Advanced Materials Research *Online: 2013-05-27*
ISSN: 1662-8985, Vol. 699, pp 735-741
doi:10.4028/www.scientific.net/AMR.699.735

Optimization of Treatment Parameters on the Recycling of Used Lubricating Oil

[1,a]Ambali Saka Abdulkareem Edison Muzenda[2,b] and Ayo Samuel Afolabi[3,c]

[1]Department of Civil and Chemical Engineering, College of Science, Engineering and Technology, University of South Africa, P/Bag X6 Florida 1710, Johannesburg, South Africa
[2]Department of Chemical Engineering, Faculty of Engineering and the Built Environment, University of Johannesburg, Johannesburg South Africa
[3]Department of Civil and Chemical Engineering, College of Science, Engineering and Technology, University of South Africa, P/Bag X6 Florida 1710, Johannesburg, South Africa

[a]kasaka2003@yahoo.com, [b]emuzenda@uj.ac.za, [c]afolaas@unisa.ac.za

Keywords: Acid Treatment, Lubricating Oil, Concentration, Recycling, Temperature, Time, Volume.

Abstract. Acid treatment is one of the cheapest techniques and least applicable processes in the recycling of used lubricating oils. In this work, the performance of sulphuric acid in the treatment used oil was studied. The effects of the critical treatment parameters (acid volume, concentration of the acid, treatment temperature, stirring time and treatment time) were investigated by varying one treatment parameter at a time and analysing metal content in the sample of the treated oil using atomic absorption spectrometry (ASS). Thereafter, an optimal solution was determined by the combination of the optimum values of each treatment parameters. The original conventional treatment parameter values, resulted in 13.2 ppm and thereafter was optimised to 11 ppm this showed a definite improvement in efficiency. This result is also comparable to other data obtained in previously studied work which employed the same conventional treatment parameters. The optimal solution is within 10% variation as compared the standard individual metal content which ranges 0-10 ppm.

Introduction

Lubricating oils from petroleum consists essentially of complex mixtures of hydrocarbon molecules. They are mostly composed of iso-alkanes having slightly long branches and the mono-cycloalkanes and mono-aromatics which have several short branches on the ring. These hydrocarbon molecules generally range from low viscosity oils having molecular weights as low as 250 $gmol^{-1}$, up to very viscous lubricants with molecular weight as high as 1000 $gmol^{-1}$ with the carbon atoms range from 20 to 34 $gmol^{-1}$ [1]. There are three major classes of lubricating oils, namely: lubricating greases, automotive oils and industrial lubricating oils. This present study focuses on the automotive lubricating oils.

Today the shortage of oil as a natural resource has become common knowledge therefore the need to look at effective alternative ways of reserving this natural resource becomes of utmost importance. Therefore, whether oil is refined or re-refined it needs to adhere to certain standards for maximum efficiency. In view of this, these automotive oils are prepared and blended to specifications that will fulfil the lubrication functions which the oils are expected to provide; these functions are to lubricate, clean, cool and protect the surfaces of solid materials [2]. Automotive oil as a lubricant function hydro-dynamically on all parts, to reduce friction, heat, and wear when introduced as a film between solid surfaces receiving a continuous flow of fluid lubricant and to function as a thin lubricant on parts such as in oil bath. The oil also serves as a cleaner by keeping parts and surfaces mechanically clean, thus preventing wear and improving performance. The purpose of automotive oil as a sealer is to prevent foreign material from entering the parts and surfaces. As a coolant, automotive oil aid transfer of heat from the parts to a cooling medium and as a protector, it shields all parts from build-up of foreign material, corrosive attacks and degradation of the lubricant itself [2].

