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Recycling of Used Engine Oil Using Extraction by Single Solvent

Mohamed Jurny[1, *], Mohamed Elbourawi[2], Ezeddine Zorgani[3]

[1]Chemical Engineering Department, Higher Institute of Sciences and Technology, Tripoli, Libya

[2]Chemical Engineering Department, University of Tripoli, Tripoli, Libya

[3]Planning and Studies Department, National Oil Corporation (NOC), Tripoli, Libya

Email address:

mmjurny@yahoo.com (Mohamed Jurny)

[*]Corresponding author

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Abstract: The need for virgin base oil is reduced and other resources are conserved during the refining of used, spent, or waste oils to make new lubricating oil. It is important to collect and recycle spent lubricating oil in order to protect the environment and natural resources. Although the lubricating oil itself remains unchanged after use, it becomes contaminated with combustion byproducts, deteriorated additives, water, and various dust particles during its time in the engine. The purpose of re-cycling is to eliminate degraded additives and impurities while restoring the oil's qualities to those specified by the Society of Automotive Engineers. Therefore, this study focuses on the extraction of engine oils utilizing a single solvent approach for re-cycling. The N-methyl-2-pyrrolidone was used as the solvent. The used oil was gathered from vehicle repair stations. After being allowed for settling to removing large suspended particles, the oil was subjected to a sequence of physical treatment processes. The solvent recovery process was carried out by using rotary evaporator equipment with a vacuum pump. The engine oil obtained at the end of the process is a base oil ready to be used again after addition of the proper additives. Eventually, the characteristics of the recycled oil were established and evaluated against the standards set forth by the Society of Automotive Engineers. According to the study, 10 litres of lubricating oil could be produced from 25 litres of used oil when it was recycled properly, as opposed to 220 litres of crude oil, which would be needed to make the same amount of oil.

Keywords: Used, Spent or Waste Oils, Virgin Base, Lubricating Oil, Dehydration, Atmospheric Distillation, Vacuum Distillation, Solvent Extraction, Additives

1. Introduction

The huge quantities of waste oils created globally by the transportation and industrial sectors make their treatment extremely significant. These Waste Oils may harm the environment if they are not managed, processed, or disposed of properly [1, 2]. The lubricating oil serves as a lubricant for a variety of automobile components, including engines and gearboxes. Lubricating oil's principal role is to minimize friction and serve as a medium for heat transfer. It also prevents corrosion and removes metal worn parts [3]. The lubricating oil undergoes no modifications after usage, but it becomes dirty due to the addition of combustion products, deteriorated additives, water, and dust particles during its duration in the engine. The base oil can be returned to its original state by removing the filth that was mixed with the lubricating oil [3].

Engine oil, transmission oil, hydraulic oil, and cutting oils are all considered waste lubricating oil [4]. Waste engine oil is a highly polluting substance that needs to be managed carefully. When waste engine oil is deposited in the ground or into water streams, including sewers, it may harm the ecosystem. This might lead to contamination of the soil and groundwater [5]. Recycling such polluted materials can help keep motor oil prices down. Furthermore, it will have a major energy-positive effect on the environment.

The recovery of lubricating oil from waste oil is suggested as a remedy for this problem. Recycling techniques employing non-hazardous and cost-efficient materials may be the optimal answer [6, 7].

The refining of spent oil has been accomplished using a variety of techniques. Recycling technology is the most essential method for reprocessing spent oil. The refining procedure involves the elimination of impurities and grime using distillation, acid treatment, solvent extraction, clay treatment, and hydrogenation, or a combination of these techniques [8]. Indeed, many studies have been made in order to find the best methods of management and reproduction of these oils. An overview on used engine oil re-cycling processes and technologies may be found in studies carried by Bachelder et al. who studied the most important methods for recycling (re-refining and upgrading [8]. Varied methods of refining crude oil may result in different characteristics and operational costs. Notably, waste from recycling operations that cannot be reused in any form must be disposed of in an environmentally responsible manner [10].

In Libya, the engine used oil have not ceased to multiply due to the growth of the car fleet, many of tons of oils lubricants are consumed annually. Consequently, considerable quantities of used oil are generated and classified as hazardous waste. Their release into the environment should be strictly forbidden by the authorities. To contribute to the management of these oils, we carried out some laboratory tests to develop an adequate re-refining process that can be used locally.

