I-ENV-O-188-09

RECOVERY OF WASTE ENGINE OIL BY SOLVENT EXTRACTION METHOD: EFFECTS OF WASTE ENGINE OIL TO SOLVENTS AND MIXED SOLVENTS RATIOS

Emma Asnachinda[1,2] , Benyapha Kaowsaard[1], Sittiya Aresiytammakul[1], Nollaya Uparakote[1], Renuka Waruttamapun[1] and Srisuda Nithettham[1,2*]

[1] Department of Chemical Engineering, Faculty of Engineering, Burapha University, Chon Buri, Thailand
[2]Research Program of Industrial Waste Management-Policies and Practices, Center of Excellence on Hazardous Substance Management (HSM), Bangkok, Thailand

*Corresponding author's e-mail address: srisudas@eng.buu.ac.th

Abstract

This work focuses on recovery of waste engine oil (WEO) by solvent extraction method. Six various type of solvents (alcohol group: methanol, ethanol, n-butanol; hydrocarbon group: hexane and toluene; ketone group: acetone) were selected to study effects of extraction for both of single and mixed solvent systems. Ratios of WEO to solvent and mixed solvent were used to be 1:1, 1:2, 1:3 and 1:4 for every extractions. To perform mixed solvent systems, butanol was added with each selected solvent at various ratios (1:1, 1:2, 1:3 and 1:4) prior to extraction process. For the single solvent extraction, methanol shows the largest extraction yield at 99.8% (1:1 of WEO to solvent ratio). Results show that solvent with high hydrogen bonding tends to separate sludge form base oil better than those having hydrocarbon and acetone group. For mixed solvent system, extraction of WEO using butanol:toluene (1:3 of WEO to mixed solvent ratio) demonstrates the best efficient extraction at 97.5% yield. Some physical properties of extracted oil were also evaluated in accordance to ASTM standards. Extraction oil characteristics were investigated by their physical properties and were reported as follow: 0.855-0.910 g/cm^3 for density, 15-83 centistoke for viscosity, -11 to –25 °C for pour point and 50-70 °C for flash point. Results indicated that all of the extracted oil samples have their physical properties close to diesel fuel.

Keywords: solvent extraction, mixed solvent, waste engine oil

Introduction

Waste Engine Oil (WEO), hazardous waste was generated from various sources especially in car service garages. Few of them were acknowledged to treat correctly followed by industrial waste disposal B.E. 2548(2005). To date, more than a hundred car service garages in Chon Buri typically produced large amount of WEO. However, only thirty seven percent of WEO have been managed to comply with law as reported by the government [1]. Waste utilization is one of alternate solutions to recover valuable compound from industrial waste. In general, WEO have particular amount of base oil in the composition that can be reclaimed. Therefore, it is challenge to find the simple and effective way to recycle them that could possibly be initiated information for further use. This work focuses on recovery of WEO by solvent extraction that is the method commonly required less complex procedures and instruments. There are many techniques to recycle WEO which typically applied in common but have to deal with large energy supply. Vacuum distillation method has been reported to encounter coke and scale formation within distill column that need to be treated for impurities removal [2]. Pyrolysis process has also been reported to be the promising way for environmental friendly method due the residue can be used as alternative fuel but it is costly and requires complex operation and knowledge [3-5]. For solvent extraction, mixing of WEO to various portions of solvents can be simply performed that impurities are able to be removed depending on type of solvent used which is also recoverable by distillation process [6]. Solvents had been categorized by Burrel's Classification which were considered from hydrogen bonding ability as high hydrogen bonding (alcohol, amide, acid, aldehyde compounds);

moderate hydrogen bonding (ketone, ester, ether); low hydrogen bonding (hydrocarbon, chlorinated hydrocarbon, nitrogenated hydrocarbon) [7]. Extraction yield percentage of WEO can be predicted by comparing the solubility parameter value (δ, $MPa^{1/2}$) between solvent used and component oil based. Previous literatures had been accomplished many patterns of WEO extraction. As reported, mixed solvent can be used for economic reason to obtain the highest extraction yield [8]. One of solvent given the good extraction efficiency was butanol. Additionally, mixed solvents developed by butanol as base solution have not been reported elsewhere. Therefore, the main objectives of this work are to evaluate the effective ratio of mixed solvent used and investigate some physical properties of extracted oil.

