



Recycling Process of Gasoline Engine Oil (LUKOIL 20W50) Using Organic Solvents

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Abstract

Used engine oil generally contains environmentally harmful pollutants, so it should not be disposed of or discarded randomly. It is not possible to reuse this oil without recycling it because its specifications change when it is used in different engine operating conditions. As a result, the goal of this study is to recycle a particular kind of locally accessible oil known as "LUKOIL 20W50" by a solvent extraction using a combination of toluene and methanol (in equal amounts) at room temperature. The ratio of used oil to composite solvents was chosen as 2:3 after several tests to determine the appropriate ratio.

The recycling process comprised three stages: filtration using a Büchner funnel to remove the solid contaminants, followed by solvent extraction of the oil, and finally the adsorption process using aluminum oxide to restore the oil color.

Several physicochemical tests, including specific gravity (S.G.), kinematic viscosity (K.V.), flash point (F.P) and density (ρ) were performed on samples of fresh and used oil to monitor the changes induced by the treatment process. The obtained results demonstrate the effectiveness of this approach to oil recycling for reuse and its compliance with environmental and technical standards. This recycling process offers a valuable contribution to resource conservation and environmental protection by effectively reusing waste engine oil.

Furthermore, a simulation of the extraction process was carried out using Aspen HYSYS V11.1. The results obtained from the simulation were highly consistent with the experimental results with an inaccuracy of less than 1%.

Keywords: Waste lubricating oil, Oil recycling, , toluene and methanol, Organic solvents, Solvent extraction, oil recovery, gasoline engine oil , Regeneration process.

1. Introduction

Lubricating oil is essential for reducing friction and wear in machinery and automotive engines. During use, engine oil undergoes oxidation and degradation, accumulating various contaminants such as metals, acids, and asphaltic compounds [1,2]. Traditional recycling methods often involve harmful chemicals or costly technologies, producing environmentally hazardous byproducts. Most lubricants are mineral oils derived from crude oil, and due to their widespread use, over 24 million tons of used oil are discarded annually, posing serious environmental threats [3,4]. This study investigates the purification of used gasoline engine oil using organic



solvents, specifically the separate and combined use of toluene and methanol, as a safer and more sustainable alternative [5].

Since the late 19th century, petroleum use has advanced with the development of gasoline-powered internal combustion engines. By 1910, gasoline became the most widely demanded petroleum product due to its essential role in automobiles. To meet performance requirements such as anti-knock quality, quick ignition, and responsiveness, gasoline is blended with components like butane, MTBE, and reformates. Similarly, diesel is produced through the hydrogenation of light oils, with a focus on high cetane value and low sulfur content [6].

Oil analysis began in the 1940s with U.S. railroads and expanded to the military and aviation sectors by the 1950s and 1960s, eventually reaching commercial labs. Fuels are categorized as solid, liquid, or gaseous, with gasoline engines typically using liquid hydrocarbons, though biofuels and gaseous alternatives are also used in urban settings. Lubricating oil primarily consists of a base fluid (72–96%) and chemical additives (4–28%) that improve performance and reduce friction and wear [7,8]. Gasoline typically contains a mixture of hydrocarbons: aromatics, alkanes, isoalkanes, alkenes, and cycloalkanes, along with additives for enhanced stability. Most lubricants are based on mineral or synthetic oils with chemical additives (2–25%) that provide properties like corrosion resistance and friction modification [9,10]. Gasoline is refined from crude oil, and straight-run gasoline is blended with other components to meet modern engine requirements, typically containing hydrocarbons in the C₄–C₁₂ range [11].

Engine oils serve multiple purposes, primarily reducing friction and heat in internal combustion engines. Choosing the appropriate oil depends on the engine type, age, climate, and driving conditions [12].

Full Synthetic Oils: Made from chemically engineered base stocks, offering superior performance, fuel efficiency, and long service intervals.

Synthetic Blends: Combine conventional and synthetic oils, providing balanced performance at a lower cost.