2. Material and Methods

2.1. Experimental Work

Samples of spent engine oil from heavy cars, light vehicles, and blended oils were obtained from local Tripoli garages and service shops and collected in a container. Prior to oil analysis and treatment by vacuum distillation followed by solvent extraction, used lubricating oil was held for several days to allow significant suspended particles to settle under gravity. Experimental work was carried out in Libyan Petroleum Institute. A laboratory scale setup was established for re-cycling used oil.

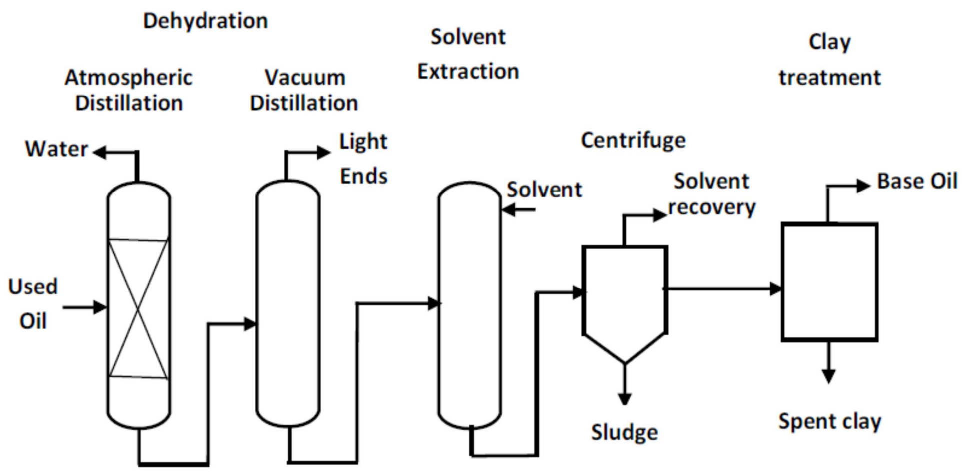

Figure 1. *Flow diagram of vacuum distillation followed by solvent treatment.*

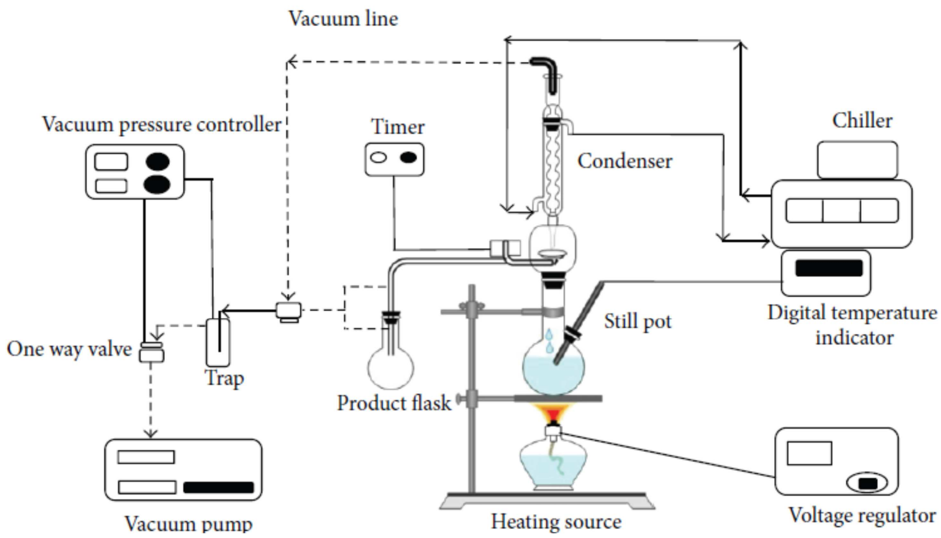

Figure 2. *Vacuum distillation of water and light fuels.*

To determine the optimal extraction efficiency, a series of experiments in which the operation conditions were systematically varied were conducted. The simple atmospheric distillation unit heats the collected spent oil to 120°C in order to remove the water that was added during combustion. Figure 1 illustrates the experimental setup for dehydration process. Following that, the dehydrated oil is vacuum distillated at a pressure of 20 mmHg and a temperature of up to 240°C. Figure 2 illustrates the experimental apparatus used to study vacuum distillation. The oil was separated into the following fractions: lubricating oil was obtained at 240°C, light fuel oil was produced at 140°C (this fraction could be utilized as a fuel source for heating), and the residual oil at this temperature (240°C) contained dirt, degraded additives, metal wear parts, and products of combustion such as carbon and was obtained as residue. The residue resembles tar, a substance that can be used in construction. The solvent used in this process was N-methyl-2-pyrrolidone (NMP), which is frequently employed in the petroleum refining industry to reduce the aromatic content of vacuum gas oil fractions; it was also utilized in the solvent extraction procedure [11]. The fraction of lubricating oil obtained through vacuum distillation is agitated with NMP in a ratio of 2:1. One hour is allowed for the lubricating