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Research Article

Experimental assessment of recycling methods of used engine oil for sustainable environment

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Abstract

Used engine oil is a high pollutant material as it contains extremely toxic contaminants accumulated during operation. These contaminants if disposed improperly can not only cause extensive damage to the environment but also affect all living organisms. To tackle this rising problem the engine oil can be recycled by recovery of its base oil and reused for various purposes. Since the cost of recycling is comparatively much lower than production from crude oil, so recycling can prove to be a preferable alternative source as crude oil reserves are getting depleted. In this research study, SAE 5W30 was collected from the vehicle where it had been used for about 3000 miles operation and the collected oil was then subjected to various recycling methods. The recycled oils obtained undergo various tests for quality check comparison by Rheometer, FTIR Spectrometer, Oil Densitometer and Flash Point Tester. From the results obtained it was clearly observed that the acid/clay treatment method fetched superlative results. The degree of viscosity reduction (%) in acid/clay treatment method was found to be 95.077% which was significantly greater than other methods. Also, different engine oil samples were analyzed and compared for contamination by FTIR spectroscopy which can assist in condition monitoring of the vehicle engine.

1. Introduction

Engine oil, also known as lubricant or motor oil, is a class of oils which has the primary purpose of reducing friction, heat and wear between the in-contact mechanical components. Lubricant (engine oil) is an oil product that separates the metal parts of an engine, reduces friction and keeps it clean [1]. The Lubrication system of engine is intended to avoid the increase of wear, over-heating and seizure of rubbing surfaces to reduce the expenses of indicated power on overcoming mechanical losses in the engine and also to remove wear products of a machine [2]. There are two basic categories of engine lubricating oil, these being Mineral and Synthetic oil. Lubricating oils refined from naturally occurring crude oil are known as Mineral oils. On the other hand, oils that are manufactured are known as Synthetic oils. Mineral oils are currently most commonly used oil as they are extracted from crude oil at low cost. Also, the viscosity of mineral oils can be varied, thus making them useful for wide range of applications.

Lubricating oils from petroleum consists essentially of complex mixtures of hydrocarbon molecules. They are mostly composed of iso-alkanes having slightly longer branches and the mono-cycloalkanes and mono-aromatics which have several short branches on the ring [3]. Lubricating oil is extremely important for the operation of the vehicles. The main

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purpose of the properly lubrication is that the engine needs to put less effort for the movement of the pistons as they tend to glide easily. Thus, ensuring that less fuel is needed by the vehicle to operate and also enabling the car to run at a lower temperature. Hence, we can safely say that the lubricating oil not only improves the efficiency of the vehicles but also ensures reduction in the wear and tear on the moving engine parts.

The modern society is based on the use of the car, which cannot operate without lubricants. With the increase of population and the number of vehicles, the quantity of waste oils has increased. The term "waste oil" characterizes any lubricating oil, mineral or synthetic, that has become unusable for the purpose for which it was originally intended [4]. Since the lubricating oil has proven to be such a valuable resource, thus there have been many efforts to recycle the used oil. Used oil, also known as sump oil, should not be thrown away as if the oil gets dirty, it can be cleaned by removing the contaminants. Disposing the used oil in the environment or burning it as a low-grade fuel, leads to some hazardous consequences such as toxic compounds in liver or complete impairment of body functions and eventually death of organism, carcinogenicity, environmental pollution, etc.

Engine oil is made up of 98% base oil and 2% additives. It loses its properties after using it for a certain period of time as high temperature degrades the additives in lubricant and dirt and wear particles get added along the way. Degradation of lubricating oil occurs when different additives or foreign substances (metallic powders, sulfur, water, carbon, ash, etc.) impurify the oil, modifying its chemical composition and affecting its properties [5]. Recycling cleans the base oil and separates the degraded additives and new additives are added to the reclaimed base oil to return the properties of the oil to original higher quality state. The conventional recycling methods used such as distillation is a high-cost technology. Recycling method serves three purposes, that is it is economical, resource conservation and environment and health protection. For this waste engine oil can be collected in batches from vehicle maintenance garages, mechanic shops, transportation companies and industries.

Various methods can be used to recycled the oil again and again so that it can be reused for various purposes. Used engine oil is an extremely dangerous pollutant as it contains high content of heavy metals and high concentrations of PAHs which are carcinogenic compounds. PAH content of used motor oil can be 670 times greater than that of new motor oil [6]. As it is insoluble, persistent and has a high content of heavy metals and other pollutants, it is necessary to collect and recycle waste oil, in order to avoid contamination of the environment [7]. The main contaminants present in the used engine oil are water, dissolved gasoline and gas oil, polymeric and non-polymeric additives, solvents, aromatics, cleaning fluids, lead, etc.