Conventional Oils: Derived from crude oil, these oils are more suitable for older engines, cost-effective but require frequent changes.

2. Gasoline engine oil recycling processes

Used engine oil becomes contaminated with both internal and external pollutants, making proper recycling essential. Improper disposal harms the environment and wastes valuable resources.

2.1 Recycling Techniques

The keys of recycling techniques include

- Acid/clay treatment
- Solvent extraction
- Vacuum distillation (with clay or hydrogenation)
- Membrane filtration

Used oil contains toxic substances like PAHs, PCBs, and heavy metals, posing environmental and health hazards. Recycling reduces pollution and offers economic value, particularly when using environmentally safer processes like acetic acid treatment, which effectively separates oil and sludge at room temperature without degrading the quality of the base oil [11].

Improper disposal of used motor oil contaminates soil, water, and marine life. Auto repair shops are major contributors. Marine oil spills cause widespread ecological and economic damage. About 75% of a vehicle's weight is recyclable. However,

25%—known as Auto Shredder Residue (ASR)—is mostly composed of plastics, foams, and rubber, lacks affordable recycling solutions. Used motor oil contains hazardous hydrocarbons in the C20–C40 range, heavy metals, and toxic additives, making safe disposal critical [13,14].

3. Experimental work

3.1. Materials and methodology

In this study, a lubricating oil of the type (LOUKOIL 20W50) produced by a private Russian company was used according to the API SL/CF standard specifications. It is one of the mineral engine oils specifically designed for gasoline engines (Figure 1A). The used oil was collected from a car with a moderately old engine (Figure 1B). It had been used in the engine for about three months and had covered a distance of about 4000 km and the samples of the unused and used oil are shown in Figure 2.



Figure1 :A: Fresh oil, B: Used oil



Figure 2 : Samples of unused and used oil

Two types of solvents were used for the study, methanol and toluene with a purity of more than 99%. The solvents were obtained from the Research Laboratory of the Faculty of Science at Sirte University.

For the adsorption process, aluminum oxide (Al_2O_3) (Figure 3) was used. This reagent is used to remove the dark color of the recycled oil and return it to a color similar to that of fresh oil. The ratio of aluminum oxide to recovered oil was taken as 1:6 by weight, as recommended in [1,2]

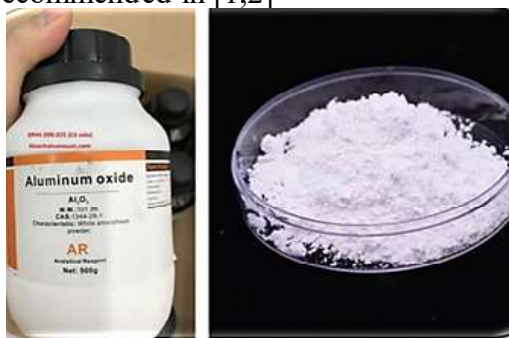


Figure 3: Aluminum Oxide

3.2 Procedure

The used lubricating oil was subjected to filtration before treatment (Figure 4). This was done using a funnel with a filter paper ($\phi 70$ mm) placed in it, and then a vacuum pump was connected to the filtering flask, to which the funnel was fixed with the aid of a rubber stopper. A total of 1500 ml of used oil was filtered through a Büchner funnel using a pump. The filtration process took two days, resulting in a final volume of 1300 ml of filtered oil.



Figure 4: Filtration process

For the extraction process, many experiments were conducted to choose the oil-to-solvents volume ratio. The oil and solvents were used in a different ratio but in small quantity of 50:50ml of oil and organic solvents. The mixture was mechanically stirred and then left in a separation funnel to settle for 24 hours (Figure 5). The best ratio was 2:3 by volume. At this ratio, the separation layers were well defined. About 200 ml of filtered used lubricating oil that filtered was mixed with a blend consisting of 150 ml of toluene and 150 ml of methanol in a closed vessel.