oil and solvent mixture to settle in the separation flask. The aromatic component and deteriorated additives of the lubricating oil fraction settle to the bottom, while the lubricating oil fraction and solvent mixture layer forms on top. The bottom layer resembles the residue from vacuum distillation, while the top layer is a mixture of lubricating oil and solvent that is exposed to atmospheric distillation. Solvent recovery process was carried out by using rotary evaporator equipment with a vacuum pump at operating temperature of 202°C for NMP for 1 hour to ensure the complete recovery of solvent used in the base oil production. Sludge was separated from the solvent-oil solution after 24 hours, and any remaining oil was then extracted by washing the sludge twice with the same solvent. Lastly, the sludge was dried to a constant weight. A solvent-oil solution was combined with the washing solvent. Vacuum distillation using a rotary evaporator was used to recover the solvent. The solvents evaporated, condensed, and collected in the flask's circular bottom. The resulting NMP vapour is condensed and combined with a new solvent to be used once more as a solvent. Figures 3 display the Rotary vacuum distillation.

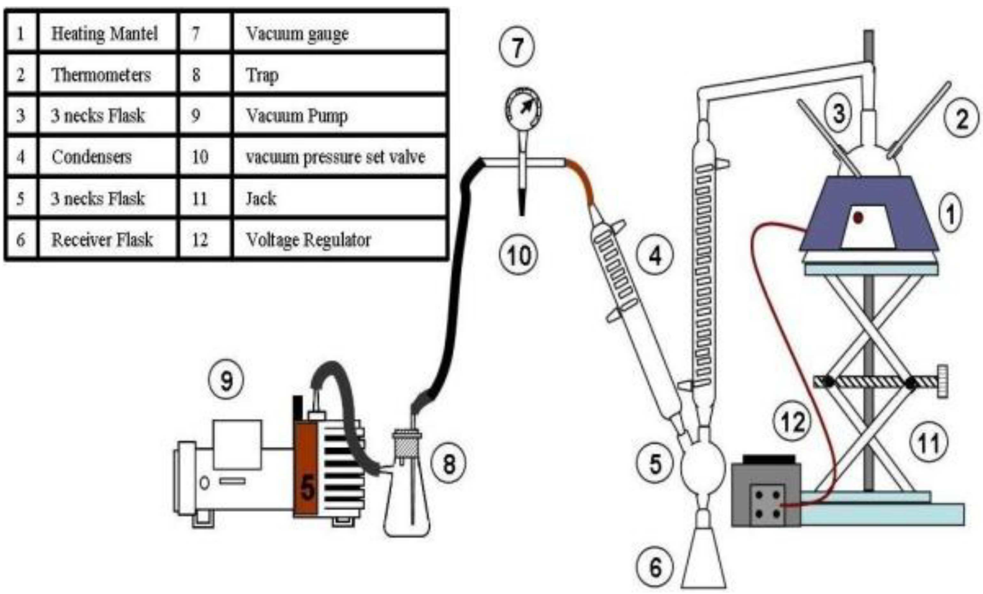

Figure 3. *The Rotary vacuum distillation.*

2.2. Re-cycled Oil Analysis and Specifications

The lubricating oil obtained at this stage appeared to be identical to available commercially lubricating oil and could be used in automobile engines after proper additives are added. However, in order to verify that its qualities match those provided by the Society of Automotive Engineers, the following analyses were performed:

2.2.1. Density and Specific Gravity

The density of a material is the ratio of its mass to its volume. Specific gravity is the ratio of a substance's density to the density of water measured at the same temperature. The density and specific gravity of spent oil indicate the level of impurities. The specific gravity of the oil increases as the aromatic content increases. Because of the existence of contaminants, spent engine oil has a higher density and specific gravity [9].