Despite the benefits of the automotive oil listed above, these viscous liquids de-grade when exposed to severe build-up of temperature, thus leading to reduction in properties such as: viscosity, specific gravity, etc. Dirt's and metal parts worn out from the surfaces are deposited into the lubricating oils. With increased time of usage, the lubricating oil loses its lubricating properties as a result of over-reduction of desired properties, and thus must be evacuated and a fresh one replaced [1]. The idea of recycling of used lubricating oil was introduced due to the increasing necessity of environmental protection and the stricter environmental legislation on the disposal of used oil [1,3]. Recycling of the used lubricants is also encouraged due to the importance of preserving the world's natural oil for future generation; hence the need for the recycling of used oils became imperative. Over the years, scientists developed several methods of used oil recycling such as: acid/clay, distillation/clay, activated charcoal/clay and acid treatments [4]. Acid treatment is one of the earliest discovered methods of re-refining lubricating oil in the early 1930s [5]. Among the advantages of using acid treatment are due to its process simplicity, low initial investment and low energy input [6]. However, in spite of the length of time that sulphuric acid has been employed in refining petroleum lubricating distillates, the mechanism of the reactions and the effects produced are still in dispute [5]. The need for more knowledge on this subject is obvious, especially since acid treating occupies a place of primary importance in refinery operation. Today, acid treatment is regarded as the least effective method of re-refining lubricating oil because of its small oil yields and production of a highly hazardous by product (acid sludge) to the environment [1].

Virgin lubricating oils extracted from mineral sources, whether straight-run or multi-blend, cannot meet all lubrication requirements. Similarly, re-refined oil cannot be expected to retain its original physical properties and functions as well as its original application. Just as natural new lubricating oils are treated as base stocks, the re-refined oil must be considered as base stock, and can be re-blended to the required specification. The re-blending process is to prevent gum build up, clean up dirt and scavenger engine parts of sludge, suspend fine particles, prevent sludge formation, neutralized corrosive acids, ensure adhesion to moving parts, reduce rate of wear at critical areas, improve viscosity to improve lubricating strength, thermal stability, performance and increase equipment life among many more other reasons [2]. Most applications of lube oils require that they be non-resinous, pale-coloured, odourless, and oxidation-resistant. Over a dozen physical and chemical tests are used to classify and determine the grade of lubricating oils. Common physical tests include measurements for viscosity, specific gravity, and colour, while typical chemical tests include those for flash and fire points. However, this study will only investigate the metal content property. The contaminants are introduced either from the surrounding air and from the engine, which are called extraneous contaminants, or from the products of oil deterioration [7]. The objective of this work is to study the effects of treatment parameters on the acid treatment method in the recycling of used lubricating oil with the hope of obtaining a product that satisfies the acceptable refined base oil standard of individual metal. The treatment parameters that are investigated in this study are ratio of volume of acid to oil, concentration of the acid, treatment temperature, stirring time and treatment time.

Materials and methods

Materials. A litre of lubricating fresh oil and 10 litres of used oil samples were collected from Mercedes Benz automobile station in Sandton, Johannesburg South Africa. About 3 litres of gasoline was collected from Engen garage at Rivonia, Johannesburg South Africa. Analytical grades (98-99.5%) of sulphuric acid and sodium hydroxide used for this experiment were obtained from Sigma Aldrid, South Africa.

Methods. Samples of fresh and used oils were both analysed for metal content. The used sample of transmission oil was filtered to remove impurities before treatment. This was done using a funnel with a filter paper placed in it. A vacuum pump was connected to the filtering flask to which the funnel was fixed with the aid of a rubber stopper. The concentrations of the sulphuric acid used were 85, 90 and 95% and the wavelength standards of 5, 10, 20 and 40 ppm were prepared for the ASS studies.

Sample of used lubricating oil was stirred thoroughly to promote homogeneity from the stock 450 ml was measured out and transferred to a beaker and 150 ml of gasoline was also measured and added to the oil. The lube base oil mixture was then placed on a shaker for minutes. It was then left to settle for another 10 minutes. This was followed by the treatment of the contents of the baker with 10 ml of 98% concentration H_2SO_4 in a separating funnel with the mixture strongly agitated. The content was then allowed to settle for 48 hours after which two layers/phases were formed. The sludge was removed from the bottom of the separating funnel. After which 100 ml solution of 10% NaOH was added to neutralize the acid. It was then allowed to settle for about 30 minutes. The alkaline phase, which was formed at the bottom, was removed and the lube oil washed with hot water twice (15 ml). The oil was heated with a bunsen burner while connected with a vacuum pump. The procedure was repeated by varying one treatment parameter at a time.

The metal content in re-refined lube oil was determined using the atomic absorption spectrometry (AAS). Samples containing the metal to be analysed were dissolved in water, if insoluble, digesting in the acid dissolved it. The cathode lamp for the element was put in position and the element characteristic wavelength selected using wavelength selector standard solutions of the element to be determined are first prepared and their absorbency measure at selected wavelength [8]. All the experimental analyses in this study are conducted in triplicate and the results present are the average value with variations of ±0.002.