Figure. 5 Sample separated into two layers (in beaker and funnel)

The clear surface oily layer containing solvents and oil was then transferred to a rotary evaporator (Figure 6) in order to separate the solvents from the regenerated lubricating oil. The sample was evaporated at 120 °C to ensure complete solvent evaporation and obtain the recovered oil. This distillation process took approximately two hours.



Figure :6 Rotary evaporator

The separated base oil was then mixed with aluminum oxide at a mass ratio of 1:6 with continuous stirring for a sufficient period. The aluminum oxide was added to remove the dark color. Then, the mixture was left for three to four hours to allow the alumina and impurities to settle, followed by filtration using filter paper to recover the base oil from the remaining mixture.

3.3 specification analysis

Analysis of fresh, used and extracted engine oil was performed and compared with standard values of SAE. The specifications analyzed were specific gravity (S.G.), kinematic viscosity (K.V.), flash point (F.P.) and density. These properties will show the quality of recycled oil, and indicate the effectiveness of the process.

- (S.G.): A 25 ml specific gravity bottle and a weighing balances were used to measure specific gravity. The empty specific gravity bottle was weighed. The specific gravity bottle was filled with oil and then weighed again. The difference gave the mass of the oil. The mass of the oil was divided with its volume to find the density of the oil. Specific gravity of oil was found by:

$$(S.G.) = \rho \text{ of oil} / \rho \text{ of water}$$

- (K.S.): Viscosity analysis shows the presence of different types of contamination in used engine oil. The products of oxidation and polymerization (these products can be both dissolved and suspended) in the oil cause an increase in the viscosity of used engine oil, while a decrease in the viscosity of engine oil shows fuel contamination. The kinematic viscosity of the samples was calculated using a viscometer (II). The time taken by the oil to pass through a small orifice and be collected in a 50 mL beaker was noted and the viscosity was calculated by using correlations.
- (F.P.): This is the lowest temperature at which the vapors in air will burn momentarily if ignited by a flame or spark. A decrease in flash point indicates contamination due to the dilution of lubricating oils with unburned fuel. An increase in flash point indicates the evaporation of the light components from the lubricating oil. This property was measured according to ASTM 93 using an open-cup flash point apparatus, the flash points were determined by heating the oil in an open-cup apparatus. The temperature at which the fumes of the oil catch fire momentarily was termed as the fire point.
- (ρ): Density was determined at 15 °C according to ASTM 7042. **Using a hydrometer, the density of the oil was determined. A hydrometer is** a device that measures the density of a liquid by measuring its buoyancy. It consists of a glass tube with a weighted bulb at one end. By floating the hydrometer in the oil sample, **the density can be read** directly from the scale on the tube.

4. Results And Discussion

The recycled oils must possess specific properties in order to meet the engine requirements. It is well known that the physical properties of used engine oil change for different reasons, such as oxidation, contamination, thermal degradation, fuel contamination and prolonged use. These changes may affect its colour, density, viscosity, flash point, etc.

Therefore, four different physical properties (S.G., K.V., F.P., and ρ) of the unused and used engine oil for this study were measured and compared. All measurements were conducted at the laboratories of RASCO Oil Company.

4.1 Specific Gravity (S.G)

The specific gravity (S.G) of engine oil is a very important indicator that expresses the ratio of the density of the oil to the density of an equal volume of water. This index is greatly influenced by the strength of hydraulic movement and reflects the energy supply in the mechanical cycle. In cars, this feature is important in determining the quality of engine oil, along with other properties. The specific gravity of engine oil samples was measured using digital hydrometer Thermo-Hygro (RASCO Oil Company) according to the standard test method of ASTM 7042 at a temperature of 15.6 °C. The resulting values are shown in Figure 7.