2.2.2. Viscosity

The resistance to fluid flow is defined as viscosity. Oil viscosity investigating reveals the existence of contaminants. Because of the addition of fuel, water, and other contaminants to the lubricating oil during its time inside the engine, its viscosity decreases. The viscosity of the oil is critical in reducing friction and should be high [9].

2.2.3. Viscosity Index

The viscosity index is a value that indicates how viscosity changes with temperature. The viscosity alteration with temperature is less pronounced when the viscosity index is high. This means that the oil is more thermally stable and provides better engine protection [9].

2.2.4. Pour Point

The pour point is the lowest temperature at which oil could indeed freely flow inside the engine. Because the lubricating oil includes waxes and paraffins, it solidifies at lower temperatures. If the oil has a lower pour point, the flow of oil into the oil pump and other engine parts will be affected at low temperatures [9].

2.2.5. Total Acid Number

The Total Acid Number (TAN) represents the amount of acid content in the oil. The TAN is the quantity of potassium hydroxide required to neutralize one gramme of acid in the oil. At high temperatures, the engine oil oxidizes, producing carbonyl products and carboxylic acid. Significantly greater TAN indicates a higher acid content, indicating that the oil requires replacement [9].

2.2.6. Total Base Number

The Total Base Number (TBN) represents the amount of base content in the oil. To neutralise the acidic product composition, internal combustion engine oils are constructed with a highly alkaline base additives package. The TBN is a measure of this package that can be used to determine when to change the engine oil. This is due to the fact that TBN depletes over time. Higher TBN values in oil are more effective at neutralizing acids over longer time periods. The rate of consumption of the additives indicates the oil's expected service life [9].

2.2.7. Color Index

The most important factor to consider when selecting lubricating oils is colour. Another test used to compare base oil produced to refinery base oils and virgin base oil was colour [9].

3. Results and Discussions

In addition to contaminants, water, and degraded additives, used oil also contains a valuable resource of recoverable base oil. Dehydration, vacuum distillation, and solvent extraction are used in the current study to refine used lubricating oil. To further enhance the properties of the finished lubricating oil, additive is added.

The difference between the specific gravity of used oil and the base oil viscosity medium is depicted in Figure 4 according to (SAE). This discrepancy shows that the used lubricating oil contains impurities and sludge. By using solvent extraction, the specific gravity of the base oil was reduced from 0.889 for used oil to 0.874, falling within the accepted range of (SAE).

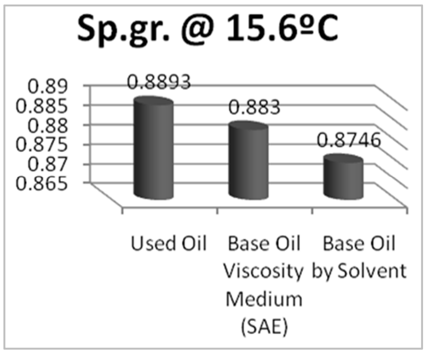

Figure 4. *Comparison of Specific gravity of SAE standards, used oil and base oil by solvent.*

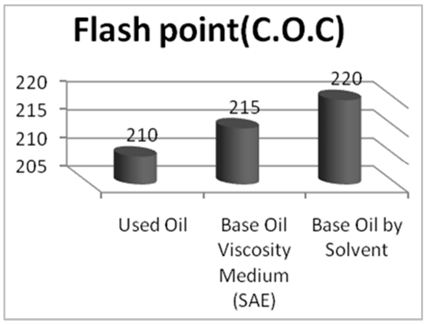

Figure 5. *Comparison of flash point of SAE standards, used oil and base oil by solvent.*

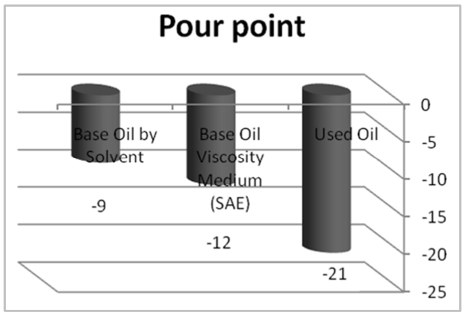

Figure 6. *Comparison of pour point of SAE standards, used oil and base oil by solvent.*

Figure 5 shows that the flash point temperatures for spent lubricating oil and base oil obtained through solvent extraction are, respectively, 210°C and 220°C, which are lower than the 230°C base oil viscosity medium (SAE). The spent lubricating oil may contain volatile impurities, as evidenced by the lower flash point value. By purifying and eliminating the impurities, the original properties can be recovered.