Results and discussion

Mismanagement of waste lube oil is a serious environmental problem with the large amount of engine oils used; the disposal of lubricating oils has now become a major problem. Unfortunately, most of used oil is handled improperly, for instance some used oil is emptied in to sewers and allowed to flow directly into water waste, which adversely affecting water treatment plants. Some is dumped directly on to the ground to kill weeds or is poured on to dirty roads or is dumped in deserts, where it can contaminate surface and ground water. Hence the disposal of used lubricating oil into the eco system creates environmental hazards; there is therefore the need to properly dispose of the used lubricant oils. Many nations are now addressing the problem of environmental pollution posed by waste or used lubricating oils in their countries. In disposing used oil, many people use it as a dust cure; that is, for dust prevention. This method of disposal is in many ways unsatisfactory as the lead-bearing dust and run-off, constitute air and water pollution. Another method by which used oil is being disposed is by incineration. This method represents another poor use of such a valuable product, and the attendant emission of probably carcinogenous products, contribute to environmental pollution. Recycling of the used lubricant oils for the purpose of re-using them as a fresh lubricant is now considered as a perfect and sustainable method of controlling the environment hazard that emanated from the present method of used oil disposal. The recycling of used lubricants has been practiced to various degrees since the 1930s and particularly during the Second World War when the scarcity of adequate supplies of crude oil during the conflict encouraged there use of all types of materials including lubricants. Environmental considerations regarding the conservation of resources have maintained interest in the concept of recycling up to the present day. High price of oil and objective of saving valuable foreign exchange also favoured the choice of recycling of used lubricant oils. Almost all types of waste oil have the potential to be recycled safely, saving a precious non-renewable source and at the same time minimizing environmental pollution. In most cases, used oil can be re-used after reconditioning with or without the addition of any additives resulting in huge saving and conservation of precious oil. This present study therefore focus on the investigation of effects of various parameters on the removal of iron from the used lubricant oil using acid treatment method. Results of various experiments conducted are presented in Figs. 1- 7

Fig. 1 shows the comparison between fresh and used lubricating oil samples in terms of their iron content analysis. It can observed that the fresh oil practically shows zero iron content as expected; while used oil shows a significant amount of metal due to contaminants which introduced during usage either from the surrounding air and/or from the engine [7]. The used oil sample has been attracted significant content of iron over a period of about six months is use.

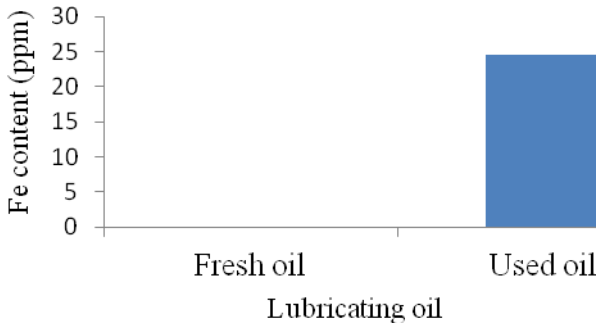

Fig. 1: Fresh and used oil metal content comparison

The results obtained on the effect of acid volume on the metal removal were studied by varying the parameter from 5 - 20 ml. It can be seen from Fig. 2 that as the acid volume increases the iron content of treated used lubricant oil decreases. A sharp drop in metal content values was observed at lower acid volumes. For acid volumes between 10-15 ml, a gradual decrease in metal content was observed with increase in acid volume. The results as presented indicate that the optimum acid volume was in the region 15- 20 ml which corresponds to minimum iron content of 12.8 ppm. This phenomenon can be attributed to the fact that, increasing the acid volume increases the medium mutual solubility of the oil resulting in better treatment efficiency.

