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Regeneration of waste automobile lubricating oil by solvent extraction

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ABSTRACT

Recycling of waste engine oil by solvent extraction is one of the potential techniques. From economical and environmental point of view, and due to various advantages of solvent extraction techniques have received due attention. The aim of this work is to optimize the parameters such as effect of solvent, solvent to oil ratio and type of sample on regeneration process of used engine oil by solvent extraction. Single solvent (methanol) and composite solvent (50% methanol and 50% 2-propanol) were used and two samples as single and multi vehicle engine oil were collected from oil change services, on which experiments were conducted. The effect of treatments on properties of treated used oil was studied tests include: specific gravity, flash point, kinematic viscosity and density. The best results were obtained using single solvent (methanol), with the solvent oil ratio 1:1, from single vehicle engine oil with highest extraction yield of 95%, followed by composite solvent (50% methanol and 50% 2-propanol) with extraction yield was 86%. By determining properties of treated oil single vehicle engine oil with single solvent (methanol) gave closet specification to fresh engine oil followed by composite solvent (50% methanol and 50% 2-propanol). It was concluded that after regeneration, solvent to oil ratio, solvent and type of sample have great impact on quality of oil generated.

Keywords:

Waste Engine oil
Solvent Extraction
Regeneration
Optimization

1. Introduction

Lubricating oils are type of fluids used in engines, hydraulic systems and gearbox, to overcome heat up and friction between solid surfaces, contacting each other and hence to work optimal lubricants are significant part of an engine [1]. Most of engine oil generated from transportation sectors, when it losses it efficiency during working condition as degrades with passage of time, having contamination and causes effective environmental pollution. It causes air pollution when burning as fuel. The used lubricants contain several impurities and by water it may enter into food chain. As a result can cause human health to risk, prevent agriculture growth as used lubricant contains metal, hydrocarbons and various compounds. This risky substance needs effective attention to make it valuable product by decreasing the used lubricant's ecological burden [2]. Hence, Treatment of used lubricant is essential in prevention of pollution and preserve oil reserves. Vural et al. 2020 studied physiochemical properties of used, refined and base oil and comparison of used engine oil recycling process such as Dewatering, filtration, acid clay, distillation, Solvent de–asphalting, TFE with (H.F) and (C.F), TFE with (S.F), solvent extraction (H.F), thermal asphalting and physiochemical generation for treatment of used Mobil [3]. The reagents used in this method were Diammonium phosphate solution, Ethylene glycol, sodium silicate, aluminum oxide, tetraethylenepentamine, acid active bentonite. By comparison of all processes it was observed that physicochemical regeneration process was efficient the recovery was found to be 85% with sediment removal of 10% - 15% [3]. Oladimeji et al. 2020 studied regeneration method, he observed that, with reduced percentage in ratios, recovery yield enhanced [4]. Adewole et al. 2019 examined techniques as dehydration, gravity settling, filtration and adsorption [5]. Investigation shows that, Viscosity index and kinematic viscosity from reclamation are above standard values, viscosity was found to be higher whereas, pour point and flash point was observed to be lower, TAN and TBN shown low acid concentration.

Oladimeji et al. 2018 discussed aspects affecting the features of the recycled Mobil such as solvent choice, speed of mixing, proportion of oil-solvent and temperature in order to treat used lubricating oil using Atmospheric distillation, Vacuum distillation and Adsorption method [6]. Santos et al. 2019 studied the thermal breakdown outline of inorganic oils recuperate with TG and the oxidative disintegration outline with DTA for recycling lubricating oils. The methods used were centrifuge and distillation using Rotary evaporator. Best yield with methyl ethyl ketone, with 80% recovery and 70% for 1-butanol [7]. Osman et al. 2018 examined percentage of sludge removal with solvent oil ratio from used oil by utilizing blend of activated alumina and solvent extraction. The methods used for treatment are vacuum filtration and rotary evaporation. Results confirm that solvent mixture (methyl benzene, butyl alcohol and methyl alcohol) provide maximum sludge removal [8]. Hegazi et al. 2017 examined the comparison between acetic and formic acid for acid treatment and some of other conventional methods on recycling of used lubricating oil. It was observed that recycled oil with proportion 10:1 oil-acid with formic and acetic acid resembles similar results compare to fresh oil [9]. Sakib et al. 2015 studied basic properties of waste lubricant and analysis the performance of recycled oil for gasoline engine is quite better than diesel engines. The recovery of used oil for diesel and gasoline engine was 80% and 90% [10]. Further, Abu-Elella et al. 2015 studied the influence on the regeneration of used

Mobil by using various acids include Acetic, Sulfuric, Phosphoric and Formic acid by bleaching earth and potassium hydroxide. Formic acid showed some oxidized components; therefore acetic acid-clay treatment gave better results [11]. Hussein et al. 2014 examined techniques used were Centrifugal tube and Soxhlet. Results shown that, butyl alcohol with 92.4% recovery were observed, followed by 1-propanol with 90.7% recovery [1].