Pour point is the lowest temperature at which oil flows unhindered. The pour point is a crucial factor to take into account in colder climates where the oil shouldn't freeze or become extremely viscous, which would impede oil circulation. Naturally, the pour point drops significantly as the oil becomes contaminated. According to solvent extraction treatment, the pour point is -21°C for used lubricating oil and -9°C for base oil, whereas the pour point is -12°C for base oil viscosity medium (SAE) and is depicted in Figure 6. As a result, oil with a lower pour point interferes with oil circulation and cannot be used any longer.

The properties of refined oil produced after solvent extraction are compared with SAE standards in Figures 7 and 8. The used lubricating oil has a TAN of 2.9 mg/g, which is higher than the base oil's medium viscosity (SAE). Such a high acid value shortens the life of engines by causing corrosion in their metal components. By using solvent extraction, the TAN was reduced from 2.9 for used oil to 0.161 for the base oil, falling within the acceptable range of (SAE). A higher TAN indicates that the oil needs to be replaced because it contains more acid.

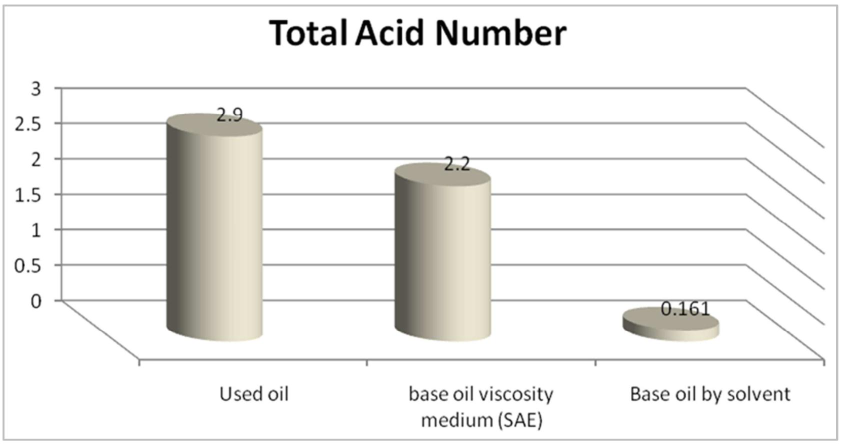

Figure 7. *Comparison of total acid number of SAE standards, used oil and base oil by solvent.*

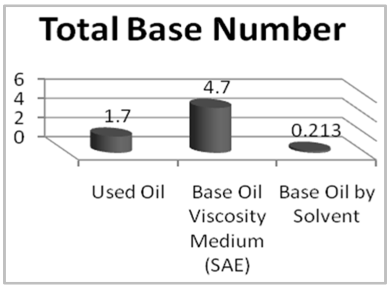

Figure 8. *Comparison of total base number of SAE standards, used oil and base oil by solvent.*

However, the TBN for used lubricating oil is higher 1.7 mg/g than the base oil's medium viscosity (SAE). The TBN after solvent extraction treatment decreased from 1.7 mg/g to 0.0 mg/g, which is within SAE accepted standards. It can be improved by adding additives to the refined oil because the base content was significantly reduced during the refining process.

Kinematic viscosity for different samples at two temperatures and viscosity index are shown in Figure 9. The result of the kinematic viscosity test at 40°C illustrations that the base oil viscosity medium (SAE) and used oils were 91cSt, 106.7cSt respectively, while that recycled oil obtained by solvent extraction treatment is 71.5cSt. Kinematic viscosity at 40°C was greatly impacted by the addition of NMP to the base oil after vacuum distillation treatment. The results of recycling of used oil by solvent extraction treatment approaches decreased the kinematic viscosity of the spent oil after vacuum distillation from 106.7cSt to 71.5cSt for solvent extraction treatment, this may be due to eliminating the additives which have been added to improve the viscosity. However, while the kinematic viscosity at 100°C was slightly affected by the addition of NMP to the base oil after vacuum distillation treatment. The kinematic viscosity at 100°C for the base oil viscosity medium (SAE) and used oils 12.5 cSt, 10.5 cSt respectively, while that obtained using: solvent extraction treatment was 9.2 cSt. Generally, oil is considered unfit for service, if the original viscosity increases or decreases to the (SAE) standards. Viscosity decrease can be caused by dilution with light fuel, while viscosity increase could happen due to oxidation or contamination [9].