Materials and Methods

Materials

Waste Engine Oil (WEO) was received from a car service garage in Chon Buri, Thailand. Solvents used in this work were ethanol, methanol, butanol, toluene, hexane, and acetone which were classified by the functional group in their structures (alcohol, ketone and, hydrocarbon). Extractions of WEO were achieved by using separatory funnels at room temperature. The extracted oil physical properties were analyzed by kinematic viscometer (viscosity) and pycnometer (density). All chemicals in this work were used as received.

Methods

Preparation of WEO and Solvents

To pretreat the fresh WEO, large particles were separated by filtration method using vacuum pump. Filtrated WEO was safely kept in clean bottle for proceeding to the next step. Extracted solvents were prepared before used and were divided into two conditions: single solvent and mixed solvent. For the extraction step, variation of WEO to single solvent ratio and WEO to mixed solvent ratio were carried out at the same values as 1:1, 1:2, 1:3 and 1:4. To prepare extracted solution, specific amount (2 g.) of potassium hydroxide (KOH) were added into each batch of single solvent and mixed solvent with well stirring before used.

Extraction of WEO by Single Solvent

Extractions of WEO by single solvent were carried out at different WEO to solvent ratios (1:1, 1:2, 1:3, and 1:4). First, all prepared solvents were mixed together with WEO in various ratios at 400 rpm for 15 min at room temperature. Next, mixed WEO and single solvent solution were filtered by vacuum pump to remove any particulates that exist. Then, solutions were rinsed in separatory funnel and allowed to settle for 1 day to observe complete separation. Finally, extraction yield percentage in each batch was calculated. To evaluate the suitable condition of WEO extraction, density and viscosity of oil product were sent further to analyze along with yield data.

Extraction of WEO by Mixed Solvent

For WEO extraction by using mixed solvent, overall experimental steps were followed the same procedures as applied in single solvent extraction. In detail, mixed solvent refers to proportion of butanol to other solvents (ethanol, methanol, toluene, hexane and acetone) in various ratios of 1:1, 1:2, 1:3, and 1:4. Percentage of extraction oil obtained from experiments were also calculated as well as density and viscosity measurement of oil product.

Physical Properties Measurement of Extracted Oil

Some typical properties of automotive oil were selected to determine in the oil obtained from each extraction. Oil density and kinematic viscosity were selected to investigate for every samples. After that, suitable batches of extracted oil sample in each solvent and ratio were evaluated for further measurements. Specific properties of fuel: specific gravity, pour point, cloud point and flash point were analyzed for those selected oil samples.

Results and Discussion

WEO Extraction Results

Receiving WEO was appeared as black, non-transparent and was contained large amount of precipitate. WEO was pretreated to remove immiscible particulates and to promote homogeneity of oil sample by vacuum filtration. These procedures were slightly reduced viscosity of WEO. Detail of extraction results are described as follow:

Extraction by Single Solvent

Single solvent extractions were conducted using six different types of chemicals classified by their functional groups: alcohol (methanol, ethanol, and butanol), ketone (acetone), hydrocarbon (hexane and toluene). WEO to solvent ratio was also varied (1:1, 1:2, 1:3 and 1:4) to evaluate the proper extraction condition. Results in Fig. 1 show relationship between yield percentage in various WEO to solvent ratios and types of solvent used. Extraction of WEO for mostly solvents are enhanced with respect to amount of solvent added which are varied between 60 to 99 percent yield. According to ratio variation, methanol has a decreasing extraction trend whereas hydrocarbons (hexane and toluene) have yield percentages about the same. However, yield percentages are differed depending on type of solvent. For alcohol and acetone groups, number of carbon atom in their chemical structure may affect to lower of extraction efficiency [9]. Solvents sorted as hydrocarbons (hexane and toluene) demonstrate high extraction efficiency greater than 95 percent for every WEO to solvent ratios. This can be explained by the like-dissolve-like principle between the given solvents and WEO which are considered as hydrophobic. Thus, amount of solvent used is not significant as pure solvents can dissolve well by themselves with individually dissolution limit. According to alcohol group, WEO to solvent ratio and number of carbon atom in solvent molecules are determined as an important factors affected to extraction efficiency. Results show the optimum WEO to solvent ratio is 1:3 which extraction yields are found greater than 85 % for every solvent used. In addition, increasing of solvent portions does not significantly affect to the yields and ratio selection is basically based on an economic reason. These findings are in an agreement as reported from literatures [7], [10].