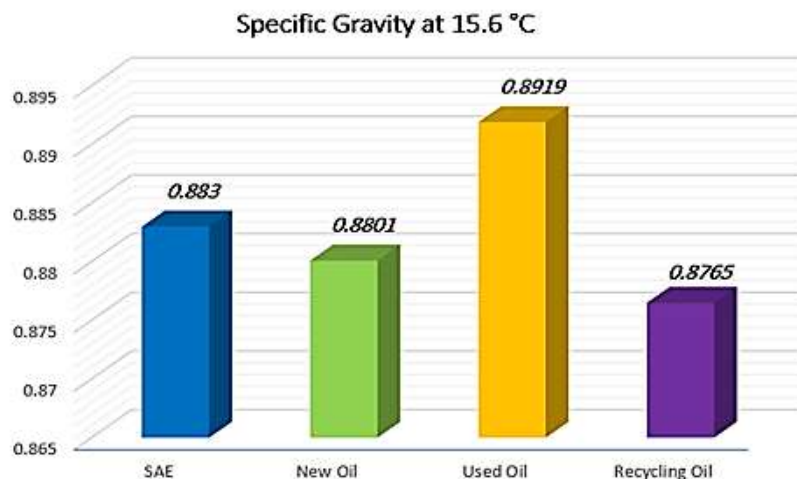


Figure7: (S.G) of engine oil at 15.6 °C

The S.G of used engine oil was 0.8919, whereas the value of the engine fresh oil is 0.8765. It is clear that the specific gravity of used oil exceeds that of fresh or unused oil by about 0.0154. At the same time, it is higher than the standard value registered by the Society of Automotive Engineers (SAE). This increase could be due to the accumulation of oxidation products and the presence of various contaminants with higher density, which undoubtedly result in an increase in the specific gravity of engine oil.

After the recycling process by solvent extraction, the specific gravity returned to a value very close to that of the unused oil. This indicates that the recycling process using composite organic solvents is effective and reliable. This effect is clearly shown in Figure 7.

If the specific gravity values of recycled and new oil were compared, it can be seen that the oil is re-refined by about 99.6%.

4.2 Kinematic Viscosity (K.V)

Viscosity is a crucial property in the manufacturing of crude oil and its derivatives, including lubricating oils. Viscosity represents the resistance of fluids to flow, which greatly depends on temperature. Viscosity is significantly affected by temperature changes. The operating temperature of car engines ranges from 40 °C to 100 °C. The standard viscosity value of lubricating oil given by the Society of Automotive Engineers (SAE).

Kinematic viscosity for all samples was measured, according to the standard test method of ASTM 7042, at temperatures of 40 °C and 100 °C, and the results are shown in Figures 8 and 9, respectively.