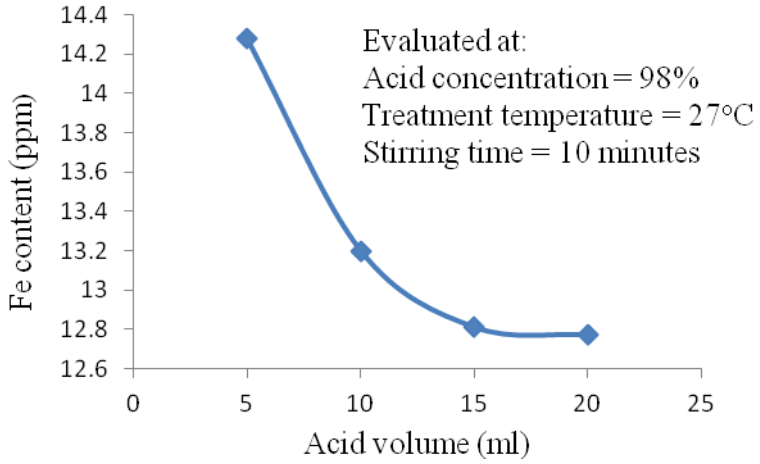

Fig 2: Effect of acid volume on metal content in the treatment of used lube oil

The effect of acid concentration on metal removal was studied by varying the parameter from 85-98% and the results obtained were plotted in Fig. 3. This result shows that acid volume is a factor that has great influence on the removal of the metal from the used oil. This is evident from the fact that the optimum metal content obtained in used lubricating oil after treatment is 12.8 and 13.2 ppm for acid volume and concentration respectively. Koh [2]. opined in is his study that an initial concentration of acid rather than number of grammes of acids should be the greatest factor which has the greatest influence on metal removal in used lubricating oil, and this suggestion is slightly different from the results obtained in this study where acid volume seems to have more influence on the metal removal than the acid concentration. This disparity can be traced to different methods employed for the removal of this metal from the used oil.

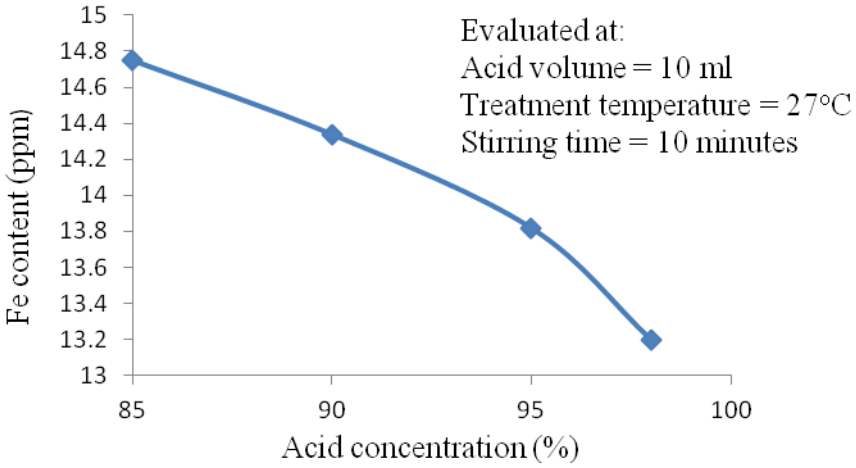

Fig. 3: Effect of acid concentration on metal content in the treatment of used lube oil

Also investigated in this study is the effect of treatment temperature on iron removal from the used lubricant oil by varying the temperature from 27 – 60^{o}C. The results obtained as presented in Fig. 4 show that as the temperature increases the concentration of the iron removed from the used lubricants decreases, until a maximum value of 13.3 ppm was reached and thereafter reduced to 13.2 ppm. This shows that lower temperatures result in better metal removal. This can be attributed to the possibility of dissolution of the iron in the used oil lubricants at higher temperature. This finding is however, contrary to that of Koh [2] where he traced reduction in treatment efficiency at low temperatures such as 15^{o}C to either poor agitation at high viscosity or failure to attain equilibrium at that temperature.