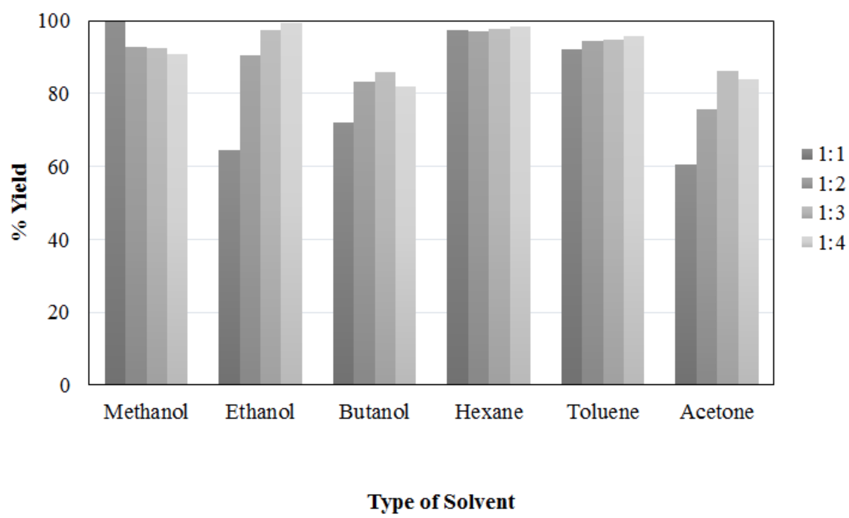

Fig.1 Yield percentage of WEO extraction by single solvent and various WEO to solvent ratio.

Extraction by Mixed Solvents

According to the results of single solvent extraction, n-butanol was selected for using in the mixed solvent system due to lower evaporation compared to methanol with a reasonable yield percentage. Fig. 2 shows yield percentage of WEO extraction to various types of mixed solvent (butanol+selected solvent). Overall results demonstrate that mixed solvents have the greater extraction yields than those using butanol alone. Moreover, mixed solvents obtained from butanol and hydrocarbons (toluene and hexane) have the highest extraction yields among other given substances whereas mixed solvents from alcohol compounds (methanol and ethanol) have the lowest extraction efficiency. In more details, when two substances have comparable solubility parameter values, the more homogeneously dissolution between these two substances are observed. Extracted oils from the experiments show properties close to diesel fuel which has the solubility parameter as 8 $MPa^{1/2}$ [11]. Summary of solubility parameter values are shown in Table 1. Solubility parameters of mixed solvent are calculated from weighting of mixed portion [12]. Results show that solubility parameter of pure butanol is apparently differed from diesel oil. However, mixing of butanol and hydrocarbons can enhance the solubility parameter of mixed solvent to preferable condition.

When considering on the effect of WEO to mixed solvent ratio on the extraction yields, the results reveal that the extraction yields are improved from 68-84% to 88-98% when increasing in WEO to mixed solvent ratios from 1:1 to 1:3 for all types of mixed solvents. However, the more amount of mixed solvents does not further enhance the extraction yields. It can be seen that the extraction yields decrease to 74-92% when using WEO to mixed solvent ratio at 1:4, representing the limitation of extraction system. The results are consistent with the literature [10].

Table 1 Summary of solubility parameter [a] for single solvent and calculated solubility parameter[b] for mixed solvent used in this work

Solvent condition	Solubility parameter, δ ($MPa^{1/2}$)
Single solvent [a]	
Butanol	11.4
Toluene	8.9
Hexane	6.9
Methanol	14.5
Ethanol	13.4
Acetone	10.0
Mixed solvent [b]	
Butanol with toluene	10.15
Butanol with hexane	9.15
Butanol with methanol	12.40
Butanol with ethanol	12.95
Butanol with acetone	10.70

Reference: [a]Batista et al., 2015
[b]Calculated from values reported by Burke, 1984

