analysis results showed band energy which is reflected with calorific value. Also, it stated that fuel was used for feedstock refinery or heavy equipment because of this hydrocarbon range.**[10].** The account of FTIR shows that catalytic pyrolysis of WPO leads to the formation of a compound mixture of alkanes, alkenes, carbonyl group containing like aldehydes, ketones, aromatic compounds and phenols.**[11].** Liquid fuel analyzed the compounds structure and functional groups determination by FTIR and GC/MS. GC/MS analysis result indicates that fuel has hydrocarbon chain C_3 to C_{27}, alcoholic group, an aromatic group, nitrogen, oxygen and halogen content.**[12].**

2. MATERIALS

2.1 CONVERSION OF WASTE PLASTICS INTO WPO

Pyrolysis is the process of thermal degradation without oxygen, performed to get WPO by utilizing as a presence of catalyst.**[13].** Various sizes and states of waste plastics were gathered and squashed without any difficulty of taking care of the cycle.**[14].** Finely squashed waste plastics were taken care of into a reactor chamber. The warming curl put around the consuming chamber is warmed and kept up at a temperature range of 320-500^{0}C for 3-4 hours of time duration. At this high temperature, waste plastic gets vaporised and passes through the condenser.**[15].** Because of the cold water absorbs the latent heat from vapour of waste plastics and converted to hot water moves in the direction of counter flow through the condenser. The vapour is condensed then saved in the oil collector in the form of WPO. **[16].**

2.2 GC-MS ANALYSIS

WPO distinguished by GC–MS was a Perkin Elmer Clarus 680 Gas Chromatograph, a Clarus 600 T Mass Spectrometer, gas helium was utilized with a stream pace of 1.5 mL/min; split proportion 1:33; particle source 250°C with EI of 70 eV; the MS filter range m/z 50–600. The stove was held at 60°C for 2 min and afterward inclined at 4 C/min to 250^{0}C, with an abide season of 20 min. Singular mixes were distinguished by ca examination of the mass range with revealed in the NIST MS Library with 2.0 an of the NIST programming and the 2002 variant of the NIST information base. While, tests were broken down in ethyl acetic acid derivation for GC–MS investigation. Then, to ensure the reproducibility of the trial results, all examinations were executed in three-fold. The exploratory blunders went between ± 5 % of the mean qualities and just the mean qualities were introduced.

2.3 FTIR ANALYSIS

A TGA (Q600 SDT, TA instrument) combined with a FTIR spectrometer (Nicolet 6700) was applied to decide substance mixes delivered during pyrolysis of Plastic waste. Around 10 mg of the Plastic Wastes test, heated from surrounding temperature to 650°C under, nitrogen utilizing a stream pace of 80 ml/min to lessen warmth and mass exchange restrictions. The substance mixes delivered during pyrolysis were straight forwardly cleared into a FTIR gas cell through a Teflon cylinder and afterward by means of a deuterated triglycine sulfate pyroelectric locator. Gas cells and the treated steel move pipe in the FTIR instrument were preheated at a consistent temperature of 200 °C to diminish plausibility of auxiliary responses. The range was gathered at 400–4000 cm^{-1} at a goal factor of 1 cm^{-1} at various temperatures, for example, 350−600°C. Relative focus (%) of substance mixes were settled by incorporating FTIR profile of comparing range.

3. RESULT AND DISCUSSIONS

3.1 GC-MS TEST FOR WASTE PLASTIC OIL

The **GC-MS** analysis of the liquid fuel sample obtained by catalytic pyrolysis of **WPO** was carried out to identify the compounds present in the fuel as shown in **Figure 1** and is summarized in **Table 1**. The maximum peak areas of Total Ion Chromatogram (TIC) of the compounds were Tridecane, Tetracosane, octadecane, pentacosane, 2-methyl octacosane, 4-isopropyl-1, 3-cyclohexanedione, heptadecane, Nonadecane, 2,3,3,-trimethyl-1-hexane, hexadecane and Eicosane. The WPO contains longer hydrocarbon chains in molecular bonding as acne and alkenes according to their carbon number which depicts the burning quality of fuel. No formation of highly toxic polyaromatic hydrocarbon chains was found, such as carcinogens, mutagens and teratogens in WPO. But there is a smaller area of the fractional formation of benzene rings which may not be hazardous.