Several recycling methods have been developed and used over the time depending on the nature of base oil and contaminants. These treatment methods include acid/clay treatment method where the process is based on treating the waste oil with different acids (sulfuric, acetic, formic) to remove pollutants and then using binders (clay or bentonite) to neutralize the resulting product [8]. Activated carbon can also be used for neutralization [9]. Another method is vacuum distillation and hydrogenation/clay treatment which is a commercially available high-cost technology where vacuum distillation is done at the temperature of 250°C and followed by hydrogenation or treatment with clay in order to remove odours and the toxic compounds of nitrogen and sulfur. Solvent extraction technology is another method used which consists of dissolving the aromatic components that affect the properties of the oils, while preserving the desired components, such as saturated hydrocarbons [10]. After treating the oil with solvent, the oil is mixed with active alumina to remove the dark colour and specific odours [11]. Solvents that can be used to treat waste oils include 1-butanol, methanol, ethanol, propane, toluene, methyl ethyl ketone, acetone, etc. [12]. Membrane filtration technology is a very promising approach for recycling of engine oil where various types of membranes such as PAN, PES and PVDF can be used to achieve superlative results. It is a continuous operation that removes metal particles, soot and dust from used engine oil and also leads to the recovery of lubrication properties of the treated oil. Despite the benefits presented by this process, the membranes are expensive and can be damaged and soiled by large particles [13]. Pyrolysis using microwave heating is a relatively recent process, in which spent hydrocarbons are mixed with a strong microwave absorbing material, such as carbon particles, as a result of microwave heating, they are then thermally cracked in the absence of oxygen in shorter chains of hydrocarbons [14].

Different recycling methods such as hydrotreating [15], adsorption [16], extraction [17], coagulation, oxidation and vacuum-distillation [18] are used to tackle the management issues of waste engine oil. However, these techniques are high-cost, require high energy consumption and generate secondary pollution by-products [19]. Environment friendly methods need to be developed that have minimal impact on the ecosystem at low cost. The paper presents the methods that are economical and the materials are easily available. There is no requirement of big set-up or large capital investment. In future more efficient and economical methods can be discovered to produce higher quality of oil as crude oil reserves are getting depleted and there is an urgent need to find an alternate source.

2. Methodology

2.1. Analysis of Used Engine Oil Samples for Presence of Contaminants

5 samples of used engine oil were collected from 5 different vehicles having same engine specifications given in table 1 below, same car brand, but different models. Same engine oil was used in all 5 vehicles for approximately 3000 miles and then the oil was replaced and the used oil was collected from all the vehicles for FTIR analysis and then the resultant spectra of each oil was compared with the spectra of the virgin oil to detect the changes in the spectra. This also enables the condition monitoring of the vehicle engine as we identify the constituent(s) present in the used oil.

Table 1. Specification details of vehicle engine

Parameter	Details
Engine Displacement	796 cc
Fuel Type	Petrol
No. of Cylinders	3
Valves per Cylinder	4
Strokes of Engine	4 cycles
Models for oil collection	2011, 2013, 2015, 2017, 2019

Engine oil used for this experiment was SAE 5W30, where 5W30 is the viscosity grade of the oil. This oil is designed to perform at cold starting temperatures as well as the normal operation temperatures of 100°C without sacrificing performance. 5W-30 specifies that this is a multi-grade oil where two numbers are separated by W. The first number 5W shows the thickness/viscosity of the engine oil on vehicle start-up, when we start the engine. W, here stands for Winter, which indicates oil performance under colder engine temperatures when the engine has not been running.

2.2. Comparison of Various Engine Oil Recycling Methods

SAE 5W30 was used as a lubricating oil in 2011 model of 800 cc car engine and the oil was collected after using it for approximately 3000 miles. The collected used oil was then subjected to various treatment methods to recycle it and the characteristics of the recycled oil were then compared with that of the virgin and used engine oil by performing tests to check Flash point, Specific gravity, change in viscosity with temperature using Rheometer and Fourier Transform Infrared Spectroscopy (FTIR) on all the oils from which the absorbance levels of various parameters were calculated from the transmittance obtained at their specific spectral locations and hence the absorbance levels were compared to study the changes in the oil samples. The various methods that were used to recycle the oil are Acid Treatment Method, Activated Charcoal/ Clay Treatment Method and Acid/ Clay Treatment Method.

2.2.1. Pre-Treatment

Filtration of used engine oil was done before any treatment method in order to remove impurities such as dust, metallic chips, sand, particles, micro impurities, etc. In the pre-treatment process a funnel was placed along with the Whatman filter paper grade 1 (circular sheet with particle retention 11 µm and nominal thickness 180 µm) on top of the vacuum flask and the vacuum pump was connected to the other outlet in the bottom of the flask and thus the filtered oil was collected in the flask. The vacuum pump created a negative pressure in the flask which sucked the oil inside and left the micro particles on the filter paper.

2.2.2. Acid Treatment Method

Oil was centrifuged at 1500 rpm for few minutes and then allowed to settle down for 10-15 mins. It was then heated on magnetic stirrer and stirred continuously. The content was then allowed to cool down and then treated with conc. H2SO4 and agitated strongly to create homogeneity. Then the mixture was allowed to settle down for 48 hours and 2 layers were detected. The sludge at the bottom was separated and the remaining oil was treated with NaOH to neutralize the acid.

2.2.3. Activated Charcoal/Clay Treatment Method

100 ml of used engine oil was treated with 50 ml ethyl acetate in a separating funnel and then left at room temperature for 24 hours. After decanting from the paste left at the bottom the separated solution was then treated with activated bentonite clay and activated charcoal.

2.2.4. Acid/Clay Treatment Method

Used engine oil was centrifuged at 1000 rpm for 20-30 mins after which decantation was done to remove liquid at the top as the suspended particles get settled at the bottom. The oil was then thermally treated. 100 ml of the oil was then treated with conc. H2SO4 and in the end activated bentonite clay was added.

