Extraction of Pyrolysis Oil from Mixed Waste Plastics Derived from Energy Efficient Pyrolysis Reactor and Red Mud as Catalyst

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Abstract- Although various techniques are implemented towards the synthesis of oil from various alternative sources such as seeds, stem layers of trees, and chicken wastes, the yielding percentage of oil was limited. The yielding of oil from these conventional techniques by mechanical expeller, Where the mechanical expeller rotates at 25 to 35 rpm to convert the seeds into oil, Solvent techniques essentially require a solvent as hexane as an absorbing agent to change the seeds into oil. The thermocracking method is the generation of oil from seeds with the help of a reactor working with temperatures of 400°C-500°C. This paper uses an energy efficient waste plastic Reactor to focus on oil extraction from mixed waste plastic. The experimental setup consists of an inner tank of 20CR80S-75µm YSZ (20% Chromium 80% Steel and 75 microns Yttria-stabilized zirconia) coated material that can withstand temperatures up to 1000°C. Experiments were carried out with 6 kgs of MWP (Mixed Waste Plastics) plastics kept inside the reactor in red mud as a catalyst for better yielding. The results observed that 450 ml of oil was yielded from 6 kgs of MWP at the reaction temperature range of 300-500°C with a reaction time of 1.5 to 2 hours for red mud catalyst. The condenser effectiveness was achieved up to 0.88 due to increased copper windings from 8 to 16, along with the implementation of two-stage condenser setups.

Keywords Red mud, catalyst, gas chromatography-mass spectrometry, fourier transform infrared spectroscopy, endoscopic endonasal transceiver approach, gross calorific value.

1. Introduction

The emissions released to the atmosphere from diesel-based engines have been rapidly increasing daily, and they have been growing by 20% to 25% globally in the last five years. The global automotive sector faced significant issues regarding emission formations from diesel engines, which pollute the atmosphere and increase fuel costs. Hence, it is necessary to choose an alternative way to reduce emissions and fuel costs. However, there is several research conducted on the generation due to the yielding percentage of oil being limited due to the availability of oil content approximately in the range of 40 to 450 ml. Hence, it is necessary to choose alternative sources that can yield much more oil content without pollution. oil extraction from plastics depends upon the catalyst's nature and type [1]. The study also reveals that max oil yielding by weight depends on the catalyst surface area and actual reaction temperature. The maximum yielding of oil from plastics relies on the shape of the catalyst that easily propagates during the pyrolysis reaction with the absence of oxygen at elevated temperatures from 400°C to 500°C. Results reveal that the uniform shape of the catalyst will improve the reaction rate and yield more fuel from the plastics [2]. The generation of waste plastics in India has globally increased up to 3.5 MMT, and there is an increase in percent by 20% in the year 2022 compared to the last two years. This is due to the increased usage of plastics in COVID-19 situations [3,4]. The study concluded that by using coal as a catalyst, oxygen can yield 60% of fuel from plastics with a time of 3 to 4 hours at a maximum reaction temperature of 520°C [5]. From the experimental analysis, using Ni as a catalyst proved that the reaction rate, melting point, and optimal yielding of fuel extracted from plastics depend upon the catalyst porosity catalyst dispersion rate [6].

The maximum oil of 400 ml from 6 kg of mixed waste plastics was extracted with a reaction time of 2.5 hours, which has been achieved with a feedstock ratio of 40:60 by pyrolysis

by pyrolysis process with a temperature of 450°C [7,8]. The chlorine removed the oil content in the extracted fuel by 35% two to wash and clean. The 8.2 % chlorine was introduced to remove the wax and oil content from the extracted fuel. Hence,

the oil content has been removed, but the final extracted oil was 75% by volume [9, 10]. This paper focuses on fuel extraction from all types of waste plastics, such as LDPE, HDPE, PVC, PP, and PET, for yielding fuel from plastics.

2. Methodology

The methods of extracting the oil from the different waste plastics, play a crucial role in this analysis. Collecting different waste plastics from different sources including water bottles, pipes, etc is the easiest phase involved in this analysis. The majority of waste plastics engaged in this analysis contain the different juice bottles used by the students at college canteens, which were collected in separate bins marked with red color to the waste bins for collecting these bottles. These bottles contain some chemical contents that result in improper shredding sizes during the process. and damage in the form of corrosion formation of the blades rotating at different rpm. Hence, it is required to separate and clean the process. The cleaning and different types of processes involved in this analysis are shown in Fig.1, the initial stage of the process starts with the collection of waste plastic bottles, including LDPE, HDPE, and PET bottles from college canteens, broken PVC pipes. All the collected mixed waste plastics were separated according to shape and size, and the dust particles on the inner and outer surfaces of the waste plastics were removed by water cleaning using spray mechanisms. The cleaned plastics were dried at room temperature for 48 hours to ensure dryness properties [11]. As per the literature review, it was observed that less yield was acquired when the different sizes of waste plastics were fed into the Reactor.

Fig.1. Methodology

To address this problem, waste plastics have been shredded with an equal size of 5×5 cm^2, and the working phenomenon of the shredder is explained in section 3. All the mixed waste plastic bottles were shredded manually, and obtained outputs from manual shredding with ununiform sizes were fed into the automatic shredder to achieve the uniform size of 4×4 cm^2 [12]. Next to the shredding, the uniformly shredded mixed waste plastics are fed into the Reactor with a catalyst. The catalyst used here is red mud, which gives maximum yield and lower price than other catalysts [13]. A ratio of 6:2 of plastics to catalyst was conducted for three trials to get accurate results. In the first trial, due to a lack of cooling in the condenser, the yield was almost 30%. In the second trial, ice cubes were added to enhance the cooling mechanism in the condenser. The observed yield was increased to 65%; further increasing the no of ice cubes in the trial three condenser tends to increase the phase change more effectively, and the yielding attained is 88%, which gives superior results compared to the last two trials. The settling and separation are carried out by the gravitational separation method to remove dust, dirt, and any other impurities from the extracted waste plastic oil. This process is carried out by observing extracted oil for 4 hours. After settling, the purified oil is removed from the funnel and sent for the thermo physical properties evaluation [14].

3. Shredding of Plastics

To yield the oil from different waste plastics is a crucial part that requires finer particles. Hence, it is necessary to convert the waste LDPE bottles into coarse particles first with the help of a Manual shredder, as shown in Fig.2. The waste LDPE bottles collected from different sources near canteens and hostel juice shops.