From recent analysis, it is calculated that almost 100,000 tons of used lubricant is produced annually from transportation only which is not effectively handle in Pakistan. Until now, no effective management programs are available and people are less aware of ecological effects of used lubricants [2].

The recycling of waste oil has tradition of near about half century. Reprocessing and re-refining are some different methods for recycling of waste lube oil. Many methods were implemented for recycling of waste lubricant i.e. are physical and chemical treatment. Since acid clay treatment create enormous amount of contaminations and it is hard to evacuate asphaltic impurities. In recent years, substantial focus has been given to solvent extraction treatment because it overcomes issues related with acid sludge caused from chemical treatment. By distillation, solvent can be regained [12].

The major objective of this research is to regenerate automobile used engine oil to produce base oil with help of solvent extraction process and to examine effect of various parameters such as solvent, solvent to oil ratio and type of sample on specification of treated base oil.

2. Materials and Methodology

2.1 Sample Collection

For experimental analysis, two different waste engine oil samples were collected for this study (Fig. 01). First sample of oil was collected from single vehicle, while other sample comprised of multi vehicle engine oil, from oil change service, Poonam petrol pump, Hyderabad. The solvent used were single solvent (methanol) and composite solvent (50% methanol 50% 2-propanol) and activated carbon as adsorbent.

2.2. Experimental procedure

Removal of water vapors

The 100ml of used engine oil was placed in round bottom distillation flask. Distillation process was carried out for 2 hours 5 mins in Distillation tester at temperature of 260°C for single and multi vehicle engine oil respectively, for removal of water vapors from waste engine oil. Process was done until no distillate produced.

Removal of light hydrocarbons and gasoline

To remove light hydrocarbon and gasoline particles, vacuum distillation was conducted for 1 hour 38 mins at temperature of 230°C and a pressure of about 3 inHg for single and multi vehicle engine oil. The process is similar to atmospheric distillation include vacuum pump.

Fig. 01: Waste engine oil samples

Solvent extraction

Two different solvents used were single and composite. Single solvent was methanol, and composite solvent was (50% methanol and 50% 2-propanol). To proper contact with each other composite solvent were stirred for 30 min. 70ml of oil's sample of single and multi vehicle and both solvents methanol and composite solvent (50% methanol 50% 2-propanol) were mixed with different proportions of solvents, (1:1, 1:2, and 1:3) were poured into 500ml beaker at speed of 500 R.P.M were stirred for half hour using midget stirrer.

Solvent recovery using atmospheric distillation

The solvent was recovered from solvent oil mixture by distillation tester. The solvent oil mixture was heated at 70^{o}C and 78^{o}C this was bit higher to boiling point of solvents for total removal of solvent from oil.

Adsorption

The 60 gram sample of oil was weighed alongside 5% weight by activated carbon's weight. This was mixed for 15 min at room temperature at speed of 500 rpm. The activated carbon left in contact for 4 hours with oil and separated with filter paper. The properties were further determined.

2.3. Characterization

Viscosity

The reading of viscosity was usually reported at 40^{o}C. To determine the kinematic viscosity of used oil sample say-bolt viscometer was used. Heat of fluid was controlled by it and time takes the fluid to fill 60cc container is the viscosity. Through fixed orifice at the bottom of cup the efflux time of specified volume of oil was measured to represent the viscosity of oil. Through a calibrated orifice the efflux time in seconds of 60 ml of oil flowing was measured under controlled conditions. By an orifice factor the time was corrected and at that temperature reported as the viscosity of oil.

Flash point

In an open cup the oil sample was place where it was heated, using thermometer its temperature was monitored. The ignition source which is a flame is passed over it at specified time intervals, until the oil sample has flashed this done. When a flame spreads on the entirety of the oil sample an oil sample has flashed.

Density

Into graduated cylinder, a volume of oil sample was put till it was three quarters full and at a relatively slow pace into this sample a hydrometer is inserted. The point on the liquid surface while the device is floating where the hydrometer rests is the specific gravity. The density was measured using equation

$$\rho = sp.gr \times 1 \tag{1}$$

3. Results and Discussions

3.1. Atmospheric distillation

The recovery from single vehicle engine oil was higher than multi vehicle engine oil. The initial boiling point of multi vehicle engine oil was slightly higher than single vehicle engine oil. Lower the initial boiling point of sample less time conducted by an experiment. The amount of residue obtained was much higher from multi vehicle engine oil than single vehicle engine oil. The following data in table 01 is listed below,

Table 01: Atmospheric distillation of waste engine oil (Average per 100 ml)

Type of oil sample	**Single vehicle engine oil**	**Multi vehicle engine oil**
Recovery (ml)	84.3 ml	65.2 ml
Residue (ml)	9.7 ml	27.4 ml
Heating losses (ml)	6.1 ml	7.4 ml
I.B.P ^oC	144.2^oC	155.3^oC
Time of I.B.P	21.2 min	27.8 min
F.B.P ^oC	260^oC	260^oC
Total time (mins)	118.1 min	132 min

3.2. Vacuum distillation

The recovery from single vehicle engine oil was slightly greater than multi vehicle engine oil. The initial boiling point was less in single vehicle engine oil than multi vehicle engine oil. The total time taken by multi vehicle engine oil was more than single vehicle engine oil. The data of following is listed in table 02.