3. Results and Discussion

3.1. Analysis of Used Engine Oil Samples for Presence of Contaminants

FTIR Spectroscopy consists of an interferometer which is used to modulate the wavelength from a broadband infrared source. The intensity of transmitted or reflected light is measured by the detector as a function of its wavelength. The interferogram obtained from the detector in form of the signal is analysed with a computer to obtain a single beam infrared spectrum by using Fourier Transform. FTIR spectra is plotted between wavenumber (cm-1) and intensity which can be represented as the light transmitted or absorbed at each wavenumber. For qualitative material identification the unknown IR absorption spectrum is compared with spectrum of known material to identify the constituent(s) of the sample. Absorption bands in the range 4000-1500 are usually due to functional groups and absorption bands in the region from 1500-400 is due to intramolecular phenomena specific to particular material. This specificity of these bands enables identification of the constituent in the sample.

Table 2. Spectral locations of various components in used engine oil (FTIR)

Component	Spectral Location (cm^{-1})
Moisture	3400
Soot	2000
Oxidation/ viscosity	1750
Carboxylic acid	1725-1700
Nitration	1650-1600
TBN	1170
Sulfation	1150
ZDDP	980
Aromatics and PAHs	650-850

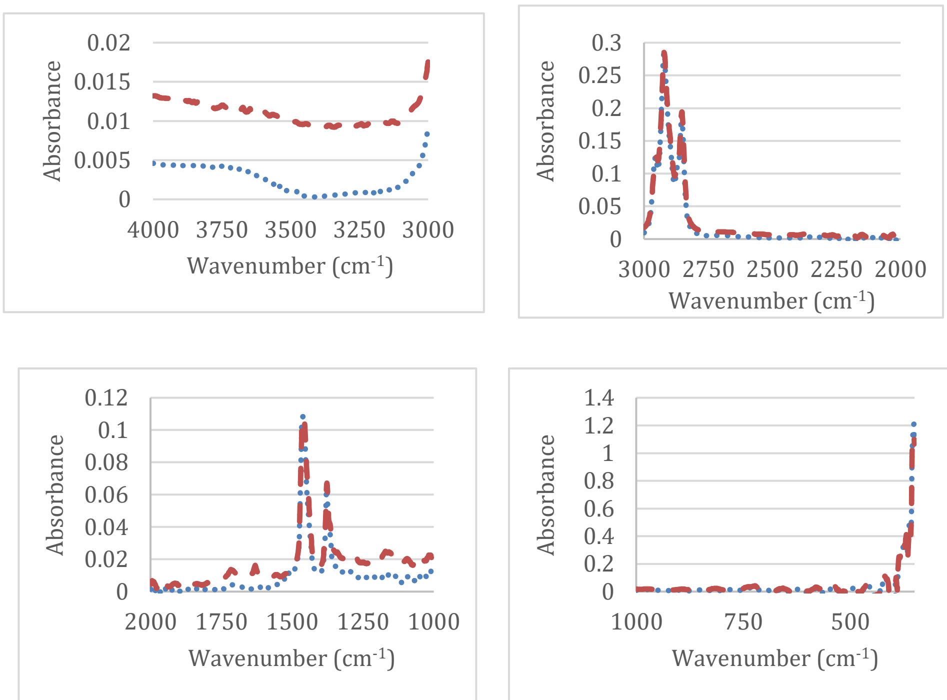


Fig. 1 FTIR of oil sample 1 from spectral locations 4000 to 300 cm^{-1} (red-used engine oil, blue- virgin oil)

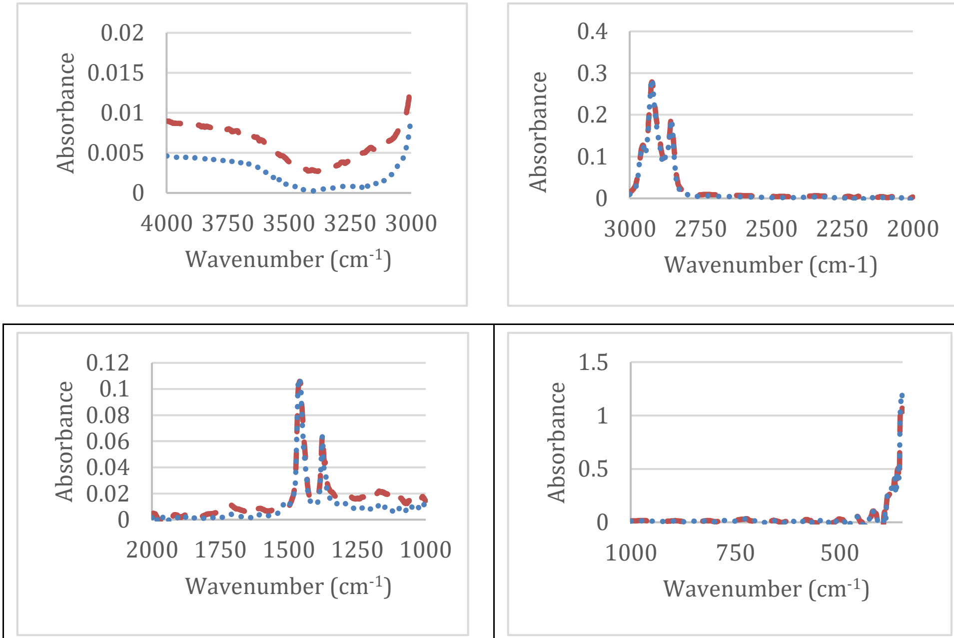


Fig. 2 FTIR of oil sample 2 from spectral location 4000 to 300 cm-1 (red-used engine oil, blue- virgin oil)