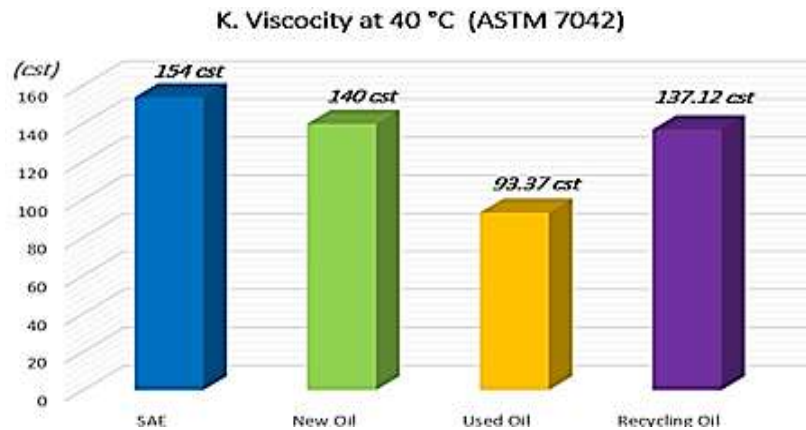


Figure 8: (K.V) of engine oil at 40 °C

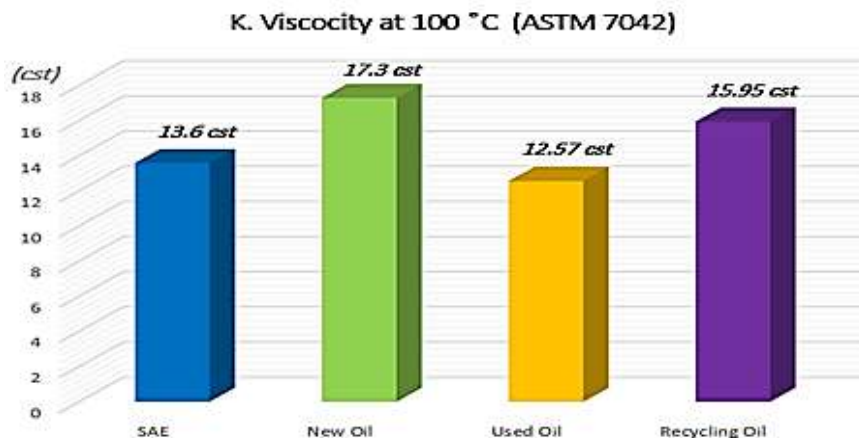


Figure 9: (K.V) of engine oil at 100 °C

The first observation from the results is that the viscosity of the new oil used in this study does not match the values listed by the Society of Automotive Engineers (SAE) at both mentioned temperatures. At a low temperature, the viscosity of new oil is less than that of the SAE value, whereas at a high temperature, the viscosity of new oil is much higher than the SAE value. This may indicate that this oil is not of high quality according to the viscosity range.

The results also indicate that the viscosity of the used oil has significantly decreased compared to the viscosity of the virgin oil.

At a temperature of 40 °C, its value decreased from 140 cSt to about 93 cSt which is very low compared to the SAE value as well as the virgin oil value. This decrease may be due to the formation of oxidized compounds, the accumulation of contaminants such as residues from the internal combustion engine, thermal degradation and/or fuel contamination due to either leaks or incomplete combustion processes.

The value of viscosity after the recycling process was about 137 cSt, with a deviation of 2% from the value of virgin oil. The deviation may be acceptable, and we can say that the recycling process is effective.

At a temperature of 100 °C, its value decreased from 17.3 cSt to about 12.57 cSt, whereas the value of viscosity after the recycling process was 15.95 cSt, with a deviation of 8% from the value of virgin oil. Despite the clear improvement in viscosity values after treatment, they still do not match those of the virgin oil. This can have improved by using some additives to enhance the oil's properties after treatment, such as polymers that improve the viscosity.

Both Figures 8 and 9, give a comparison of kinematic viscosity values at 40 °C and 100 °C, respectively, of all samples and the SAE value. These plots clearly show the effectiveness of the recycling process in improving the viscosity of engine oil under study.

4.3 Flash Point (F.P)

An open-cup flash point apparatus was used to analyze the flash points of the samples according to by the standard test method of ASTM 93. A beaker containing a certain amount of sample was placed on a Bunsen Burner, which was fitted with a thermometer. A flame source was brought at intervals to determine the temperature at which a flash appeared on the surface of the sample while the lube oil in the beaker was heated.

The flash point of the fresh engine oil was 195 °C, that of the used engine oil flash point was 172°C, and that of the recycled engine oil treated using the composite solvent treatment method flash point was 185 °C, as shown in Figure 10.

The Lower flash point the value of used engine oil is due to the presence of unburned fuels and/or contaminants, which may be due to either leaks or incomplete combustion processes. Another observation is that the flash point of the fresh engine oil is lower than the value specified by SAE. This may indicate an information that the properties of the engine oil used here do not exactly match the standard values. However, flash point of recycled engine oil using composite solvents (Methanol and Toluene) is suitable compared to the value of fresh oil.