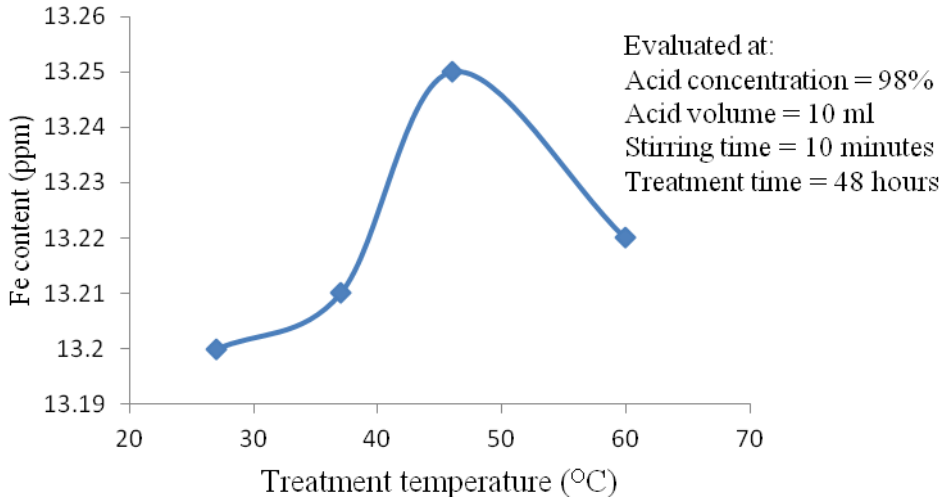

Fig. 4: Effect of treatment temperature on metal content in the treatment of used lube oil

The effect of stirring time on the removal of metal content from used oil was studied by varying the parameter from 5-25 minutes and the results obtained are presented in Fig. 5. As can be seen in Fig. 5, as the stirring time increases from 5 minutes, there is a decrease in metal content until a minimum value of 13.0 ppm and thereafter an increase to 13.2 ppm. This shows that an increase in stirring time increases metal removal with the optimal solution reached at 20 minutes. This finding can be attributed to the fact that stirring time promotes homogeneity and equilibrium therefore at lower stirring times treating efficiency is expected to reduce resulting in higher metal content in re-refined oil.

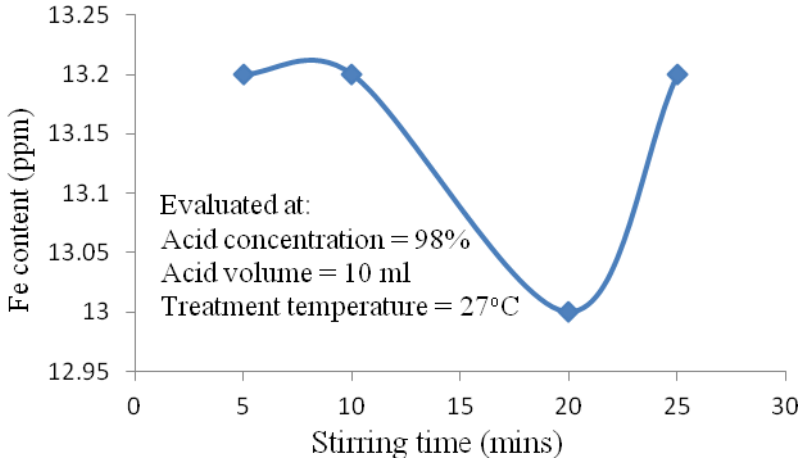

Fig. 5: Effect of stirring time on metal content in the treatment of used lube oil

The effect of treatment time on metal removal was studied by varying the parameter from 24-96 hours. As shown in Fig. 6, the metal content and treatment time have an indirect proportion relationship, with the metal content decreasing as the treatment time increases. This observation can be attributed to the increased settling (acid sludge settles) in the separating funnel as settling is known to be favoured by increase in time.

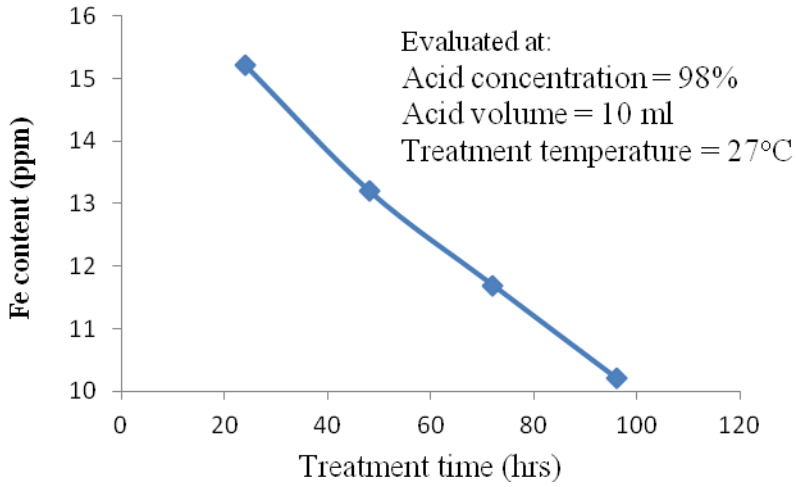

Fig. 6: Effect of treatment time on metal content in the treatment of used lube oil