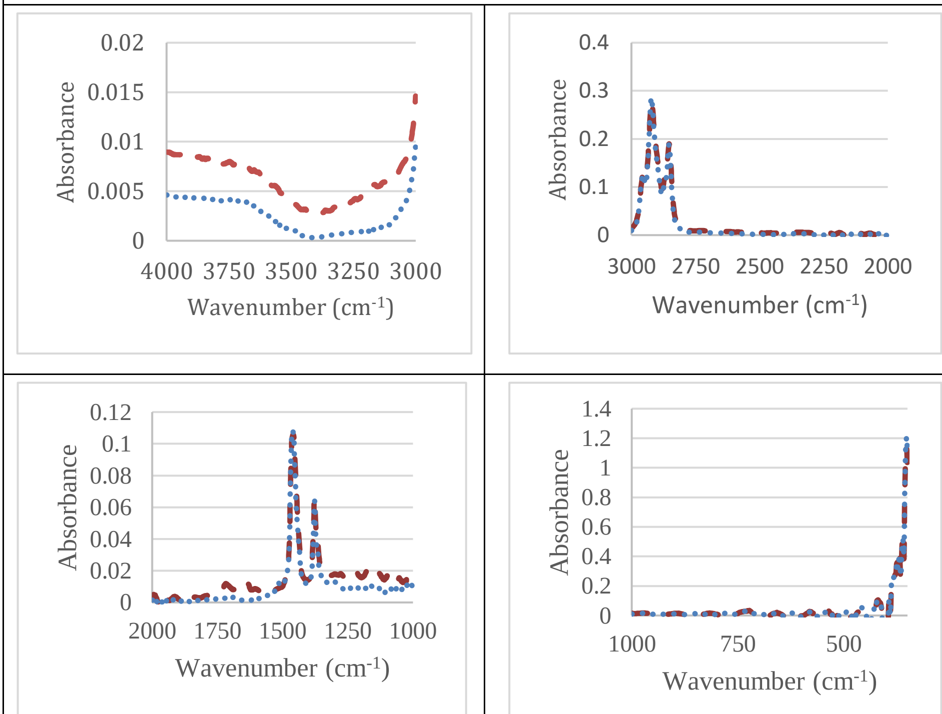


Fig. 3 FTIR of oil sample 3 from spectral location 4000 to 300 cm-1 (red-used engine oil, blue- virgin oil)

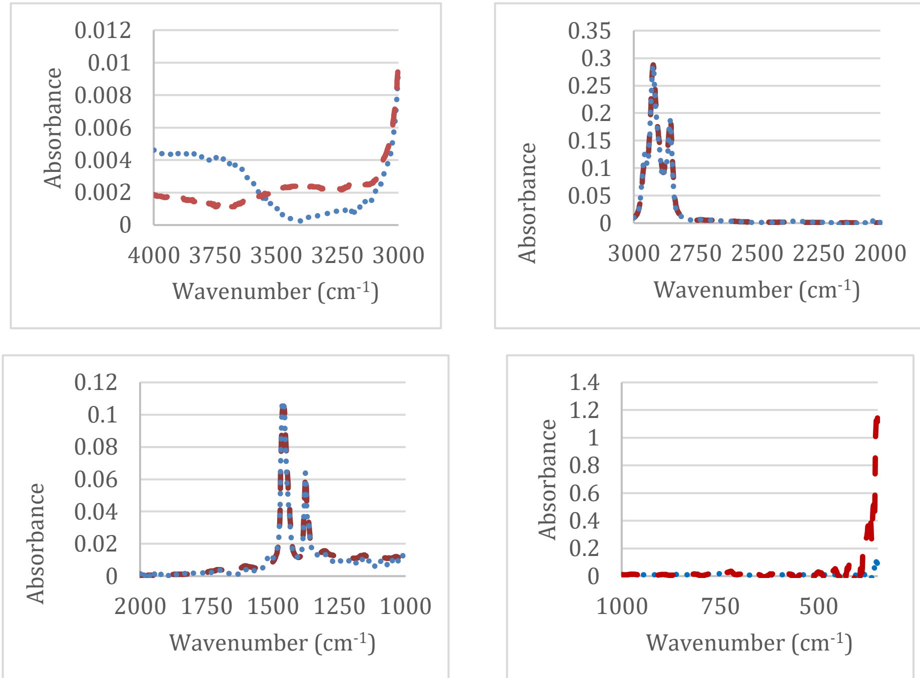


Fig. 4 FTIR of oil sample 4 from spectral location 4000 to 300 cm^{-1} (red-used engine oil, blue- virgin oil)

