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Recycling of Waste Engine Oil using Acetic and Lactic Acids as Washing Agents

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Abstract

Waste engine oil (WEO) is known to contain metal, carbon and oxidized contaminants which are harmful to human and the environment. This research refines WEO using acetic and lactic acids as washing agents. Parameters such as kinematic viscosity, flash point, pour point, specific gravity were analysed for oils. The result of the experiment showed that the kinematic viscosity of WEO (165.52 cSt) increased when washed with acetic (181.20 cSt) and lactic acids (179.96 cSt) at 40ºC similarly at 100ºC closer to fresh oil value (192.71 cSt). The decreased flash point of WEO (175 ºC) increased when treated with acetic (215 ºC) and lactic acids (212 ºC) compared to fresh oil (230 ºC). The increased pour point of WEO (-6 ºC) was reduced when treated with acetic (-11.5 ºC) and lactic acids (-10.9 ºC) which are close to fresh oil (-13 ºC). The high specific gravity of WEO (0.9186) were reduced by acetic (0.8756) and lactic acids (0.8745) closer to fresh oil (0.8815). These reduced parameters in the WEO and its increased pour point and specific gravity indicates impurities and contaminants in WEO. The improved values with acetic and lactic acids showed that they are good washing agents. FTIR analysis of WEO showed additional peaks at frequencies 1054.8, 1109.2 and 2310 cm^{-1} representing the primary oxidized products at high temperature which are absent in fresh oil and WEO treated with acetic and lactic acids.

Keywords — Recycling, Waste engine oil, Acetic and lactic acid, Acid/clay technique, Oil parameters, Fourier transform infrared spectroscopy (FTIR).

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I. INTRODUCTION

Engine oil (lubricating oil) is a complex hydrocarbon having large numbers of carbon atoms per molecule obtained through fractional distillation of crude oil. It is known for its application in the lubrication of engines, machines and automobiles (Ugwele et al., 2020). Engine oil prevents wear and tear in machine parts alongside removing contaminants from engine. It also acts cleaning agent, anti-corrosive and anti-cooling agent for machine parts. During usage, engine oil accumulates and absorbs impurities which affect its efficiency as lubricating, cooling and anti-corrosive oil. Impurities such as burnt carbon, sulfur, lead, oxidized hydrocarbons, barium, zinc, steel, copper, water, etc. have been reported to be present in used or waste engine oil and some of them are poisonous and harmful to human and the environment (Kwao-Boateng et al., 2020, Abro et al., 2013).

Waste engine oil (WEO) is contaminated used engine oil, cutting and servicing oil depending on the application that is to be disposed. WEO is a pollutant that affects our health, environment, plants and animals if not well disposed. In Nigeria, most WEO are poured directly on the ground or in water ways which in turn contaminates the water ways and soil affecting aquatic and plant growth and also exposing us to dangerous metal and oxidized pollutants (Sardasht et al., 2013).

This environmental and health concern about the disposing of WEO to the environment has brought the need for recycling of WEO to its original base form for re-use and the removal of its impurities. Different techniques have been applied to recycle WEO such as vacuum distillation, which uses sulphuric acid to refine the WEO but also produces by-products with high sulphuric contents and also damages essential additives in the oil (Udonne et al., 2011). Acid-clay techniques, solvent extraction and membrane filtration techniques have also been used but they have their drawbacks such as being too expensive to operate, generation of more pollutants, wastage of solvent, damage of essential base oil additives and the inability to refine modern multi-grade oil (Anisuzzaman et al., 2021, Sardasht et al., 2013, Boadu et al., 2019).

Another way of refining WEO is through the use of inorganic acid. This involves the use of mostly concentrated sulphuric acid which is found to be effective but is known to produce toxic by-product which is harmful to the environment. This has made researchers to look at using organic acids as washers for recycling waste WEO. Different researchers have carried out recycling of WEO using organic acids and other acids such as acetic acid (Sardasht et al., 2013), acetic and formic acid (Saleh et al 2017), acetic, phosphoric, nitric and sulphuric acid (Stan et al. 2018). Their results showed improvement in the specific gravity, viscosity and flash point of the used oil compared to fresh oil when formic, sulphuric and phosphoric acids were used. Also a combination of acetic and formic acid improves the viscosity and colour of the used oil. But these non-organic acids (formic, sulphuric, phosphoric, nitric) affected other parameters such as removal of oil additives, kinematic viscosity, and pour point of the used oil and besides they are not environmentally friendly. Acetic acid on the other hand improved the used oil parameters close to the fresh oil with minimal distortion of the oil properties. This research work uses organic acids; acetic and lactic acid as refining agents in recycling WEO and compares the effectiveness of these organic acids in recycling WEO with one another.