Fig.2. Manual shredder

The attainment of oil from coarse particles is very low due to the irregular shapes of the waste plastics with different sizes. This causes more reaction time to vapourize, condense, and phase change process. Hence, it is necessary to change the un uniform particles. The obtained plastics from the manual shredding machine were fed into the automatic shredding machine, shown in Fig.3, and its specifications are mentioned in Table 1. The automatic shredding machine consists of 5 blades, two blades stationary and three blades rotary rotating at 250 rpm, which converts the un-uniform and coarse size plastics into uniform plastics with a mesh size of 5×5 cm^2.The

conversion of ununiform coarse and fine particles into smaller and uniform finer particles with sharper blades with motoring or pulley mechanisms is called shredder [15]. Usually, the size of the collected non-uniform plastics was around 25 cm in height and 6.5 cm in diameter. Hence, feeding these dimensional plastics into the shredder machine was tough. The obtained granular sizes of different types of plastics in the sizes of 5×5 cm^2 were indicated in Fig.4 and Fig.5. Figure 4 shows the HDPE, LDPE, and PET type of plastics, In contrast, Figure 5 suggests that types of plastics such as PVS, PP, and PVC. Each 1 kg of plastics is mixed in a 6:2 plastics-to-catalyst ratio with the catalyst as red mud.

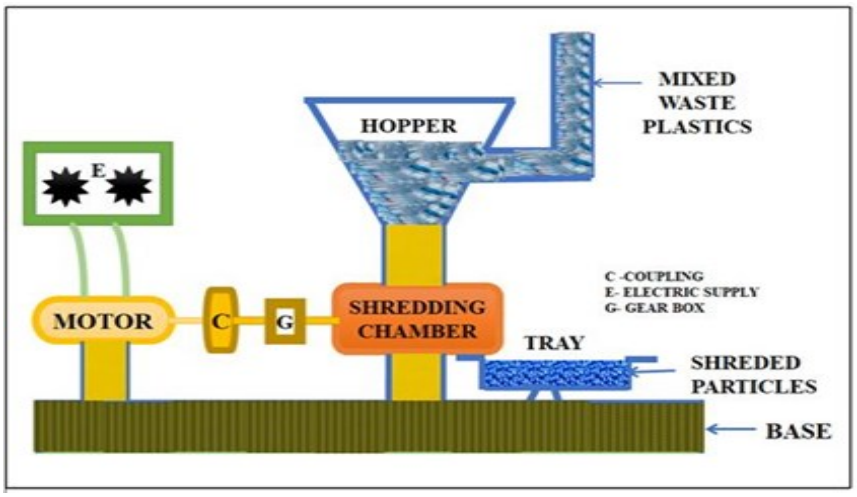

Fig.3. Automatic Shredding machine.

Table 1. Specifications of automatic shredder

S.No	Description	Technical Specification
1	Motor	3.5 hp
2	Grinder capacity per hour	20 kgs
3	size of the mesh	1.5 cm
4	No of blades	5
5	Blades length	8 inches
6	Machine Weight	250 kg
7	Dimensions (L×W) mm	960×660

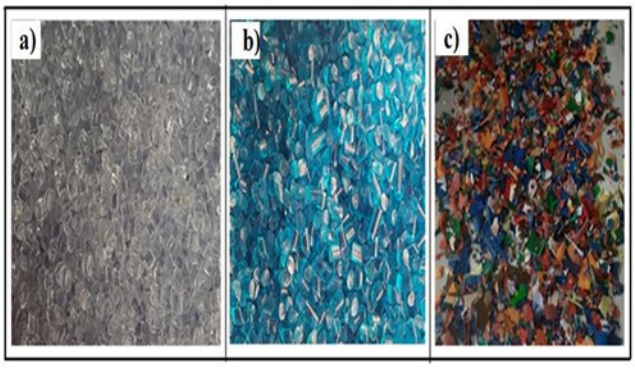

Fig.4. (a) HDPE (b) LDPE (c) PET.

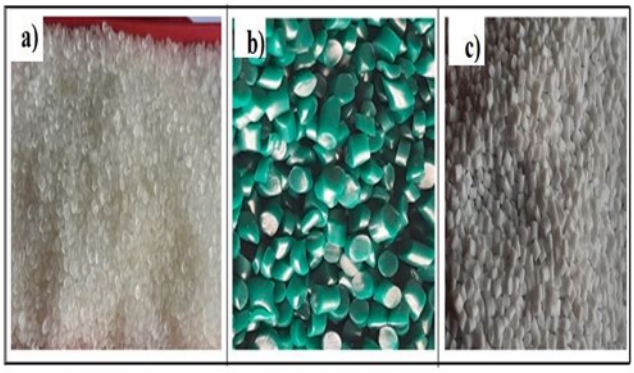

Fig.5. (a) PVS (b) PP (c) PVC.

Figure 6 depicts the pictorial view of the red mud catalyst. The red mud catalyst is derived from the residues called bauxite with the combination of high-resisting agents such as silica oxides and oxides of alumina with a definite percentage of clay. The proportions were approximately 20% Fe2O3 and 30% $Al2O_3$ oxides, a substantial rate of 20% silica oxides, and 30 % TiO_2 Oxide.

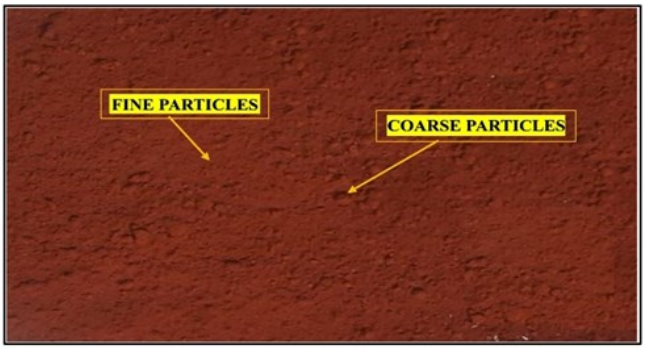

Fig.6. Catalyst (Red Mud).

The sample of 1ml of HCl increases the amount of TiO_2 elements to improve the reaction rate of the combustion process. The main benefit of using red mud as a catalyst is its high compressive strength, lesser conductivity, and lower swelling, increasing the penetration rate of chemical reactions. Figure 7 indicates the SEM morphology of the red mud catalyst. From this analysis, it is understood that the irregular particles tend to yield less oil from the waste plastics. The determination of the presence of the elemental concentrations that diffracted from one medium to another medium with SEM analysis [16]. SEM confirms Irregular, Angular particles have rough, jagged, non-uniform edges. This technique identifies surface morphology present and how they are diffracted from one phase to another during the chemical reactions [17,18].