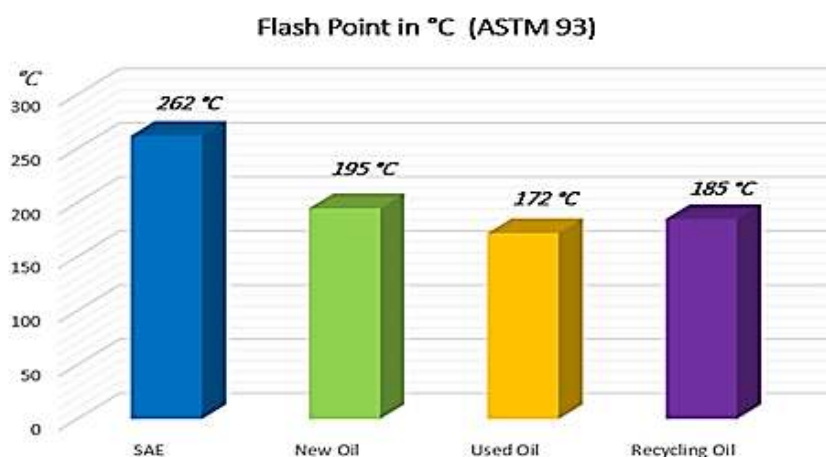
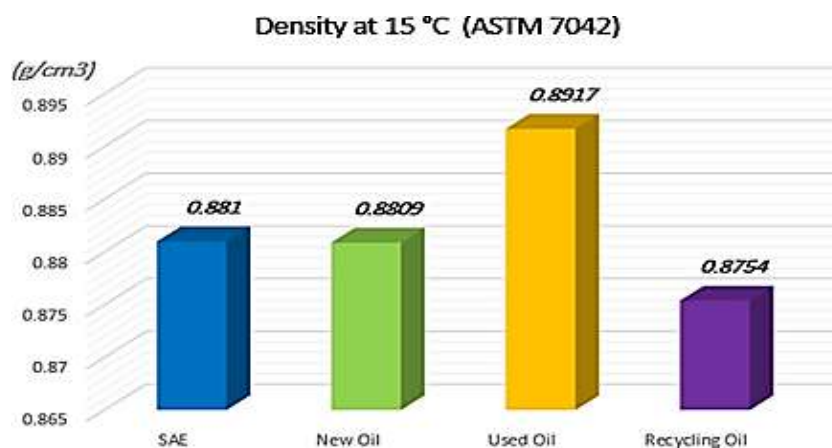


Figure 10 : (F.P) of engine oil

However, the flash point of recycled engine oil using composite solvents (Methanol and Toluene) is suitable compared to the value of fresh oil. The improvement in the flash point value of the recovered engine oil was about 95% of the flash point value of the virgin oil. This indicates the efficiency of the recovery process using the composite solvents.

4.4 Density (ρ)

Densities of engine oil samples were measured according to the standard test method of ASTM 7042 at a temperature of 15 °C. It is clear from the results that the measured density value of fresh oil and the value according to SAE are identical. Moreover, the density of recycled oil was recovered by about 99%. This indicates that the suspended impurities in the used oil have been effectively removed, and the oil has regained its density, making it reusable.

Figure 11: (ρ) of engine oil

5. Conclusion

The lubricating oil is a very important material used in industry. Therefore, the extraction process for recycling of used lubricating oil as an efficient method requires further study. Extraction using composite solvents is one of the effective methods for the recycling process. This study develops a method by which contaminated lubricating oil can be recovered effectively and inexpensively with minimal amount of oil loss. The study examines the performance of two cheap and regeneratable solvents (namely, methanol and toluene) at different solvent to oil ratios and at room temperatures. The base oil was separated from impurities and regenerated from solvent-oil mixtures by treating the mixture under vacuum distillation. Based on the experimental work, it was found that the method effectively removed contaminants from used lubricating base oil and returned the oil to a quality essentially equivalent to that of oils produced by fresh lube oil stocks. Quality tests were also performed to determine the properties of lubricating oils. The quality tests showed that the properties of the recovered base oil sample were in close proximity to the results for fresh lubricating oil. However, the differences observed when comparing the recovered oil with virgin lubricating oil can be minimized by introducing additives and conducting the process under more controlled conditions.

The results obtained in this article provide evidence that re-refining used oils using the applied methods offers an effective approach toward reducing environmental pollution and promoting sustainable resource utilization. However, there remains a wide scope for future research to enhance understanding and improve the outcomes.

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