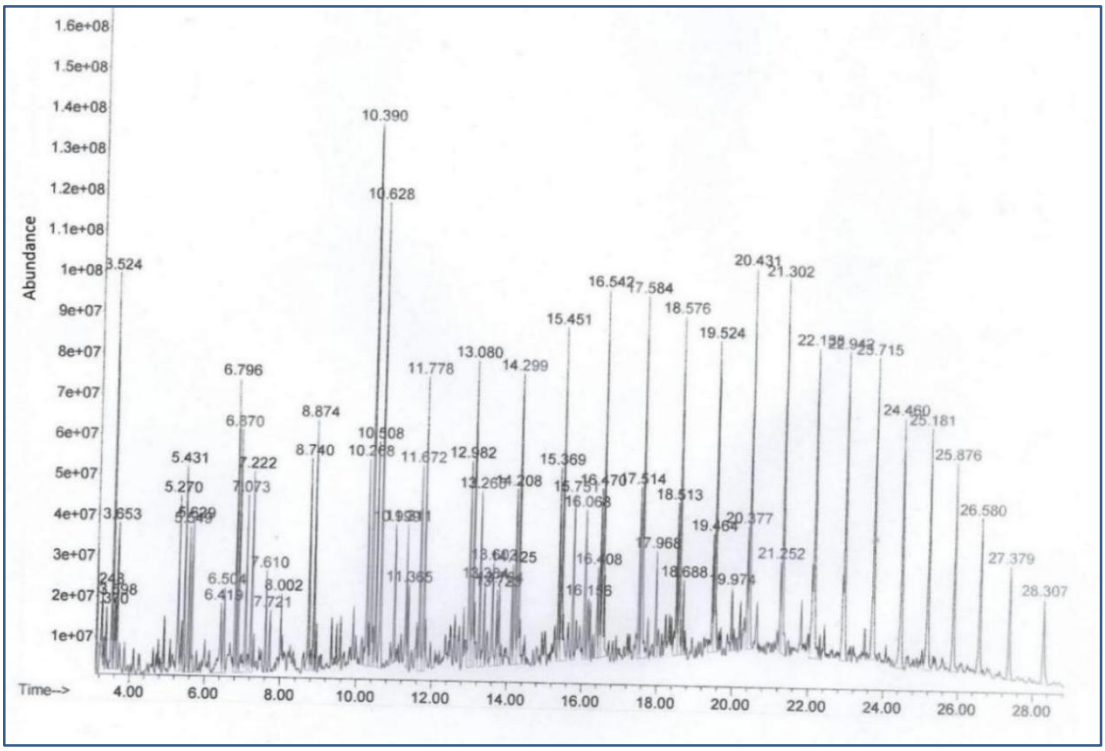

Figure 1 GC/MS test for WPO.

However, the addition of emulsions with the plastic oil leads to the oxidation of alkane and alkenes. This reduces the formation of continuous hydrocarbon chains of WPO inside the combustion chamber.**[17].**

Table 1. GC/MS Chromatogram compounds list of WPO

Peak	Retention time	Area %	Name of the compound	Chemical formula	Probability (%)
1	3.247	0.30	Cyclopropane,1,1-dimethyl-2- (2methyl-1-propenl)	$C_{13}H_{22}O$	70
2	3.363	0.34	1,2,4,4-tetramethylcyclopropane	C_7H_{14}	93
3	3.523	2.44	2,3,3,-trimethyl -1-hexane	C_9H_{18}	38
4	3.595	0.50	Benzene, 1,3-dimethyl-	C_8H_{10}	94
5	3.653	0.99	Nonane	C_9H_{20}	94