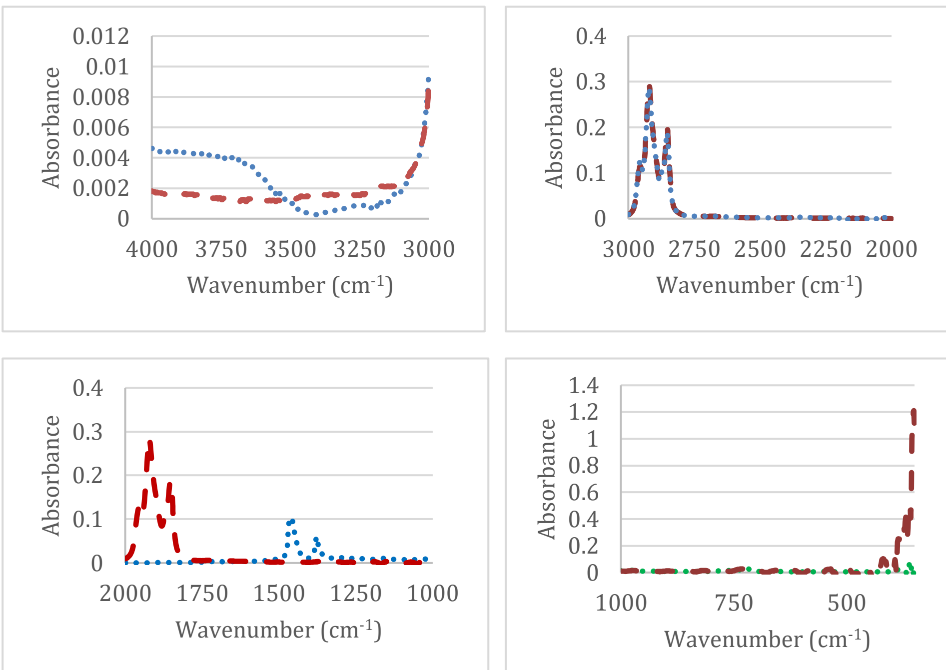


Fig. 5 FTIR of oil sample 5 from spectral location 4000 to 300 cm^{-1} (red-used engine oil, blue- virgin oil)

Table 3. Summary of parameter comparative graphs

Contaminant	Vehicle make (year)				
	2011	2013	2015	2017	2019
Moisture	Increases	Mild Increase	Mild Increase	Mild Increase	Mild Increase
Soot	Increases	Decreases	Increases	Decreases	Decreases
Oxidation/Viscosity	Increases	Moderate Increase	Increases	Mild Increase	No change
Nitration	Increases	Moderate Increase	Moderate Increase	Mild Increase	Mild Increase
TAN	Increases	Mild Increase	Increases	Mild Increase	No change
TBN	Decreases	Mild Decrease	Decreases	Mild Decrease	No change
Sulfation	Increases	Moderate Increase	Increases	Mild Increase	Mild Increase
ZDDP	Mild Increase	Decreases	Mild Increase	Decreases	Mild Increase
Aromatics &PAHs	Mild Increase	Mild Increase	Mild Increase	Mild Increase	Mild Increase

Instrumental Error and uncertainty:

With reference standards, uncertainty level of ±0.03 % has been observed in FTIR Spectrometer and instrumental error of almost ± 3% in rheometer. In oil densitometer creation of bubbles in sample can cause error in readings. The oil densitometer is capable of determining the density of liquids across temperature range of -40 to 150°C, at pressures from 0.1 to 30 MPa with expanded uncertainty of 0.015% (at 95% confidence).

3.2. Comparison of Various Engine Oil Recycling Methods

3.2.1. Flash Point and Specific Gravity

Flash point is the lowest temperature at which enough vapours are developed for ignition under specified conditions. This is an important characteristic as it contributes to the scope of lubricating oil since a vehicle can achieve the temperature of 150°C, so no engine oil with flash point of 150°C or less can be used.

Specific gravity or relative density is the ratio of the mass of given volume of product and mass of equal volume of water at same temperature. Standard reference temperature to measure specific gravity is 15.6°C. It is determined by ASTM D 1298. Higher the specific gravity of the material, heavier it will be.

At flash point, oil develops enough vapors to ignite and then it continues to burn afterwards. Oil with flash point of 150°C or less cannot be used as the vehicle engine has the capability of attaining 150°C during operation and can increase fire and explosion risk. Thus, it is advisable to change the engine oil after certain period of time as it is evident from table 4 that the flash point of used engine oil has decreased considerably to 156°C due to dilution and addition of contaminants during operation. It is further observed from the readings that increase in flash point after recycling of oil is quite evident and hence deeming it safe for usage.

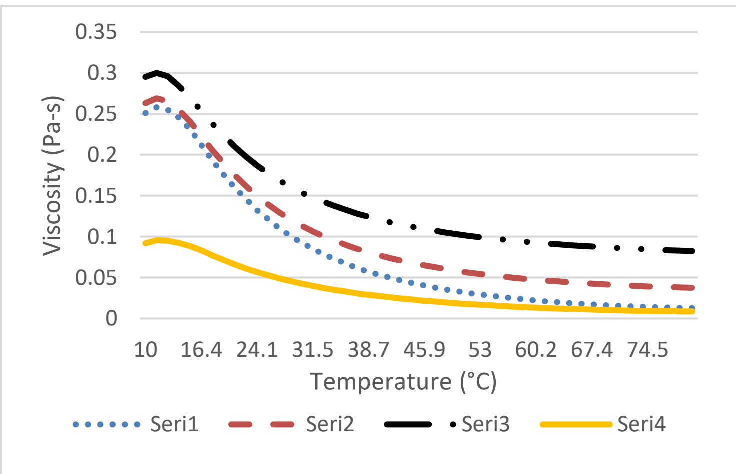
Specific gravity relates density of oil to that of water and is measured by oil densitometer. Since it is known that specific gravity of water is equal to 1, so if the oil attains specific gravity of greater than 1, then it will become heavier than water and anything lighter than water will have specific gravity of less than 1. Since engine oil has specific gravity of less than 1, so it is less dense than water. Hence, if there is moisture problem in the vehicle engine, it will get collected and settled at the bottom of the sump, so it can be drained out first and easily. From table 4, it is observed that in used engine oil there is increase in specific gravity and it occurs when oil becomes thicker due to addition of contaminants. This will in turn cause wear particles and contaminants such as rust to settle down slowly, which can lead to failure of the system, as longer the particles are in the suspension, more cavitation and corrosion they can cause.

