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Application of Solvent Extraction Process for Revivification of Used Lubricating Engine Oil

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Authors' contributions

This work was carried out in collaboration between all authors. Authors DOA and OOG designed the study and performed the experiments while author MOA analyzed and discussed the results. All authors read and approved the final manuscript.

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ABSTRACT

In this work two single (ethanol and 1-butanol) and one composite (1-butanol-ethanol) solvents were used for refining Used Lubricating Engine Oil (ULEO) at temperatures 35ºC, 45ºC and 50ºC. The solvents performances were investigated at Solvent Oil Ratio (SOR) 1:1 to 7:1 using percentage oil yield as performance metric. The study revealed that 1-butanol produced the best performance for regenerating ULEO. The results of this study demonstrated the potential of 1-butanol-ethanol for regenerating ULEO.

Keywords: Regeneration; re-refining; extraction; used oil.

1. INTRODUCTION

The additives inclusion in lubricating engine oil is for efficient engine function, friction reduction, protection against engine wear and reduction of high temperature build-up on the moving surface [1]. Performing these tasks with increased time of usage resulted to reduction and loss of its properties [1]. Thus the used lubricating engine oil must be removed and replace with fresh one.

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The erroneous disposal of used lubricating engine oil has become a threat to public health and ecology [2] owing to hydrocarbons, heavy metals, PCBs (Polychlorinated Biphenyls) and other halogen compounds it contains with large amount of it being generated annually [3]. Recycling of waste oil has become very important due to increasing necessity of environmental protection and to turn it to usable product so that the quantity being disposed of improperly can be reduced [4]. The re- refining of used lubricating engine oils is a physical and chemical conversion process which consists the removal of mechanical and oxidation contaminants from the oil. These contaminants that are of engine sludge are products of oxidation from chamber, wearing or interactions between the engine oils and fuels. Water entering the crankcase and fuel tanks by natural breathing and condense constitutes a contaminant of lubricating oil [5]. The water content in the used lubricating oil samples need to be determined and removed prior to any treatment through dehydration [6]. During the heating process, gasoline, glycol solvents and some derivatives additives are also removed [7]. Recycling of used automobile oil has been carried out by several methods which include the old and popular proven technology acid-clay process for used oil recycling [8]. The process gives lower yield due to loss of oil in sludge as well as clay because of higher dosage of clay required [9,10]. This process is on its way out as most countries adopted stringent pollution control regulations as a result of acid gas emission, acid sludge generation and its disposal problem [11,12]. Acid activated clay is a simple recycling process that required no acid which is suitable for small capacity plant [13]. However, high clay consumption, low yield, inconsistent quality and disposal of large quantity of spent clay apart from dependency of the process on a particular type of clay are among the shortcomings of this process. Vacuum distillation is another method suitable for high capacity plants capable of yielding quality base oil without causing pollution [14]. However, it required high capital investment, highly skilled personnel and sophisticated equipment [15]. Among the potential techniques is solvent extraction that practically offers environmental and economic advantages over others and has received due attention [8,15]. Several materials have been employed for carrying out solvent extraction process and these include the use of new hydrocarbon solvents. Liquefied petroleum gas (LPG) condensate and stabilized condensate are among the solvents with the use of demulsifier to enhance the treatment process [16]. The use of supercritical carbon dioxide as solvent has also been proposed as an environmentally friendly process [9]. Many processes have been demonstrated using other hydrocarbons as solvents that include, either as single or composite solvent, 2-propanol, 1-butanol, methyl ethyl Ketone, methyl isobuthyl Ketone and butanone for an optimum extraction [17,18] with little attention paid to ethanol. Reference [19] reported the potential of ethanol as solvent, when mixed in equal proportion with 1-butanol, for recycling used lubricating engine oil in order to segregate impurities in the form of sludge at different extraction factors. Extraction by composite solvent has been identified as one of the best methods of recycling [17]. Work carried out on the use of 1-butanol, 2-popanol and ethanol as solvents, maximum base oil recovery in this order was reported [15]. Research on the use of mixture of 2-propanol, 1-butanol and butanone as composite solvents in different proportion at various solvent oil ratios revealed that composite solvents prove effective in regeneration of ULEO than single solvent [8] without considering single solvent. This current investigation aims at regenerating base oil from used lubricating engine oil utilizing single and composite solvents, respectively and studying the effects of solvent types and extraction factors (solvent to oil ratio and temperature) on the properties of regenerated oil.