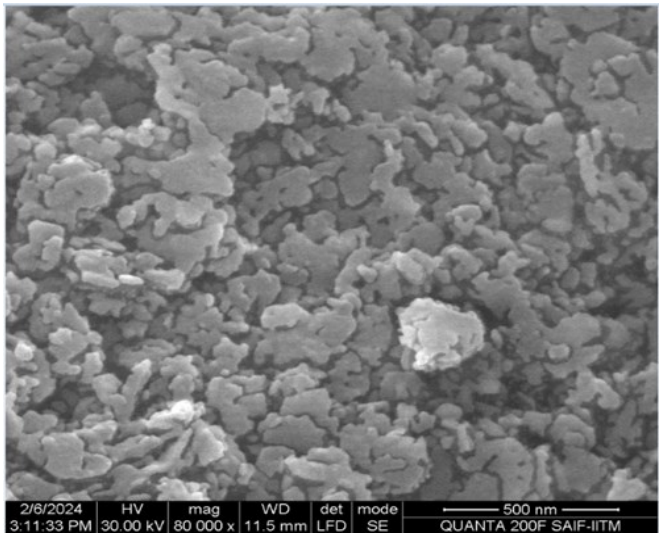

Fig.7. SEM image of red mud catalyst.

4. Experimental Setup

The design of experiments to be carried out is crucial to yielding the oil from different waste plastics. The yield depends upon the minimum thermal expansion of the reactor. The experiment setup is shown in Fig.8. It represents the experimental setup used in this analysis. Here, the two-stage condenser is designed and fabricated to carry out the study. The inner tank of Reactor R is made up of 20CR80S -75µm YSZ alloy for better heat resistance, and the heating capacity of the coils surrounding the Reactors is 220 volts and 500 watts [19]. The number of coils surrounding the Reactor is 8 to ensure better heating capacity, and the minimum heating time attained for achieving the process is 1.5 hours. The utilization of ice cubes in the first-stage and second-stage reactor is shown in the respective figures followed by Fig.9.

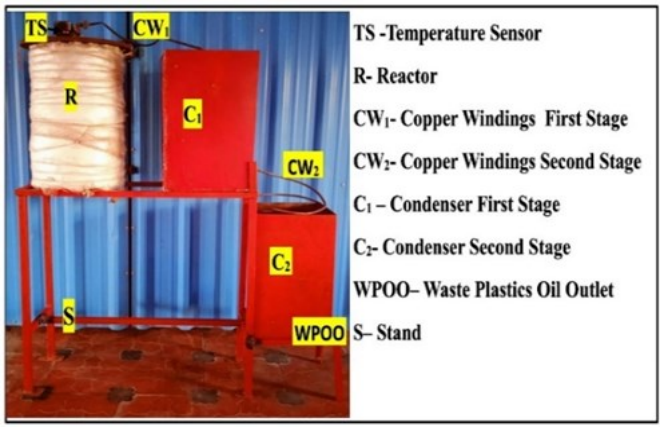

Fig.8. Experimental setup.

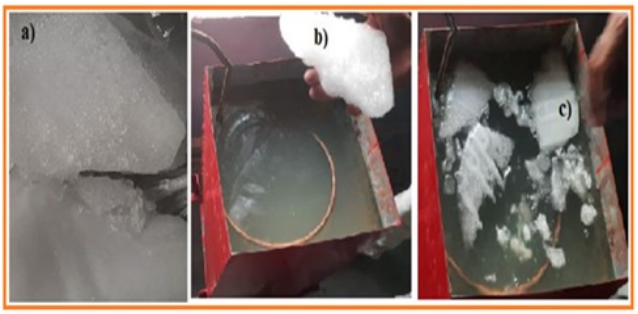

Fig.9. (a) ice cubes (b) first stage (c) second stage.

The average ice cubes for stage one and stage condenser to yield 450 ml from 6 kg of waste plastics utilized 6 kilograms of ice with definite intervals of 2 kilograms for the first valorization with a time interval of 20 mins, 2 kilograms of ice for the second valorization with a time interval of 15 minutes and 2 kilograms of ice. with a time interval of 10 minutes.

5. Uncertainty Analysis

The analysis that is required to predict the errors and accuracies of the instrument used and its deviations is called uncertainty analysis. The experiments that can be repeated to carry out the analysis are repeated three times to calibrate the nature of accuracies. The nature of errors obtained can be identified using this analysis to predict or determine the nature of the instruments used. According to a recent research study on uncertainty analysis [20]. Table 2 represents the measure of uncertainties in this analysis, and Table 3 represents occurred uncertainties in percentages. From Table 2 and Table 3, it is easy to understand that all the deviations occurred in this analysis. The measure of uncertainty is expressed in the Eq. (1) referred from [21]

$$\Delta R = \frac{2Q_i}{Q_i} * 100 \quad (1)$$

Q_i = Actual deviations that Occured are repeated by uncertainties

ΔR = Resultant Gaussian occured deviations

Table 2. Measure of uncertainties

Instrument	Units	Range	Accuracy	Error %
Pressure sensor	bar	0-350	±2.5	1.2
Stopwatch	-	-	±0.35	0.33
Ice cubes	kg	0-20	±0.5	1.1
Gas sensor	ºC	1200	±20	1.8
Residues	%	0-50	±10	1.3
Heat flux sensor	W/mm^2	0 -19000	±3.5	1.8
Temperature indicator	ºC	0 -1100	±10	1.9
Stopwatch	-	-	±0.38	0.22
Ftir probe angle	Deg	60–310	±2.5	1.5
Catalyst weight	kg	6	±1.2	1.2
Velocity sensor	m/s	0-31	±7.4	0.82
Oil yield	ml	300 600	2.2	1.7

Table 3. Uncertainties and its percentages

S. No	Measured parameters	Percentage uncertainty
1	Catalyst weight	±1.2
2	Inlet Reactive pressures	I
3	Outlet Reactive pressures	±2.2
4	Plastics coarse size	±2.8
5	Plastics fine mesh	±2.1
6	Temperatures of gas at the inlet	±2.5
7	Temperatures of gas at the Outlet	±0.98
8	Oil yield	±1.5

The measure of uncertainties is based on dependent variables and the calibrated data repeated by the number of experiments conducted and expressed by Eq.(2) followed by reference [22]

$$RN = f(N1, N2, N3 \ldots\ldots\ldots\ldots\ldots Zn) \quad (2)$$

Eq.(3) depicts the possible iterations that deviated during the analysis, and from this expression, it can be deliberately understood that the measure of uncertainties depends upon atmospheric errors due to dust and other instrumental defects referred from [23]

$$\Delta G = \sqrt{(\frac{\partial g}{\partial g_1}\Delta t_1)^2 + (\frac{\partial g}{\partial g_2}\Delta t_2)^2 + (\frac{\partial g}{\partial g_n}\Delta t_n)^2} \quad (3)$$

$\Delta t_1, \Delta t_2, \Delta t_3 = uncertainty\ deviations$

$\frac{\partial g}{\partial z_n}$ = Actual values during experimentation.