6	5.265	1.23	1-decene	$C_{10}H_{20}$	96
7	5.425	1.12	decane	$C_{10}H_{22}$	93
8	5.556	1.07	Heptane, 2,5,5-trimethyl-	$C_{10}H_{22}$	64
9	5.628	1.02	Octane, 2,3,6,7-tetramethyl-	$C_{12}H_{26}$	64
10	6.413	0.99	2-octene, 2,3,7-trimethyl-	$C_{11}H_{22}$	47
11	6.500	0.78	Decane, 3,6-dimethyl-	$C_{12}H_{26}$	50
12	6.790	1.72	2-undecene, 4-methyl-	$C_{12}H_{24}$	43
13	6.877	1.44	2,3-dimethyl-3-heptene, (Z)	C_9H_{18}	47
14	7.066	1.43	1-undecene	$C_{11}H_{22}$	95
15	7.226	1.42	Undecane	$C_{11}H_{24}$	95
16	7.603	0.55	2,3-dimethyl-3-heptene, (Z)	C_9H_{18}	68
17	7.720	0.44	2,3-dimethyl-3-heptene, (Z)	C_9H_{18}	38
18	7.996	0.28	Cyclopropanemethanol	$C_{11}H_{20}O$	42
19	8.736	1.36	1-dodecene	$C_{12}H_{24}$	96
20	8.882	1.49	Dodecene	$C_{12}H_{24}$	96
21	10.261	1.53	1-tridecene	$C_{13}H_{26}$	97
22	10.392	4.21	Tridecane	$C_{13}H_{28}$	42
23	10.508	1.67	4-isopropyl-1,3-cyclohexanedione	$C_9H_{14}O_2$	60
24	10.624	2.76	4-isopropyl-1,3-cyclohexanedione	$C_9H_{14}O_2$	41
25	11.002	0.97	3-decene,2,2-dimethyl-, (E)	$C_{12}H_{24}$	49
26	11.307	0.98	3-decene,2,2-dimethyl-, (E)	$C_{12}H_{24}$	49
27	11.365	0.58	Bicyclo[2.2.1]heptane-2,5-dione,1,7,7-trimethyl	$C_{10}H_{14}O_2$	68
28	11.670	1.47	2-tetradecene, (E)-	$C_{14}H_{28}$	97
29	11.772	1.83	Tetradecane	$C_{14}H_{30}$	93
30	12.977	1.61	1-pentadecene	$C_{15}H_{30}$	95
31	13.079	2.09	Pendecane	$C_{15}H_{32}$	95
32	13.267	1.35	Cyclohexane, 1,2,4-trimethyl-	C_9H_{18}	45
33	13.384	0.76	Cyclohexane, 1,2,4-trimethyl-	C_9H_{18}	50
34	13.601	0.95	Cyclohexane, 1,2,4-trimethyl-	C_9H_{18}	49
35	13.718	0.49	Cyclohexane, 1,2,4-trimethyl-	C_9H_{18}	50
36	13.790	0.60	Dodecane, 1-cyclopentyl-4-(3-cyclopentylpropyl)-	$C_{25}H_{48}$	53
37	14.124	0.72	2,6-dodecadien-1-ol, 3,7,11-trimethyl-, (Z,E)-	$C_{15}H_{28}O$	53

38	14.211	1.47	Cetene	$C_{16}H_{34}$	99
39	14.299	2.38	Hexadcane	$C_{16}H_{34}$	96
40	15.373	1.32	3-heptadecene, (Z)-	$C_{17}H_{34}$	99
41	15.446	2.52	Heptadecane	$C_{17}H_{36}$	96
42	15.751	1.25	Cyclohexane, 1,1,3,5-tetramethyl-cis-	$C_{10}H_{20}$	38
43	16.070	1.22	6-tridecene, 7-methyl-	$C_{14}H_{28}$	52
44	16.158	0.58	Cyclobutanecarboxylic acid, 4-hexadecyl ester	$C_{21}H_{40}O_2$	59
45	16.404	0.75	6-tridecene, 7-methyl-	$C_{14}H_{28}$	52
46	16.477	1.06	Z-8-haxadecene	$C_{16}H_{32}$	98
47	16.550	2.95	Octadecane	$C_{18}H_{38}$	97
48	17.508	1.11	1-nonadecene	$C_{19}H_{38}$	99
49	17.581	2.85	2-methyloctacosane	$C_{29}H_{60}$	91
50	17.973	0.74	Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	$C_{20}H_{40}$	49
51	18.510	1.32	E-15-heptadecenal	$C_{17}H_{32}O$	95
52	18.583	2.32	Eicosane	$C_{20}H_{42}$	99
53	18.685	0.54	1,3-dioxolane, 4-ethyl-5-octyl-2,2-bis (trifluoromethyl)-,trans-	$C_{15}H_{24}F_6O_2$	58
54	19.469	0.98	1-nonadecene	$C_{19}H_{38}$	99
55	19.527	2.58	Heneicosane	$C_{21}H_{44}$	93
56	19.977	0.45	Tert-hexadecanethiol	$C_{16}H_{34}S$	55
57	20.384	0.87	9-tricosene, (Z)-	$C_{23}H_{46}$	94
58	20.427	2.59	Heptadecane	$C_{17}H_{36}$	95
59	21.255	0.61	Z-5-nonadecene	$C_{19}H_{38}$	97
60	21.299	2.76	Octadecane	$C_{18}H_{38}$	93
61	22.141	3.65	Tetracosane	$C_{24}H_{50}$	98
62	22.940	2.94	Pentacosane	$C_{25}H_{52}$	93
63	23.710	2.59	Nonadecane	$C_{19}H_{40}$	91
64	24.465	2.42	Octadecane	$C_{18}H_{38}$	97
65	25.176	2.19	Octacosane	$C_{18}H_{38}$	99
66	25.873	1.77	Tetracosane	$C_{24}H_{50}$	96
67	26.585	1.48	Octadecane	$C_{18}H_{38}$	97
68	27.384	1.16	Tetracosane	$C_{24}H_{50}$	97