Table 4. Flash point and specific gravity of all oil samples

	Used Engine oil	Recycled oil (Acid Treatment Method)	Recycled oil (Activated Charcoal/ Clay Treatment Method)	Recycled oil (Acid/Clay Treatment Method)	Virgin oil
Flash Point (°C)	156	192	202	213	232
Specific Gravity @ 15.6°C	0.956	0.901	0.897	0.891	0.8818

3.2.2. Change in Viscosity with Temperature

Viscosity is inversely proportional to the temperature and can be measured by a rheometer, as when temperature increases the lubricant becomes thinner and thus its load bearing capacity is reduced. But when the temperature decreases, lubricant becomes thick which makes it difficult to pour or pump it. Increase in viscosity of engine oil can be a contribution of oxidation, polymerization, soot, other contaminants, anti-freeze, etc.



Series 1 Recycled oil (Acid/Clay Treatment Method)
Series 2 Recycled oil (Activated Charcoal/ Clay Treatment Method)
Series 3 Recycled oil (Acid Treatment Method)
Series 4 Pure/ Virgin oil

Fig. 6 Effect of temperature on viscosity (Rheometer readings)

Oil thickness, also termed as viscosity determines the film strength of engine oil and its efficiency to prevent friction and thus wear between two moving parts of the engine. If the oil has high viscosity, it is thick and vice versa. For proper operation, engine oil should have perfect viscosity so that it is neither too thick to pour at low temperatures, nor becomes too thin as the temperature increases that it will not create an appropriate film between two parts as the temperature of the vehicle engine varies from ambient temperature to 150°C during operation. For too thick oil, engine has to work harder which in turn generates more heat whereas too thin oil is not enough for friction, hence causing unnecessary wear and tear in both cases. From figure 6, it is clearly observed that acid/clay treatment method has lower viscosity at low temperature and the viscosity gets closer to that of virgin oil as the temperature increases.

The flow characteristics of the oil are mostly affected by the operating temperatures. At high temperature, since viscosity is reduced so it is easy to pump the oil. In order to evaluate the improvement in flow characteristics of obtained recycled oils, we can calculate the degree of viscosity reduction (%) from rheometer observations of viscosity as a function of temperature at constant shear rate, where;

$$\text{DVR (\%)} = \frac{initial\ value - final\ value}{initial\ value} \text{ x } 100$$

and, thus from table 5 we can observe that the recycled oil obtained from Acid/clay treatment method has maximum DVR % reduction and hence has better fluidity enhancement.

Table 5. Viscosity reduction of various recycled oils

Recycled oil	Initial Value Viscosity (Pa-s)	Final Value Viscosity (Pa-s)	DVR %
Acid Treatment Method	0.3	0.0823	72.56
Activated Charcoal/ Clay Treatment Method	0.269	0.0375	86.05
Acid/Clay Treatment Method	0.258	0.0127	95.077

3.2.3. Fourier Transform Infrared Spectroscopy

The oil can be analyzed by Fourier Transform InfraRed (FTIR) Spectroscopy which is a proven technique to analyze and characterize the used and recycled engine oil samples. When the engine oil is exposed to infrared radiation, the molecules absorb radiation at different wavelengths and thus the contaminants are detected by the absorbance value at particular spectral locations, the absorbance value being directly proportional to the quantity of the contaminant. Following absorbance levels were recorded by FTIR in the oil samples at specific spectral locations of various functions groups:

Since absorbance value of contaminants and functional groups is directly proportional to the quantity of contaminant present in the oil, as more the contaminant, more radiation it will absorb. So, from table 5, it is observed that there is increase in the absorbance value of used engine oil when compared to that of virgin oil due to addition of contaminants and then decrease in the absorbance values can be observed in recycled oils.

In the research study various methods were used to return the lubricating oil to its original state so that it can be reused by removing the contaminants. Analyzing the results, we can observe that oil recycled by Acid/clay treatment method has shown maximum recovery and improvement. It was also observed that using materials such as sulfuric acid for recycling can be harmful as it produces high sulfur level by-products that are toxic.

Used engine oil is an incredibly toxic material. It does not wear out and only gets filthy by the addition of contaminants and thus can be cleaned of contaminants and recycled continuously to the point where it can be reused as fuel oil, hydraulic oil or in the manufacture of many petro-chemical based products such as plastics.