6. Results and Discussion

This chapter deals with the discussion of yielded oil from different waste plastics and the identification of the physical properties of WPO and pure diesel. The physical properties of oil is tested to identify the number of elements present inside the pure diesel and waste plastic oil and also this section deals with FTIR segments of the WPO and diesel during the dispersion of the molecules. The yielded oil samplings of 450

ml from red mud catalyst is shown in the Fig.10. The sample oil for conducting the GCMS and FTIR analysis.

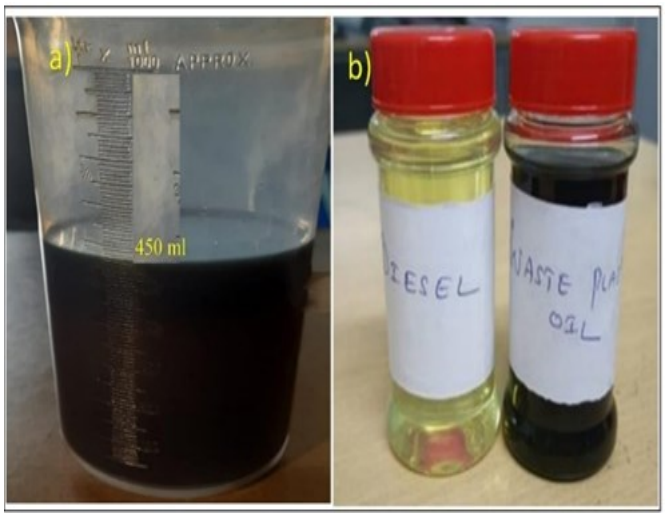

Fig.10. Physical View of (a) yielded WPO (b) Sample oil for testing WPO and diesel.

The physical properties of the oil are tested at the EETA lab at the local testing center, Chennai. India. This results and discussion section contains different sections, followed by section 6.1, Physical Properties, section 6.2, which describes the FTIR analysis of pure diesel and waste plastic oil, and section 6.3, which represents the GCMS analysis. Section 7 deals with the oil yield and residues, Section 8 deals with the Measurement of density and specific gravity, Section 9 deals with the measurement of Kinematic viscosity, Flash point, cetane number, and GCV, and Section 10 deals with the conclusion section.

6.1. Physical Properties

The physical properties of oil to be measured in the oil is very important in the testing. This defines the amount of the desirable chemical characteristics present in the oil. The main Physical properties of derived pyrolysis oil is shown in Table 4, and the properties of the derived oil is compared with ASTM Methods and diesel.

Table 4. Physical properties of derived pyrolysis oil

Properties	Method	Units	WPO	Diesel
Density-15 °C	ASTM D1298	kg/m^3	826	837
Specific gravity-15 °C	ASTM D1298	-	0.86	0.98
Kinematic viscosity-40 °C	ASTM D445	cSt	1.75	4.04
Flash point	ASTM D93	°C	40.04	70.03
Cetane index	ASTM D4737	-	32.88	62.03
Gross calorific value	ASTM D240	MJ/kg	40.05	44.06
Lubricity	ASTM D6079	µm	342	234
Moisture content	ASTM D93	%	0.031	0.021
Sulfur content	ASTM D6751	%	0.016	0.012
Carbon residue	ASTM D93	%	0.01	0.04
Acid number	ASTM D6751	Mg/gram	0.35	0.41

6.2 FTIR Analysis

Identifying unknown elements and their wavelength during the travel of dispersed liquid particles caused by the exertion of surface pressures caused by surface tension and capillarity phenomenon is scientifically examined by unique infrared rays technology named FTIR [24,25].

This analysis accurately identifies the energy required for a collision of molecules and the unknown elements present in the liquid [26,27]. Figure 11 is the indication of FTIR results obtained from pure diesel. The transmittance percentage of dispersed fluid for diesel was high in the range of 98 %, and the corresponding peak wave number was found to be 3300 $cm^{-1.}$ This is due to the property of surface tension and cohesion leading to a gradual increase in transmittance and reaching peak levels [28]. Significantly, there is a sudden decrease in wavelength at a wave number of 2800 cm^{-1}.

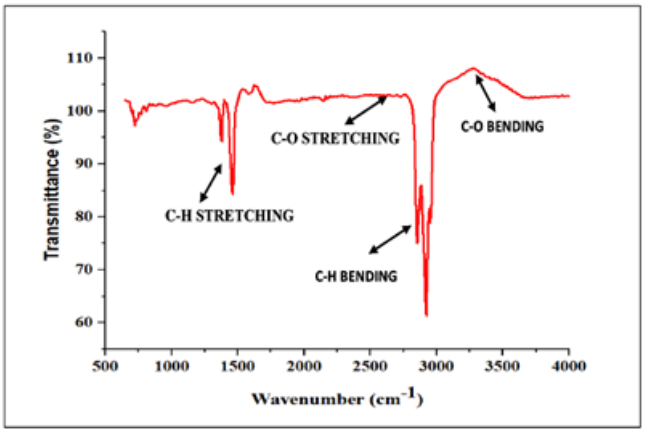

Fig.11. FTIR analysis of pure diesel.

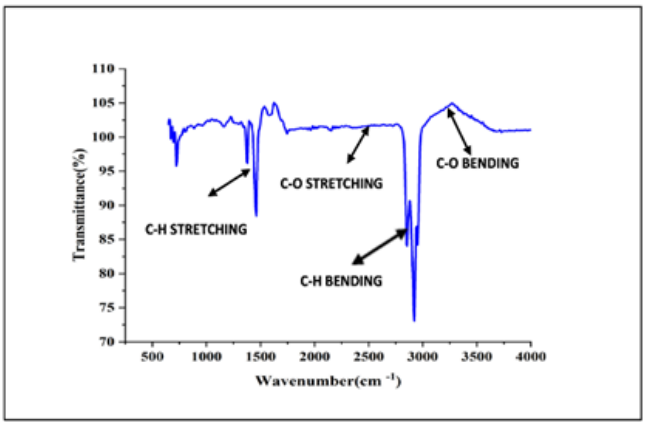

Fig.12. FTIR Analysis of WPO.