2. METHODOLOGY

Used lubricating engine oil was collected from different vehicles service stations and repair workshops. The oil collected was mixed in a single container to represent a typical feed stock to a re-refining plant for automotive used lubricating engine oil. The collected oil was allowed to settle under gravity for a period of seven days. The oil was heated at 140ºC under atmospheric pressure for a period of 1 h [20,21] in order to remove the residual free and emulsified water [22]. A laboratory scale (glassware) setup was made with selection of three solvents namely, ethanol, 1-butanol and mixtures of 1-butanol-ethanol for this work. Each solvent was mixed with used lubricating engine oil (W) varying from 1:1 to 7:1 in order to evaluate the extraction performance of these solvents. Each sample was stirred at 300 rpm for 30 min and heated at 35ºC in the water bath for 30 min to maintain a constant temperature. This was followed by separation of sludge phase from mixture of solvent and extracted oil. Standard distillation process was used to separate the extracted oil (W_1) from the mixture. The procedure was repeated at 45ºC and 50ºC. The Percent Oil Yield (POY) at various SOR considered was evaluated using Eq. (1) below.

$$POY = \frac{W_1}{W} \times 100\% \qquad (1)$$

3. RESULTS AND DISCUSSION

Fig. 1 shows the result of solvent to oil ratio on percentages of regenerated oils at extraction temperatures 35, 45 and 50ºC using ethanol as solvent. It was observed that, ethanol regenerated zero percent of oil yield (POY) from 1:1 to 1.9:1 at all temperatures. At higher ratio, as solvent to oil ratio increases there was improvement in POY. At temperature 35ºC SOR 6:1, the POY was 4.4% as maximum. This is in close agreement with [15] that obtained 0% and less than 5% at SOR 1:1 and 6:1, respectively using ethanol as solvent. The figure shows that from 2:1, the oil yield increases with the extraction temperature. However there was retreating effect in POY from SOR 4:1 at all temperatures considered despite further increase in SOR. The result revealed that there is limit to which increase in SOR can improve oil yield.

Fig. 2 shows the effect of solvent to oil ratio in terms of POY at extraction temperatures 35, 45 and 50ºC, respectively utilizing 1-butanol as solvent. As can be observed from the figure, with increase in SOR the POY decreases in exponential decay manner. In a similar trend, the POY decreases as temperature increases indicating improvement in sludge removal. This shows that there was improvement in physical properties of oil yield as SOR and temperature increases. It was observed that at extraction temperature 35ºC there was quick drop in POY at lower SOR (1:1 – 1:9). At SOR (2:1 – 2.8:1) the POY found decreases while a retreating effect was observed at higher ratio. The oil regenerated at 1:1 was 71.07% and 67.34% at 6:1. This is in close agreement with 70.64% and 67.80 obtained by [8] but in disagreement with improvement in quantity of regenerated base oil with increase in solvent oil ratio reported by [15].

Fig. 3 shows the performance of mixture of 1-butanol and ethanol as solvent in terms of POY. The curve is similar to that in Fig. 2. It was observed that there was rapid decrease in oil yield at solvent to oil ratio (1:1 – 2:1), gradual at (2:1 – 3:1) and quick at (3:1 – 4:1). However a retreating effect was observed at SOR (4:1 – 6:1). The same trends were found at different temperatures. This is in close agreement with the result obtained by [8]. This is an indication that there is a limit to which sludge removal from used lubricating engine oil can be improve with increase in SOR for a particular temperature.