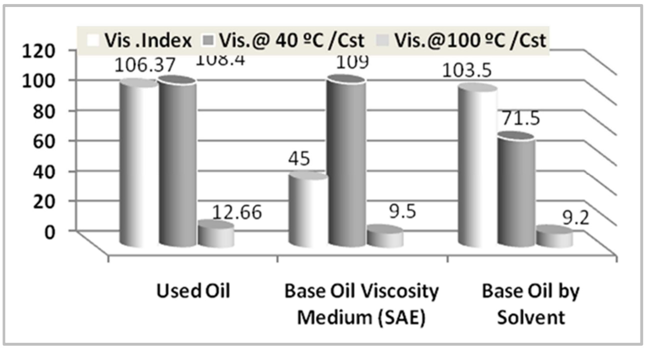

Figure 9. *Comparison of Viscosity and Viscosity index of SAE standards, used oil and base oil by solvent.*

Figure 10 shows that the Color index was improved from over 8 to 2, which is in the accepted standards of SAE. The higher value was due to the presence of the aromatics and other unsaturated substances in the used oil. The lower value indicates that they were not totally eliminated by vacuum distillation. However, they are saturated to an acceptable low level of 2. Thus, Color is one of the most important considerations in choosing lubricating oils.

In this context, many studies have been conducted to treat and reuse waste oil using different materials. For example, Ricon et al. stated that among the alternative techniques, the solvent extraction process garnered the most interest [12]. Nimir et al. have conducted research on the solvent 2-propanol and determined that a rise in SOR results in an increase in PSR but a decrease in POL [13]. In another study, Manzoor et al. described the used lubricating oil collection places in Libya through a field assessment, noting that used oil has been disposed of as a substance of little value. From an economic and environmental protection standpoint, re-refining to high-quality base oil from high-quality used oil is the most appropriate approach to utilize it [14]. According to Khelifi et al., regenerated used oil helps to conserve the environment, preserve important resources, and lessen its environmental impact [15]. Despite the different methods used in the treatment, this method used N-methyl-2-pyrrolidone as a suitable solvent for separation. N-methyl-2-pyrrolidone can also be extracted from the extracted oil easily. Therefore, the oil treated could be used as refined oil following the treatment process.

4. Conclusions

Recycling used lubricants may have positive effects on the environment and the economy. According to this study, recycled engine oil could be produced using N-methyl-2-pyrrolidone (NMP). Based on experimental research, it was found that all methods produced base oils that were comparable to those made using traditional techniques and efficiently removed contaminants from used lubricating base oil. The recycling lubricating oil shows properties as comparable to that of base lubricating oil. The specific gravity, viscosity, viscosity index flash point, pour point, TBN and TAN were 0.889, 106.7 cSt, 12.66 cSt, 113 cSt, 210°C, -21°C, 1.7 mg/g and 2.9 mg/g respectively. After recycling, these properties improved to, 0.874, 71.5 cSt, 9.2 cSt, 103.5 cSt, 220°C, -9°C, 0.00 mg/g and 0.161 mg/g respectively. Furthermore, these qualities are now much better after additives were added to the recycled oil, and they meet SAE standards and can be used in engines again. Overall, recycling used lubrication oil will lessen the environmental threat it has previously posed. Additionally, since lubricant-rich crude is a limited resource, the demand for it will decline.

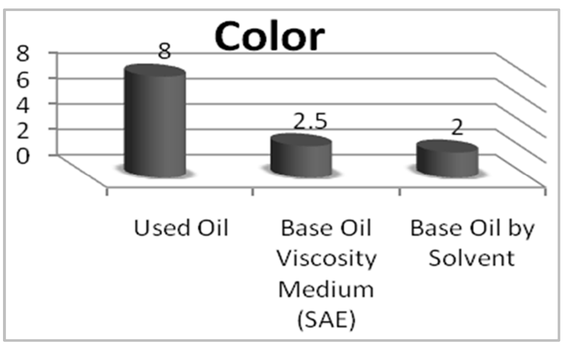

Figure 10. *Comparison of color index of SAE standards, used oil and base oil by solvent.*

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