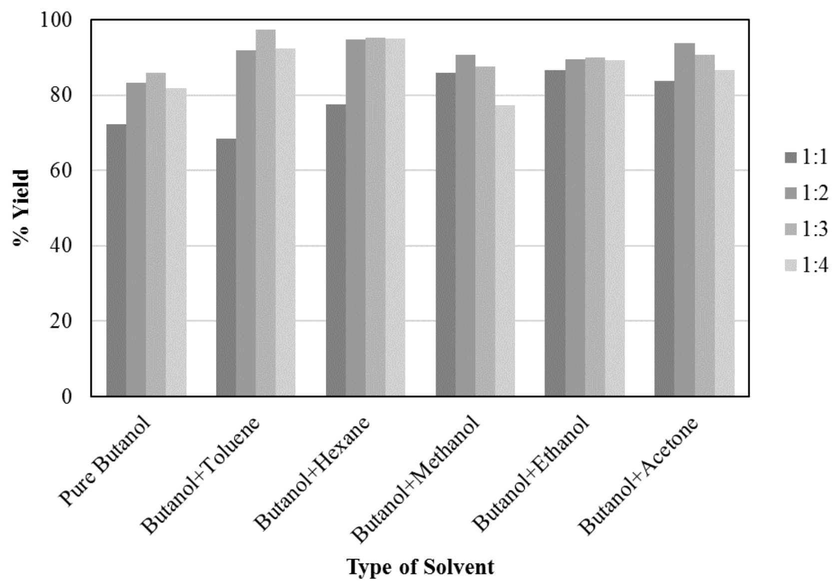

Fig.2 Yield percentage of WEO extraction by mixed-solvent and various WEO:solvent ratio.

Physical Properties of Extracted Oil

The physical properties of extracted oil by single and mixed solvent are summarized in Table 2 which shows that the properties of the extracted oil are closed to those of diesel oil. Extraction by using butanol (single solvent) and all mixed solvents yield the oil with density in range of 0.855-0.872 g/cm^3 which fall within the diesel standard specification. Viscosity and pour point are also improved to the reasonable values. However, flash point of all extracted oil samples are not enhanced to meet the standard specification. This may because the halide compound in synthetic oil cannot be effectively removed by the extraction method. Therefore, the other treatment process such as adsorption should be conducted after finishing the extraction which will be further studied.

Table 2 Summary of extracted oil properties compared with diesel standard

Properties	Fresh lube oil	WEO	Diesel standard[a]	Extracted oil							Literature (Mohammed et al., 2013)
				Single solvent			Mixed solvent				
				Toluene	Hexane	Butanol	Butanol+ hexane	Butanol+ ethanol	Butanol+ acetone	Butanol+ toluene	
				1:1	1:2	1:3	1:1	1:2	1:2	1:3	
Density (g/cm^3)	0.846	0.865	0.81-0.87	0.891	0.895	0.855	0.871	0.872	0.872	0.870	0.899
Viscosity at 40 °C (cSt)	61.45	63.76	1.8-4.1	58.65	46.26	56.63	60.83	54.82	63.07	72.17	72.00
Pour point (°C)	-24	-25	< 10	-17	-14	-25	-18	-15	-20	-16	-11
Flash Point (°C)	70	42	> 52	52.7	53.4	53.5	55	54.4	50	58	220

[a]Department of Energy Business, Ministry of Energy, Thailand

Conclusion

Recovery of WEO by solvent extraction method can be applied to avoid complex operation. Performance of this method depends on type and ratio of solvent used as determined by comparable solubility parameters between WEO and solvent. Optimum extraction ratio for every systems were reported to be 1:3 whereas the enhancement of solvent portion beyond this point was exceeded their extraction limit. All WEO samples performed in mixed solvent system showed an increasing of extraction yields due to the improvement of solubility parameter. In addition, viscosity and pour point values of all batches (mixed solvent and single solvent) were improved after extraction whereas density of all systems were not changed as much. Importantly, solvent extraction failed to mend flash point for all WEO samples. Thus, further purification was required to remove existing impurity of halide compound. However, other properties of extracted oil were discovered close to diesel fuel.

Acknowledgements

Authors would like to express the appreciation to Department of Chemical Engineering, Faculty of Engineering, Burapha University for grants and technical supports in this work. Another, this study has been carried out in the scope of waste management research supported by the Center of Excellence on Hazardous Substance Management (HSM). The authors would like to thank HSM for financial support to perform this research.

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