Fig. 7 is a representation of all the optimal solutions for each of the investigated parameters obtained in this study. The conditions from this Fig. which are; 98%, 20 ml, 27^{o}C, 20 minutes and 96 hours for acid concentration, acid volume, treatment temperature, stirring time and treatment time respectively, were employed in the final step of treatment of used oil and an ultimate optimal solution of 11 ppm was obtained. The value is very close to the findings of Udonne [1] where a combination of distillation/acid and activated charcoal with clay methods were used to obtain an optimum value of 10.5 ppm. The optimum solution obtained in this study is within 10% variation compared to acceptable refined base oil standard of individual metal contents of 10 ppm.

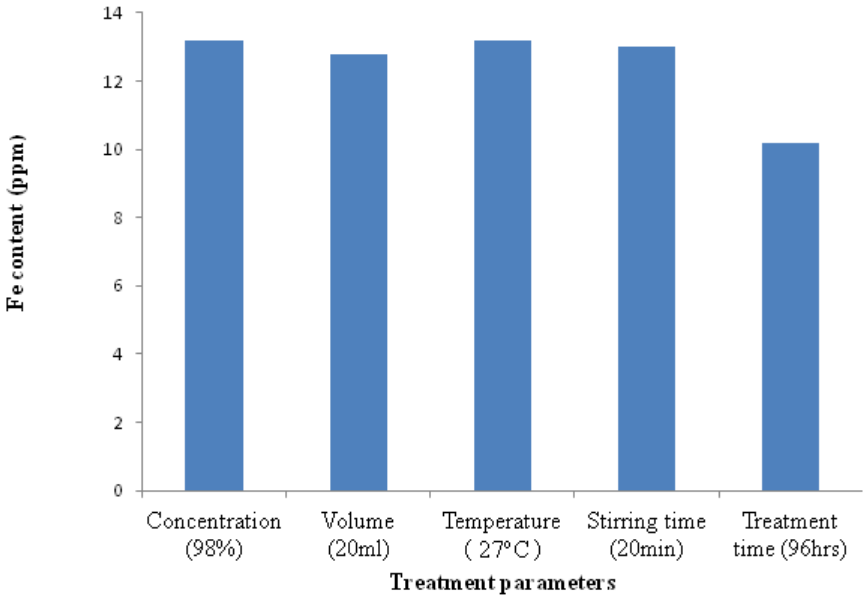

Fig. 7: Optimum treatment parameters for the recycling of used lube oil

Conclusions

In this study, acid treatment method was employed to optimize the effects of treatment parameters on the recycling of used lubricating oil with the aim of obtaining an optimal solution that depicts improved efficiency and at the same time is within the range of acceptable refined base oil standard of individual metal content. An optimal solution of 11.0 ppm that was obtained in this study shows improved efficiency from the original 13.2 ppm, which was obtained using the conventional treatment parameter values. This optimal solution is within 10% variation compared to the standard iron content which ranges from 0-10 ppm.

Acknowledgement

The authors gratefully acknowledge the financial support of the University of Johannesburg. The authors are also very grateful to the anonymous referees for their valuable contribution.

Corresponding Author

All correspondence must be addressed to: Prof. Ayo Samuel Afolabi, Tel: +27732364421, E-mail: afolaas@unisa.ac.za

References

[1] J. D. Udonne, *Journal of Petroleum and Gas Engineering* Vol. 2 (2010), pp 12-19.

[2] J.L. Koh. *Deep Space Network Support Section.* (1981) pp 42-64.

[3] M. A. Khawaja, M. M. Aban, *Environmental Management and Health* (1996) pp 23-32

[4] Technical team Everest Transmission (2005) *"Lube Purification"*

[5] H.M. Wier, W.F. Houghton, F.M. Majewski, *The Atlantic Refining Company Philadelphia, PA* 22, 12, (1930), pp 1293-1300.

[6] L. Stevens, M. Van Mouwerk, M. D. Seese, W. Bashan, *Environmental Contaminants Encyclopedia* (1997).

[7] F. Awaja, D. Pavel, *Design aspects of used lubricating oil re-refining*, UK: Elsevier, Inc. (2006) pp 24-25

[8] A. S. Abdulkareem, A. S. Afolabi, S. O. Ahanonu, T. Mokrani, *Manuscript accepted for publication in Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. Taylor and Francis*, (2011).