This is due to the phenomenon of compressibility of the fluid and less transmittance forces at the range of 70 % due to higher colloidal forces [29]. It was significantly found that higher the transmission occurred from wavenumber 3000 to 1800. This is due to the cohesion property at the surface of the liquid, which tends to travel in uniform motion [30]. Further, the higher the increase in transmittance, the higher the wavenumber was found at wavenumber 1500 cm^{-1}. This is due to cohesion, and surface tension tends to collide, causing the fluid to stretch [31]. Figure 12 represents the FTIR analysis results obtained from waste plastic oil. It was observed that the maximum wave number was 3500 cm^{-1}. This is due to lesser surface tension and adhesion as compared to diesel [32]. This is due to lesser transmittance forces and less cohesion property for WPO than diesel [33,34].

6.2.1. Depolymerization process

The depolymerization process involved in forming the carbon molecules into hydrogen molecules with melting temperatures of 100ºC proved by [35].

6.2.2. Carbon isomeric formation single bond

The carbon isomeric process involved in forming the single carbon molecules bond into hydrogen molecules with melting temperatures of 100 ºC to 300 ºC proved by [36].

6.2.3. Carbon isomeric double bond formation.

The double carbon isomeric process involved in forming the single carbon molecules bond into hydrogen molecules with melting temperatures of 500ºC to 800ºC is given referred from [37].

6.2.4. Transfer of hydro intermolecular reactions

The transformation of intermolecular temperatures from the temperature range of 600ºC to 800ºC with the presence of catalysts is referred from [38].

6.3. GCMS Analysis

GC refers to gas chromatography is applied on 1 ml of sample liquid such as waste plastic oil and diesel with the help of highly inert gas such as helium to split stationary oil into movable form. Figure 13 represents the GCMS tests for a 1 ml diesel [39]. Figure 14 represents the GCMS test analysis for the sample of 1 ml. MS stands for mass spectroscopy, excessively used to identify the number of unknown elements present in accelerated oil percentage-wise [40,41]. The compounds present in the diesel are tabulated in Table 5 and waste plastic oil are shown in Table 6.

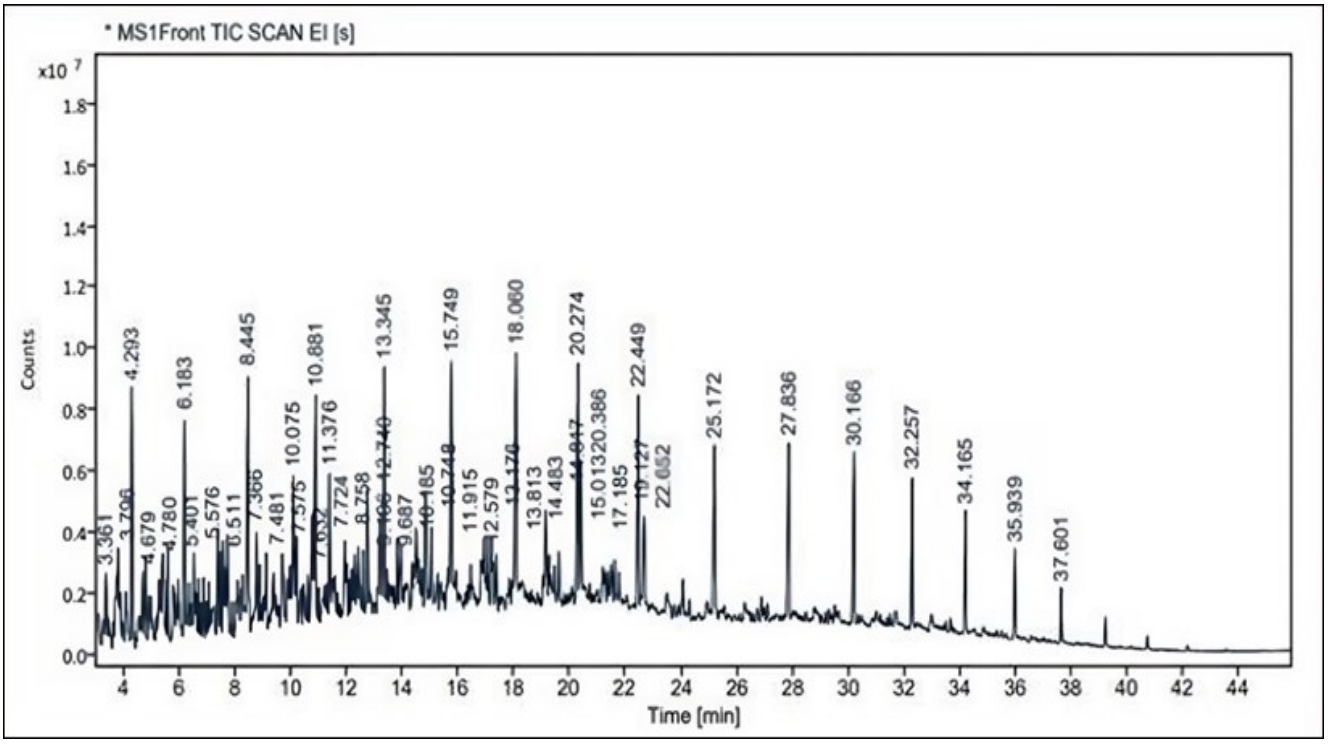

Fig.13. GCMS analysis of diesel.