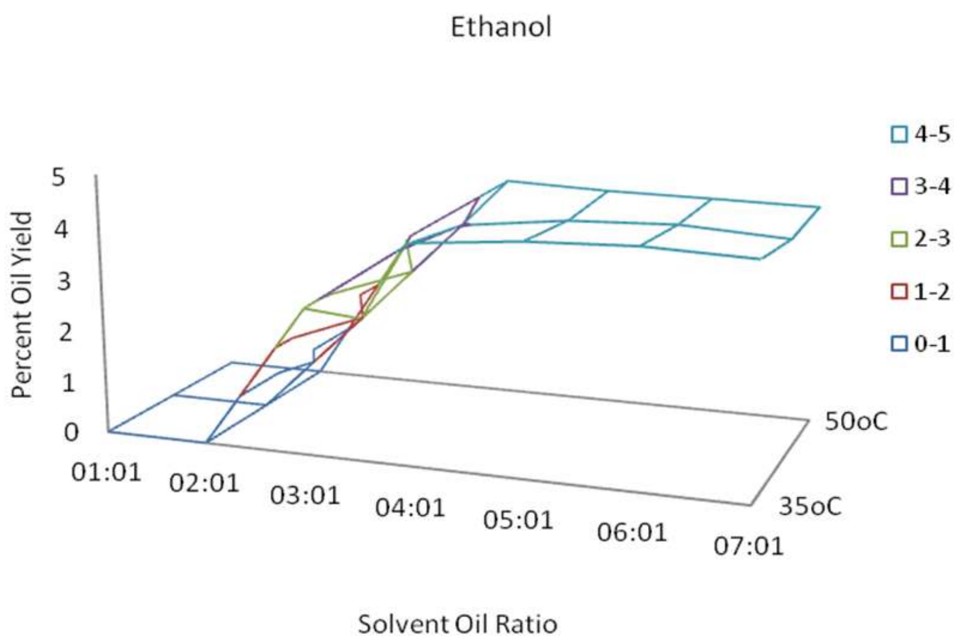

Fig. 1. Percent oil yield curves for ethanol as solvents at different temperatures

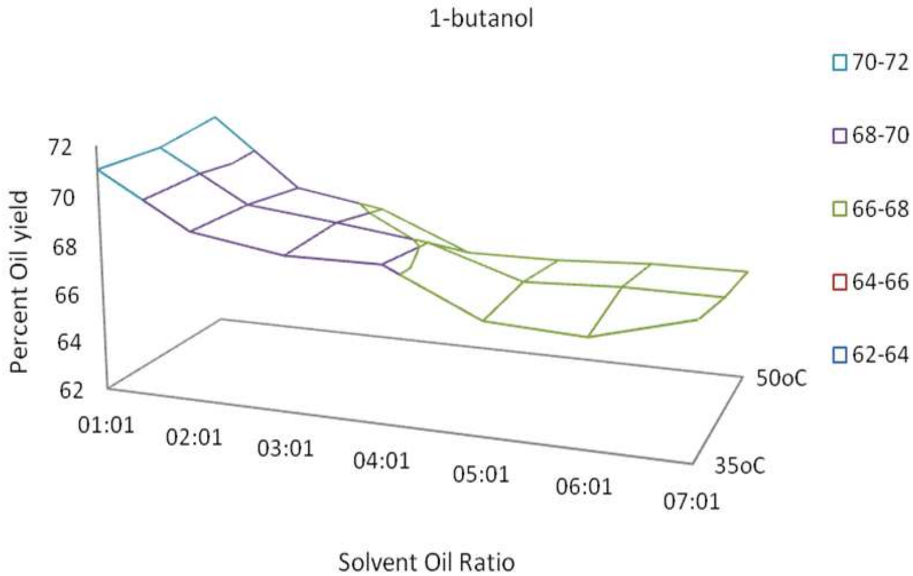

Fig. 2. Percent oil yield curve using 1-butanol as solvent at different temperature

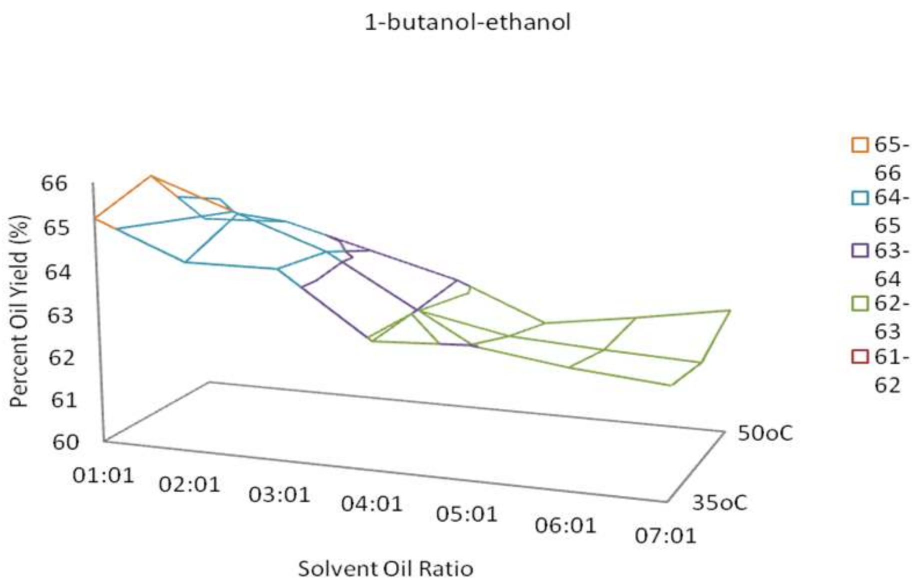

Fig. 3. Percent oil yield curve using mixture of 1-butanol and ethanol as solvent at different temperatures