69	28.313	1.12	Eicosane	$C_{20}H_{42}$	96

3.2 FTIR TEST FOR WASTE PLASTIC OIL

FTIR is a chemical compound analysis technique used to detect the various characteristic functional groups present in the samples. **Figure 3** shows the infrared spectrum of the pyrolysis oil obtained by FTIR analysis and the general classification of chemical compounds from the FTIR spectrum; the classification was defined based on the degree of infrared absorption detected at various frequencies over the infrared spectra obtained from the WPO. The FTIR spectroscopy of WPO to analyze the wave numbers obtained from the reflected light intensity that can yield a substantial amount of energy to power the combustion engines. **[18].** FTIR spectrum of WPO obtained at 430°C by catalytic pyrolysis and is observed from this figure that the presence of alkenes and alkanes is detected at 3074.59 cm^{-1}& 2890.59 cm^{-1} with simple C-H stretching vibrations respectively. The existence of ketones is noticed at 1713.78 cm^{-1} with *C=O* stretching vibrations. *C=C* stretching vibrations at 1652.06 cm^{-1} indicates the existence of alkenes. The wavelength of 1264.36 cm^{-1} with C-C stretching, vibration indicates the presence of alkenes at the fingerprint region. The components present in the waste plastic oil are mostly, the aliphatic hydrocarbons with carbon number C_{10}- C_{25}.

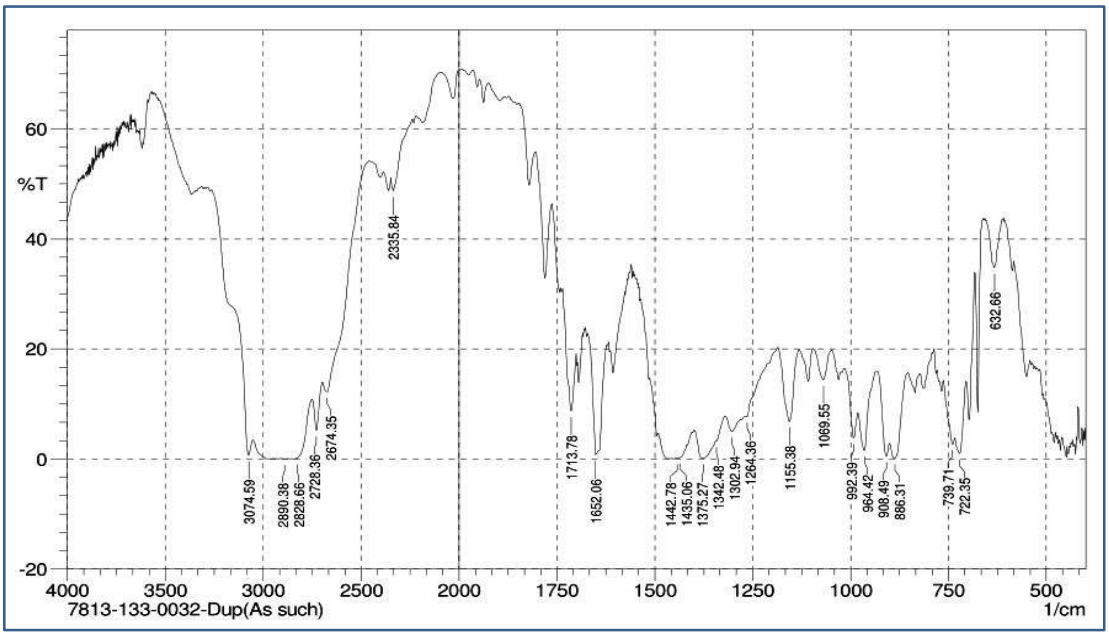

Figure 2 FTIR Spectrum test for Waste Plastic Oil

4. CONCLUSION

The WPO contains longer hydrocarbon chains in molecular bonding as acne and alkenes according to their carbon number which depicts the burning quality of fuel.

- No formation of highly toxic polyaromatic hydrocarbon chains was found, such as carcinogens, mutagens and teratogens in the WPO. But there is a smaller area of the fractional formation of benzene rings which may not be hazardous.
- FTIR spectrum of WPO obtained at 430°C by catalytic pyrolysis and is observed from this figure that the presence of alkenes and alkanes is detected at 3074.59 cm^{-1}& 2890.59 cm^{-1} with simple C-H stretching vibrations respectively.
- The existence of ketones is noticed at 1713.78 cm^{-1} with *C=O* stretching vibrations. *C=C* stretching vibrations at 1652.06 cm^{-1} indicates the existence of alkenes. The wavelength of 1264.36 cm^{-1} with C-C stretching, vibration indicates the presence of alkenes at the fingerprint region.
- The components present in the waste plastic oil are mostly, the aliphatic hydrocarbons (alkanes and alkenes) with carbon number C_{10} - $C_{25.}$

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