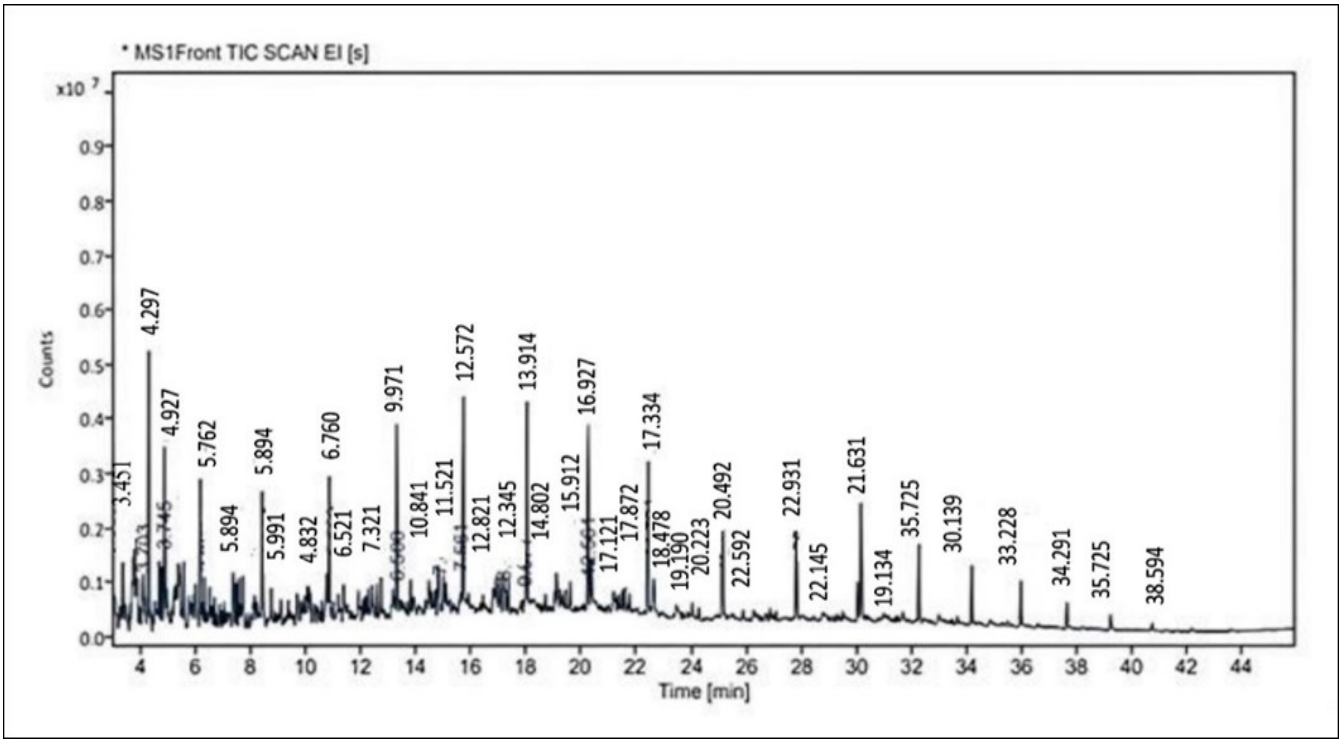

Fig.14. GCMS analysis of WPO.

Table 5. Compounds present in diesel

S.NO	Compound name	Retention time	Area (%)	Probability (%)
1	1-Dodecanol, 3,7,11-trimethyl	3.361	1.46	3.68
2	Benzene, 1-ethyl-3- methyl	3.796	0.84	32.98
3	Decane	4.293	3.78	29.93
4	Decane, 4-methyl	4.679	0.71	14.95
5	Mesitylene	4.780	1.15	25.21
6	Dimethyl acetate	5.401	0.79	33.01
7	Decane, 3-methyl	5.576	1.11	9.53
8	Naphthalene, decahedran	6.511	1.10	23.31
9	5-Ethyl-oxazoline	7.366	2.15	13.23
10	1-Octadecanesulphonyl chloride	7.481	1.02	10.19
11	Benzeneacetic acid	7.575	1.12	5.91
12	Naphthalene, 1,2,3,4-tetrahydrone	7.632	0.84	31.62
13	Ethanol	7.724	1.76	6.08
14	Dodecane	8.445	4.48	29.19
15	Undecane, 2,6-dimethyl	8.758	1.31	22.36
16	Bicyclo	9.106	1.12	11.01
17	Naphthalene	10.075	1.50	46.51
18	Tetradecane, 2,6,10-trimethyl	10.185	0.73	16.2
19	Naphthalene	11.376	1.88	28.27
20	6,9-Octadecadiynoic acid	11.915	1.49	9.47
21	1-Hexadecanol, 2-methyl	12.579	0.79	7.81
22	Tetradecane, 2,6,10-trimethyl	12.740	1.93	18.42
23	Tetradecane	13.345	4.39	32.34
24	Falcarinol	13.813	1.07	14.62
25	Tetradecane, 2,6,10- trimethyl	14.817	2.39	14.74
26	Tert-Hexadecanethiol	17.185	0.99	12.92
27	Hexadecane	18.060	4.67	18.53
28	Heptadecane	20.274	4.51	24.24
29	Octadecane	22.449	4.09	37.43
30	Tetradecane, 2,6,10-trimethyl	22.652	2.15	7.77
31	Eicosane-2	27.836	3.58	34.32
32	Heneicosane	30.166	3.18	36.25
33	Docosane	32.257	2.59	13.3
34	Tricosane	34.165	1.98	23.6
35	Pentacosane	37.601	0.76	26.39

Table 6. Compounds present in WPO

S.NO	Compound name	Retention Time	Area (%)	Probability (%)
1	5-Octadecane	3.451	2.39	3.99
2	Nonane, Four methyl	3.703	0.78	19.01
3	1-Octanal, Two-butyl	3.744	1.00	6.25
4	Benzene, 1-ethyl-3-methyl	3.789	1.33	38.07
5	Mesitylene	3.883	0.57	39.01
6	Decane	4.297	6.32	30.66
7	Decane, Four -methyl	4.921	1.08	10.97
8	Bicyclo, Heptane	5.762	0.61	5.41
9	Cyclohexane	5.894	0.73	10.96
10	Decane, Two-methylene	5.433	0.56	21.64
11	Tricyclopentane	5.991	0.76	8.69
12	Dicyclopentane	4.832	4.14	64.06
13	Undecane	6.760	2.98	24.6
14	Naphthalene	6.521	0.93	26.94
15	1-Phenyl-1-butene	7.321	1.94	12.86
16	1-Octadecanesulphonyl chloride	7.470	0.95	10.25
17	Benzeneacetic acid	7.561	0.94	6.32
18	Ethanol	7.712	1.34	6.37
19	Dodecane	8.411	3.53	22.92
20	Undecane, 2,6-dimethyl	8.740	0.83	14.07
21	1H-Indene, 1-ethyl	9.971	1.01	9.82
22	Dodecane	10.841	3.27	5.25
23	Naphthalene, 1,2,3,4-tetrahedran	11.521	1.44	17.1
24	Disulfide, di-tert-dodecyl	12.572	0.74	7.7
25	Tetradecane, 2,6,10-trimethyl	12.821	1.31	18.09
26	5,8,11-Heptadecatriynoic acid	13.914	0.86	11.08
27	Tetradecane, 2,6,10-trimethyl	14.802	1.85	21.44
28	Pentadecane	15.912	5.06	29.83
29	Tert-hexadecane thiol	16.927	0.52	9.96
30	Dodecane, 5,8-diethyl	17.334	0.93	9.23
31	Heptadecane	20.223	4.81	24.18
32	Ethanol, 2-(octadecyl)	30.981	4.04	8.39
33	Eicosane	33.228	2.25	9.37
34	Pentacosane	35.725	1.30	8.75
35	Octadecane, 3-ethyl	38.594	0.68	24.54

7. Oil Yield and Residues

The percentages of the residues in the form of gas and charcoal and also the oil yield in the analysis are essential criteria during the analysis. The maximum amount of oil yielding and its residue percentages can be measured with the help of residue analysis as shown in Fig.15. This analysis defines the amount of oil yielded from mixed waste plastics in percentages based on weight.