Table 6. Absorbance values of all oil samples measured by FTIR spectroscopy

Contaminant/ Functional group	Virgin oil	Used Engine Oil	Recycled oil (Acid Treatment Method)	Recycled oil (Activated Charcoal/ Clay Treatment Method)	Recycled oil (Acid/Clay Treatment Method)
Moisture	0.0002	0.00943	0.00283	0.0024	0.0015
Soot	0.00147	0.004715	0.00049	0.00049	0.000177
Oxidation/ Viscosity	0.002045	0.00753	0.00424	0.0029	0.00205
Carboxylic Acid	0.000397	0.01363	0.01188	0.01144	0.005
Nitration 1600 cm^{-1} (Series 1)	0.00156	0.0097	0.00679	0.00499	0.00307
Nitration 1650 cm^{-1} (Series 2)	0.00392	0.01148	0.00804	0.00655	0.00451
TBN	0.0109	0.0248	0.0166	0.01264	0.0102
Sulfation	0.0096	0.02305	0.0184	0.01366	0.0102
ZDDP	0.01416	0.0191	0.01365	0.01366	0.01246
Aromatics & PAHs 650 cm^{-1} (Series 1)	0.00828	0.0162	0.00745	0.00977	0.00853
Aromatics & PAHs 720 cm^{-1} (Series 2)	0.0323	0.0339	0.0304	0.0311	0.0319
Aromatics & PAHs 850 cm^{-1} (Series 3)	0.01068	0.0185	0.0124	0.0143	0.0122

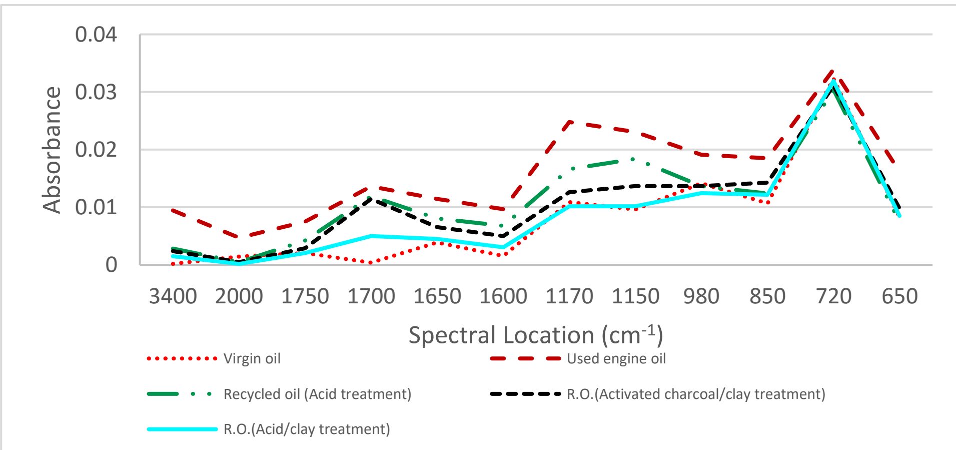


Fig. 7 FTIR Spectroscopic comparison of recycled oils

Table 7. Comparison of efficiency in reducing contaminant level by various methods

Contaminant	Acid Treatment Method	Activated Charcoal/Clay Treatment Method	Acid/Clay Treatment Method
Moisture	Minimum decrease	Median decrease	Maximum decrease
Soot	Minimum decrease	Minimum decrease	Maximum decrease
Oxidation/Viscosity	Minimum decrease	Median decrease	Maximum decrease
Carboxylic Acid	Minimum decrease	Median decrease	Maximum decrease
Nitration 1600 cm^{-1}	Minimum decrease	Median decrease	Maximum decrease
Nitration 1650 cm^{-1}	Minimum decrease	Median decrease	Maximum decrease
TBN	Minimum decrease	Median decrease	Maximum decrease
Sulfation	Minimum decrease	Median decrease	Maximum decrease
ZDDP	Minimum decrease	Minimum decrease	Maximum decrease
Aromatics & PAHs 650 cm^{-1}	Maximum decrease	Minimum decrease	Median decrease
Aromatics & PAHs 720 cm^{-1}	Maximum decrease	Median decrease	Minimum decrease
Aromatics & PAHs 850 cm^{-1}	Median decrease	Minimum decrease	Maximum decrease

Table 8. Impact of contaminants found in used engine oil

Contaminants	Observed effect
Poly-cyclic aromatic hydrocarbons (PAHs) formed by incomplete combustion of organic matter	They are classified as human carcinogens causing various types of cancers.
Heavy metals	Cancer, anemia, skin ulcerations and cardiovascular diseases.
Particulates produced by burning of used oil	Respiratory problems such as loss of lung function, loss of ability to resist infection and death.
Sulphur dioxide and Nitrogen dioxide	Adverse respiratory effects on humans and deterioration of foliage and plant growth.
Organo-chlorine compounds such as dioxins and furans	Skin toxicity, immune-toxicity, Carcinogenicity and adverse effects on reproduction, development and endocrine functions.
Polychlorinated biphenyls (PCBs)	Liver damage, respiratory problems, cancer promotion, endocrine disruption and neurotoxicity.
Harmful metals such as arsenic, cadmium, chromium, zinc and lead formed by the decomposition of the additive lead tetraethyl	Acute toxicity in fish and tumors. Also, direct toxicity in plants.
Mercury, PCBs and Organo-chlorine	Secondary poisoning in organisms.
Oil floating on surface of water bodies	Prevents penetration of oxygen in water and has an adverse effect on aquatic life.