Figs. 4 - 6 show the result of solvent to oil ratio on the oil yield percent for solvents 1-butanol, ethanol; mixture of 1-butanol and ethanol at 35, 45 and 50ºC, respectively. At extraction temperature 45ºC; SOR (1:1), the oil yield were 70.9% and 65.72%, respectively using 1-butanol and mixture of 1-butanol-ethanol. At SOR (6:1), 66.85% and 62.45% were the percent oil yield. At extraction temperature 50ºC; SOR (1:1) the oil yields were 71.4% and 64.2% while 66.5% and 62.9% were the yield at (6:1) for the solvents.

The quality of oil yields improved as SOR increases. The improved properties of regenerated oil as a result of percentages of oils recovery revealed that the optimum was obtained at solvent to oil ratio 5:1. The re-refined lubricant base oil was characterized at this ratio and compared with virgin and used oil. ASTM standard methods were used to determine the various properties of the oils as shown in Table 1. The kinematic viscosity at 40ºC and 100ºC were in close agreement with the results reported by [20,22]. This can be improved with inclusion of viscosities improver. The flash point, pour point and viscosity index of the extracted oils kowtow to the literatures. Crackle test carried out revealed that the extracted oils were free of water. The results presented in Fig. 4 - 6 and Table 1 revealed that mixture of ethanol and 1-butanol has a potential to precipitate out the contaminants in ULEO. The best performance was produced by 1-butanol follow by mixture of 1-butanol and ethanol. However the results obtained utilizing mixture of 1-butanol and ethanol as solvent are in close range with the use of 1-butanol.

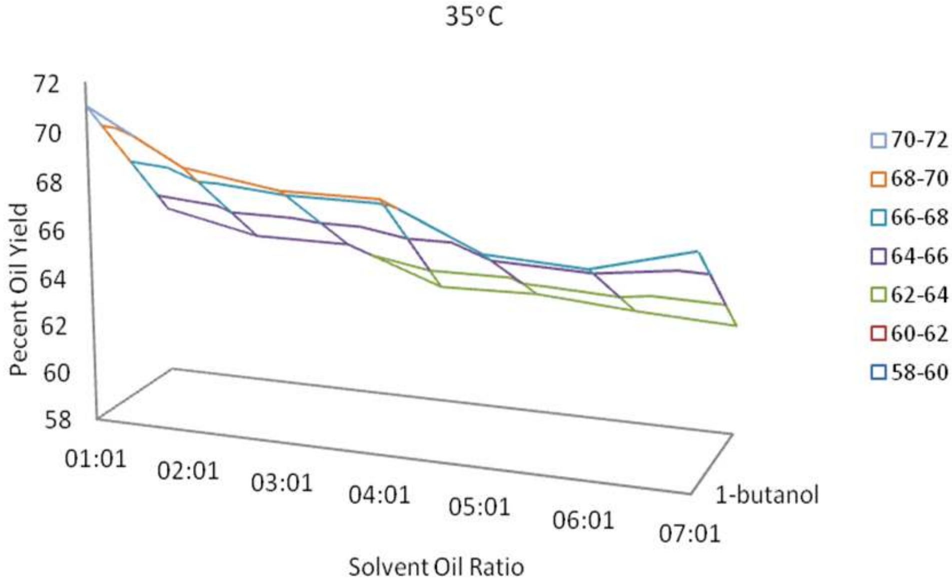

Fig. 4. Percent oil yield curve at temperature 35ºC using 1-butanol and mixture of 1-butanol and ethanol as solvents