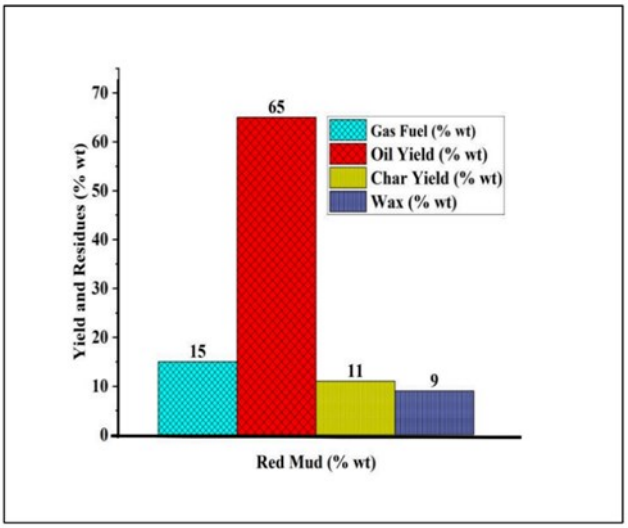

Fig.15. Residues and oil yields from red mud catalyst.

The number of gases evolved after the experimentation process is found to be 15% by weight, the maximum amount of oil yield is found to be 65% by weight, the char yield percentage by weight is found to be 11%, and the tiniest formation of wax is found by 9% by wt, because of higher coarse particles resulting from penetrating the reaction concerning the surface area of the catalyst and the plastic melting zones [42], This results from a yield of 450 ml from the 6 kg of plastics with the ratio of 6:2; the higher the penetration or higher the yielding can be obtained only by the modification of red mud catalyst with fine granular particles. Hence, modifying the catalyst from a coarser to a finer medium will improve the results.

8. Measurement Of Density and Specific Gravity

Density is an important property indicating the cubic volume of oil flow rate concerning the oil mass [43]. This property determines the mixture compositions present in the oil for estimating the flow capability concerning the purification and quality of mixing concentrations [44]. Figure 16 represents the density of oil for attained WPO and pure diesel. It was observed that the density of oil achieved from mixed WPO was 826 kg/m3, and for pure diesel, 837 kg/m3. The difference in densities is 1.2 % for WPO as compared to diesel.

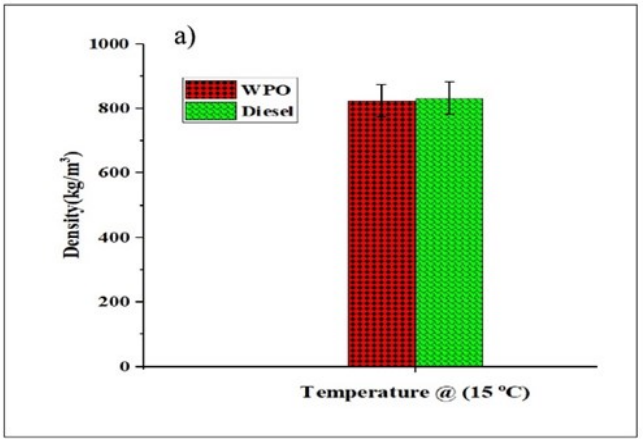

Fig.16. (a) Density @ 15°C.

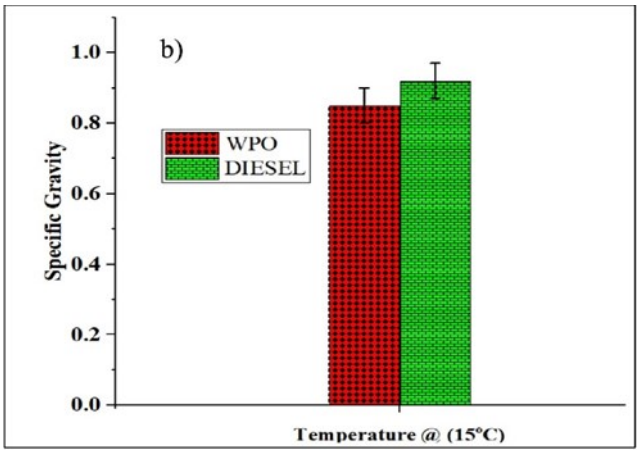

Fig 16. (b). Specific gravity @ 15°C.

The critical correlation to estimate the density of the oil is given by Eq.(4), referred from [45] given by

$$\rho_o = \frac{M_F}{V_f} \qquad (4)$$

$$M_F = Mass\ of\ the\ Oil\ in\ Kg.$$

V_f = Volume of the fluid in m^3

This is due to fewer aromatics compounds and fewer elements in WPO than diesel [46]. The optimal performance of petroleum-based and diesel-based fuels can be predicted or measured by specific gravity, defined by the ratio of specific densities of oil to water [47]. The instrument used to measure the particular gravity is a hydrometer. From Figure 16, it was found that the specific gravity of WPO was 0.86, and for pure diesel, it was found to be 0.98, a decrease in specific gravity values of WPO by 0.07% compared to pure diesel. This is because lighter carbon atoms in WPO lead to slower concentrations by light weights than pure diesel [48].

9. Measurement of Kinematic Viscosity, Flash Point, Cetane number, and GCV

The flow of oil due to the presence of shear stresses involved as an internal part due to opposite travel offered by fluids against cohesion and surface tension property is called the kinematic viscosity of the fluid [49]. In other words, the kinematic viscosity depends upon the density of the fluid to be offered over the material's surface [50].

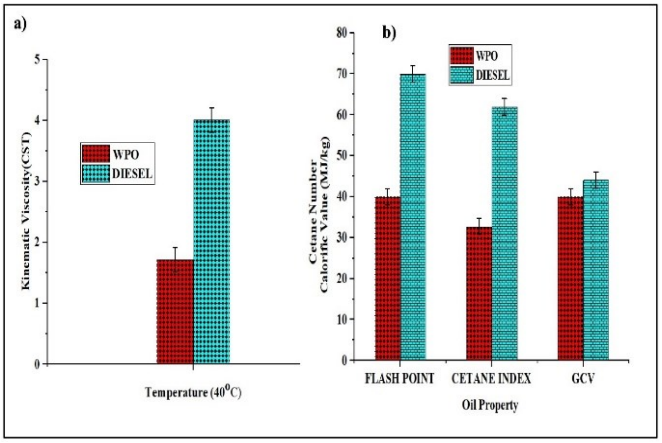

Fig.17 (a) Kinematic viscosity at 40°C-cst b) Flashpoint, cetane number, and GCV.