Oil sample on x-axis:

1- Virgin oil

2- Used Engine oil

3- Recycled oil (Acid Treatment Method)

4- Recycled oil (Activated Charcoal/ Clay Treatment Method)

5- Recycled oil (Acid/Clay Treatment Method)

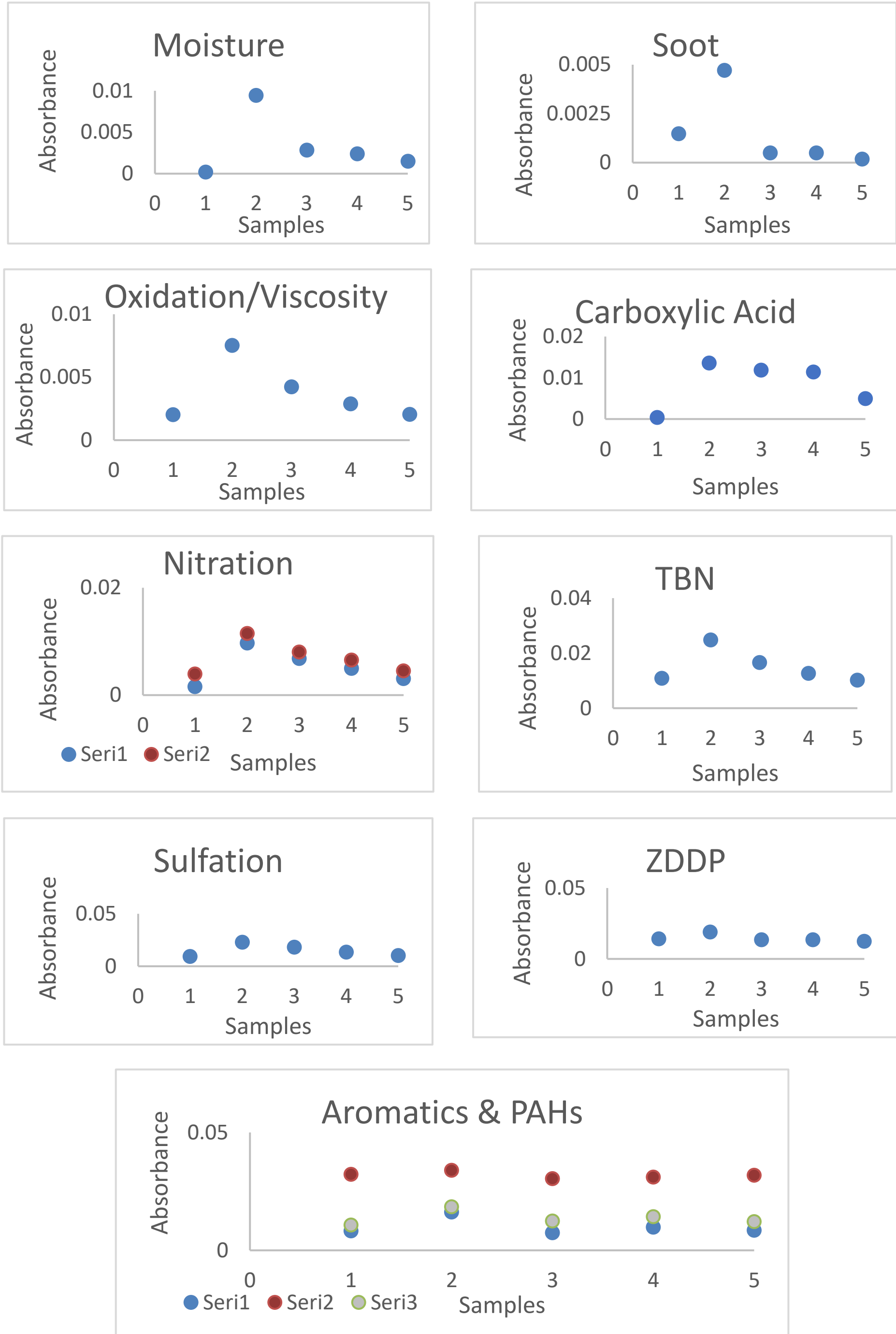


Fig. 8 Comparison graphs of contaminants in all oil samples

4. Conclusion

Million tonnes of used engine oil are spilled into the environment each year thus leading to massive damage of human health and of other living organisms including the plants. Recycling and reusing used engine oil is considered to be a preferable way rather than disposal as it can provide great environmental benefits. Recycled engine oil can be processed into fuel oils and can be used as low-grade oil. Re-refining removes the to produce new base oil and the base oil obtained can be blended with fresh additive to restore the oil to its original effectiveness. Successful recycling of this used engine oil can not only solve the environmental pollution problem but also can prove to be economical as well as the crude oil reserves are getting depleted day by day. Experimental results obtained from this research indicate that a good quality base oil can be obtained from waste engine oil at relatively very low cost when compared to production from crude oil. Further research in this field can provide additional benefits as there is a scope of converting the by-products of the experiments into valuable products. Since already existing commercially used distillation process is costly and has tendency to break down frequently, the methods used in this research can prevent that downtime and thus the loss of time, labour and money. The benefits of recycling and reusing used engine oil are three-fold:

- *Economical:* Since oil is considered to be a non-renewable resource, so it will become increasingly difficult to find new reserves in future. The price of oil rises with time as the reserves of crude oil gets depleted. Recycling will provide time to develop alternate fuels and thus reusing of the recycled oil will save lot of money.
- *Public Health:* Health sector can be seriously threatened if oil is disposed of improperly as it enters the air, water and soil. Recycling and reusing waste oil can prevent its improper disposal and thus entering into the systems of plants and animals where it can cause toxic reactions and various terminally ill diseases like cancer etc. which can eventually lead to death of organisms.
- *Environmental:* Improper disposal of waste oil can create both air and water pollution which can have various hazardous consequences. It can only be prevented by reusing the waste oil and thus saving the environment as the contaminants in the gases can even cause damage to the ozone layer.

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