3.3. Solvent Extraction

Time for solvent oil mixing was 30 min and speed was 500 R.P.M. Taking oil sample quantity of 70 ml with ratio 1:1, 1:2 and 1:3 of solvent, losses of solvent oil mixture with composite solvent (50% methanol 50% 2-propanol was much higher in both type of oil, with single vehicle engine oil were 15 ml, 16 ml and 20 ml for ratios 1:1, 1:2 and 1:3 respectively, whereas with single solvent (methanol) it were 12 ml, 14 ml and 15 ml. Moreover, losses of solvent oil mixture with composite solvent (50% methanol 50% 2-propanol) were also higher, in multi vehicle engine oil it were 15 ml, 20 ml and 24 ml for ratios 1:1, 1:2, and 1:3 respectively, whereas with single solvent (methanol) it were 14 ml, 15 ml and 18 ml.

Table 02: Vacuum distillation of waste engine oil (Average per 100 ml)

Type of oil sample	Single vehicle engine oil	Multi vehicle engine oil
Recovery (ml)	73.5 ml	72.6 ml
Residue (ml)	12.1 ml	12 ml
Heating losses (ml)	14.3 ml	15.3 ml
I.B.P ^{o}C	112.6^{o}C	122.6^{o}C
Time of I.B.P	11.5 min	11.8 min
F.B.P ^{o}C	230^{o}C	230^{o}C
Total time (min)	83.3 min	91 min

3.4. Solvent recovery using atmospheric distillation

The recovery of single solvent (methanol) was higher from single vehicle engine oil as 57 ml, 126 ml and 192 ml from ratios of 1:1, 1:2 and 1:3 respectively, whereas recovery of composite solvent were 55 ml, 119 ml and 186 ml from ratios 1:1, 1:2 and 1:3. Moreover, the recovery of single solvent (methanol) from multi vehicle engine were 56 ml, 121 ml and 184 ml from ratios of 1:1, 1:2, and 1:3 respectively, whereas recovery of composite solvent (50% methanol and 50% 2-propanol) were 54 ml, 121 ml and 182 ml from ratios of 1:1, 1:2 and 1:3 respectively.

3.5. Recovered oil analysis

The properties of regenerated oil are listed in table 03, moreover, these were compared with those of fresh oil. The obtained resulted revealed that, single vehicle single solvent (methanol) gave best results comparing fresh engine oil, with single solvent (methanol) ratio 1:1, whereas composite solvent (50% methanol 50% 2-propanol) was also effective. Solvent to oil ratio has more effect than type of sample, with decreasing solvent to oil ratio increases recovery.

Table 03: Comparison of regenerated engine oil with fresh engine oil.

Properties	**Flash point ^{o}C**	**Kinematic viscosity@ (40^{o}C)**	**Density (g/ml)**	**Specific gravity**
Fresh engine oil	224	86.9	0.8809	0.8818
Single vehicle, single solvent (1:1)	213	82.5	0.8869	0.8878
Multi vehicle, single solvent (1:1)	199	77.3	0.8904	0.8913

Table 03: *contd.*

Single vehicle, composite solvent (1:1)	193	74.7	0.8926	0.8935
Multi vehicle, composite solvent (1:1)	184	71	0.8934	0.8943
Single vehicle, single solvent (2:1)	179	69.5	0.8704	0.8713
Multi vehicle, single solvent (2:1)	170	66	0.8714	0.8723
Single vehicle, composite solvent (2:1)	165	64.3	0.8738	0.8748
Multi vehicle, composite solvent (2:1)	157	61	0.8745	0.8754
Single vehicle, single solvent (3:1)	151	57	0.9218	0.9318
Multi vehicle, single solvent (3:1)	141	55	0.9236	0.9246
Single vehicle, composite solvent (3:1)	135	52	0.9268	0.9278
Multi vehicle, composite solvent (3:1)	126	49	0.9276	0.9286

4. Conclusion

From analysis of this research, it was shown that from waste engine oil, all solvents utilized can efficiently remove impurities. From comparing characteristics, it was observed that single solvent (methanol) gave closet specification fresh lube oil at optimum solvent to oil ratio 1:1, with maximum recovery of 95% from single vehicle engine oil. Amount of recovery of oil and removal of impurities were higher with decreasing solvent to oil ratio 1:1. The percentage for removal of impurities and recovery of oil were greater with single solvent (methanol). The single vehicle engine oil had shown most favorable characteristics.

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