The Kinematic Viscosity for the oil is scientifically expressed by the Eq. (5) referred from [51],

$$\gamma = \frac{\mu_o}{\rho_o} \qquad (5)$$

$$\mu_o = Dynamic\ viscosity\ in\ \mathrm{Ns/m^2}$$

$$\rho_o = Density\ of\ Oil\ in\ kg/\mathrm{m^3}$$

$$\gamma = Kinematic\ Viscosity\ of\ the\ \ in\ \mathrm{CST}$$

The Expression for Calculating the Calorific value of the fuel is correlated in Eq. (6) referred from [52],

$$\Delta_H = \frac{Q_M}{V_f} \qquad (6)$$

$$\Delta_H = calorific\ Value\ of\ the\ fuel\ in\ \frac{MJ}{Kg}.$$

$$Q_M = Heat\ Evolved\ combustion\ in\ kj/kgk$$

$$V_f = Volume\ of\ the\ fuel\ in\ \mathrm{m^3}$$

From Figure 17, the kinematic viscosity of WPO is found to be 1.72 CST, and for the diesel, it was found to be 4.01 CST. The marginal difference of 2.29% was less for WPO than diesel. This is because the lower densities of WPO tend to cause lesser frictional resistance due to the lower organic compounds present in WPO than in diesel [53]. The determination of the occurrence of flash at a specific temperature is said to be a flash point. This is a fundamental property in measuring the thermal ignition quality of the fuel [54,55]. The flash point, cetane number, and Gross calorific value that occurred for the WPO and pure diesel. However, the flash point for the WPO was found to be 40°C, and for diesel, it was found 70°C; the marginal difference of 30% was efficient for WPO compared to diesel. The scientific correlation to estimate the cetane number or cetane index of the fuel is given by referred from [56].

This is due to the phenomenon of better oxidation capacity of organic compounds present in WPO, which tends to speed up the ignition process as compared to pure diesel [57,58]. The ignition quality of the fuel offered to overcome the knocking is measured with the cetane number [59,60]. However, the cetane number from Figure 17 for the WPO is found to be 32, and for diesel is 62. The marginal difference is 30% lower for WPO as compared to pure diesel. This is due to the lesser volume occupied in probability, and higher aromatic compounds tend to lower the cetane number for WPO than pure diesel [61,62]. The actual heat is deliberately produced during the evolution of the combustion phenomenon due to the collision particles; these collision particles will absorb the heat [63,64]. The property that measures the evaluation of heat absorption is called the fuel's Gross calorific value (GCV) [65,66]. From Figure 17 , it was observed that the GCV value of WPO was found to be 40 MJ/kg, and for diesel, it was found to be 44 MJ/kg. There is a lesser marginal difference of 4% for WPO compared to pure diesel [67]. This is due to lesser distillation capacity and higher carbon atoms present in WPO, which tend to produce lesser calorific value than pure diesel [68,69].

10. Conclusion

The experimentation on the extraction of mixed waste plastic in the reactor coupled with a double-stage condenser, which is made up of nickel steel alloy, is completely investigated with the help of red mud as a catalyst; applied on the red mud surface of the catalyst with sample 1ml of HCl to identify the oxides present. The SEM analysis has been conducted thoroughly to identify the irregularities and fine particles of the catalyst morphology section. The utilization of red mud as a catalyst in the ratio of 6:2 given with three trials has been conducted in the experiment.

- The results observed that 450 ml of oil was yielded from 6 kgs of MWP at the reaction temperature range of 300 - 600°C with a reaction time of 1.5 to 2 hours.
- The yielding performance was observed as 30% at the first trial due to the lack of cooling at the condenser.
- The yield was 65% in the second trial with 2 kgs of ice cubes in single-stage and double-stage condensers.
- The maximum yielding was attained as 88 % at the third trial with 6 kgs of ice cubes in single-stage and two-stage condensers, and the reaction time was 1.5 hours.
- The condenser effectiveness was achieved at 0.88 due to the number of copper windings, which has increased from 8 to 16.
- The sample of 1 ml extracted from WPO has been tested for further analysis like GCMS and FTIR analysis.
- The stretching and bending movements of carbon to hydrogen carbon to oxygen are similar to that of WPO and Pure diesel in the 500 to 4000 cm^{-1} range.

- The GCMS analysis identifies the dispersion of unknown elements with a resolution range of 300 -5000cm$^{-1.}$ Dicyclopentane from WPO has the highest probability rate of 64.2% compared to other elements, which results in achieving definite physical properties of WPO compared to diesel.
- The number of gases evolved after the experimentation process is found to be 15% by weight, the maximum amount of oil yield is found to be 65% by weight, the char yield percentage by weight is found to be 11%, and the tiniest formation of wax is found by 9% by wt.
- It was observed that the density of oil attained from mixed WPO is 826 kg/m^3, and for pure diesel, it is 837 kg/m^3. The difference in densities is 1.2 % for WPO as compared to diesel. The lesser aromatics compounds and lesser elements present in WPO compared to diesel.

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Future work

The extracted WPO is going to be tested on diesel engines with the addition of Nano additives to ensure the reduction of emissions and to improve the engine performance characteristics such as Brake thermal efficiency, specific fuel consumption and measure combustion parameters of diesel engines with mixed Nano additives. The mixed percentage of 3%, 5%, and 10% of Nano additives with B5, B10, and B15 with 3%, 5%and 10% of nano additives need to be tested on DI engines.

Abbreviations

ASTM	Americam Society for Testing Materials
Al_2O_3	Aluminum Oxides
B5	5% Nonadditive 95% biodiesel
B10	10% Nanoadditive 90% biodiesel
B15	15% Nann additive 85% biodiesel
CST	Centistokes.
DI	Direct Ignition
EETA	Endoscopic endonasal transceiver approach
FeO_2	Ferrite Oxides
KeV	Kilo electron Volt
LDPE	Low density polyethylene
GCV	Gross Calorific Value
HCl	Hydrochloride
HDPE	High density polyethylene
IIT	Indian Institute of Technology
MWP	Mixed Waste Plastics
PVC	Polyvinyl chloride
PS	Polystrene
PET	Polyethylene terephthalate
TiO_2	Titanium Oxide
GCMS	Gas chromatography
MS	Mass spectroscopy
FTIR	Fourier transform infrared radiation
20CR80S	20%chromium 80% steel
YSZ	Yitteria stabilized Zirconium
WPO	Waste Plastic oil

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