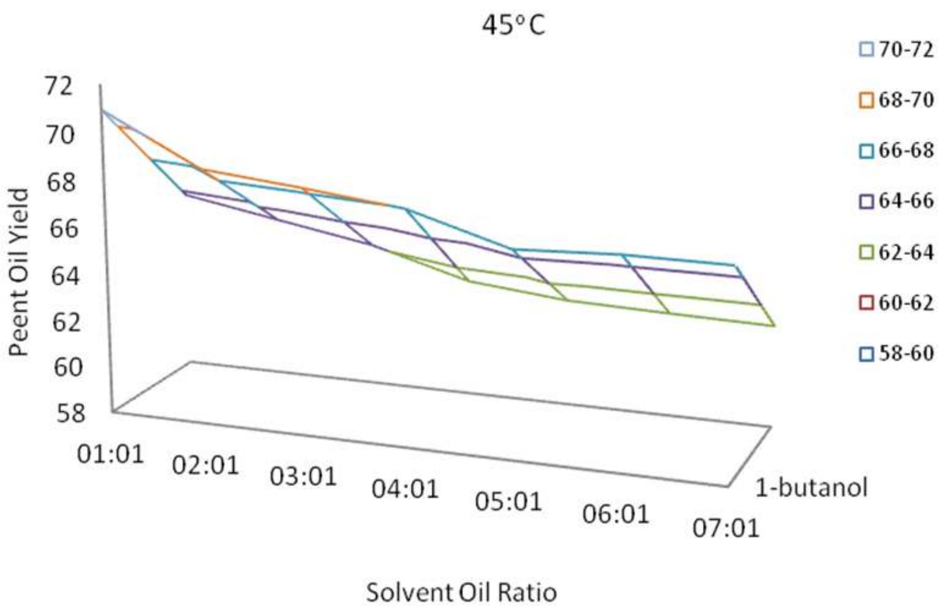

Fig. 5. Percent oil yield curve at temperature 45ºC using 1-butanol and mixture of 1-butanol and ethanol as solvents

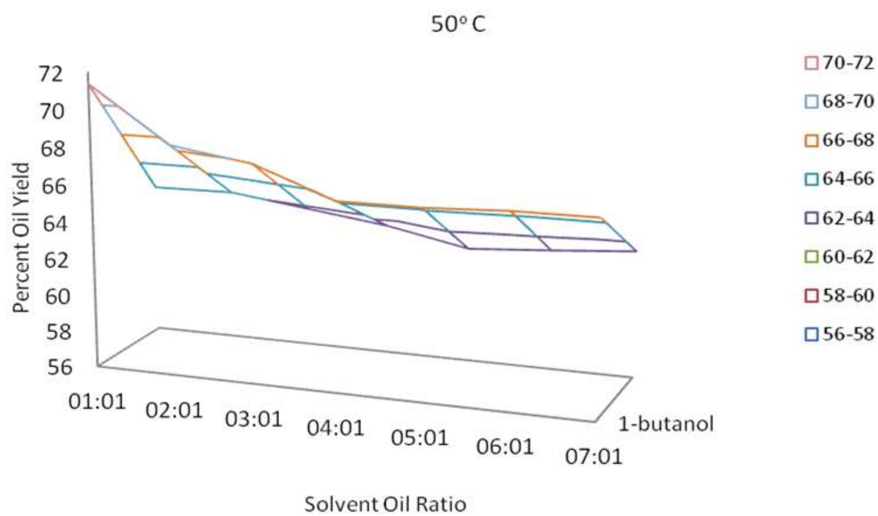

Fig. 6. Percent oil yield curve at temperature 50ºC using 1-butanol and mixture of 1-butanol and ethanol as solvents

Table 1. Test analysis results of the used lubricating oil, virgin base oil and regenerated oil

Parameter	**Standard (ASTMD)**	**Base oil**	**ULEO**	**Regenerated oil using different solvents**		
				ethanol	**1-butanol**	**1-butanol+ ethanol**
Appearance		Bright	Dark	Dark brown	Dark brown	Dark brown
Odour			Foul	Odourless	Odourless	Odourless
Kinematic viscosity at 40ºC (cst)	445	90 min-100 max	125	99.1	98.7	98.5
Kinematic viscosity at 100ºC (cst)	445	10.5 min-12.0 max	13.4	11.7	11.2	11.5
Crackle test (g)	96	pass	Fail	Pass	Pass	Pass
Specific gravity at 15ºC (Kg/l)	1298	0.900	0.907	0.892	0.697	0.882
Viscosity index	2270	95	102	98	97	98
Flash point (ºC)	92	240	140	199	210	202
Water content (g)		Nil	5.73	Nil	Nill	Nill
Ash content wt%	874	0.94	1.35	0.98	0.96	0.97
Pour Point	97	-12	-9	-12	-13	-13

4. CONCLUSION

In this study, revivification of used lubricating engine oil was carried out using single and composite solvents at different solvent oil ratio and temperature. It was found that oil ratio 5:1 gave the best extraction for all the solvents used and at different temperatures considered. The most effective solvent in the extraction process was 1-butanol followed by 1-butanol-ethanol mixture; it was found that overall best performance for the two solvents was obtained when extraction was carried out at 50ºC. Although there was improvement in properties of the revivified oil, future work should look into the properties of the lubricating oil not considered in this work to meet the standard as lubricating oil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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