II. MATERIALS AND METHOD

The following chemicals and equipment were used for to carry out the experiment.
($Al_2O_3.SiO_{2}.2H_2O$), Visco 2000 WEO and fresh oil (SAE 20W-50). Beaker, stirrer, electric heater, mass balance, measuring cylinder, centrifuge and magnetic stirrer.

A. Filtration and acid treatment of the waste engine oil

500 ml of the WEO was measured with a measuring cylinder and filtered with a filter paper to remove dirt's and colloidal particles. 150ml of the filtered WEO respectively was placed in two 250ml beakers respectively and heated at 250ºC for one hour to vapourize water and volatiles that might be present in the oil. The acids were added to the oils in the beakers at ratio 1:10 volume of acid to WEO. That is 15 ml of acetic acid (AC) was mixed with WEO in one of the beakers and 15 ml of lactic acid (LC) in the other beaker. The mixtures were left at room temperature and pressure for 24 hours. Supernatants in the acid treated oil (acidic base oil) were decanted into two 250ml beakers respectively. The acid sludge left in the beakers was discarded and the acidic base oil (ABO) in beakers were centrifuged at 3000 rpm for 30 minutes and decanted to remove impurities.

B. Bleaching and neutralization of the decanted base oil

The decanted ABO's were mixed with Kaolinite in the ratio of 1:25 by volume of Kaolinite to base oil. 4g Kaolinite was stirred in 100ml of base oil in beakers while heating the mixtures on hot plate at 110^0C for 15 minutes. This process changes the dark coloured base oils to red. Kaolinite addition to the oil removes the smell from the oil and changes the dark colour of the oil caused by oxidation of the oil during use.

The pH of the treated oils was neutralized with hydrated lime in the ratio 1:25 volume of lime to base oil. 4g of hydrated lime was mixed with 100 ml of the bleached oil with continues manual stirring for 15 minutes. The mixtures were left to sediment for 24 hours and filtered with a filter paper.

C. Determination of oil parameters

The oil samples were taken to a laboratory in Port Harcourt where the flash point of the oils were analysed using an open cup flash point tester with ASTM D-92 guidelines. ASTM is American Standard for Material Testing. The pour points of the oils were measured using Ducom pour point tester machine following ASTM D5949 guidelines. The kinematic viscosities were measured using Brookfield DV-E viscometer and the specific gravity of the oils measured using oil density hydrometer.

III. RESULT AND DISCUSSION

Fig. 1 shows the WEO (A), fresh oil (B) and WEO treated with acetic (C) and lactic acid (D) respectively. From the figure it can be seen that WEO is dark in colour due to contaminants and usage. The fresh oil labelled B is clean with green brown colouration. The acetic and lactic treated WEO had similar colour compared to fresh oil but darker. This is due to the washing activities of acetic and lactic acid in recycling of WEO and removal of some oil additives in the process.

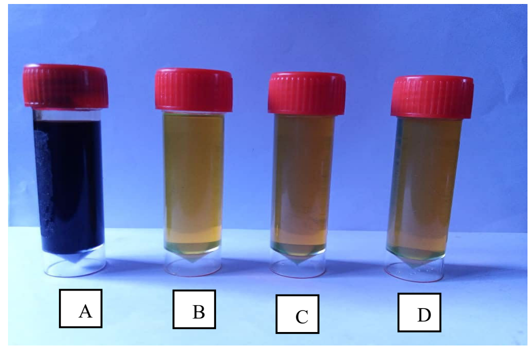

Fig. 1 WEO compared to fresh oil and acetic and lactic treated WEO.

Table 1 shows the measured properties of fresh oil, WEO and acid treated WEO. The table showed that the kinematic viscosity of WEO decreases by 27.19 centistoke (cSt) to 165.52 (cSt) at 40^0C compared to the fresh oil (192.71cSt). Also at 100^0C, the kinematic viscosity of WEO decreases by 4.15 to 14.20 cSt compared to the fresh oil (18.35 cSt). These decreases in viscosity indicate the presence of contaminants in the WEO. The kinematic viscosity is a measure of how oil flows when force is applied. Thus the higher the kinematic viscosity, the lesser the shear stress and oxidized products.

Table 1 Measured oil parameters

S/N	Samples	Kinematic viscosity (40^0C) (cSt)	Kinematic viscosity (100^0C) (cSt)	Specific gravity	Flash Point ^{0}C	Pour Point ^{0}C
1	Fresh oil (SAE 20W-50)	192.71	18.35	0.8815	230	-13
2	WEO	165.52	14.20	0.9186	175	-6
3	WEO + Lactic acid	179.96	15.77	0.8745	212	-10.9
4	WEO + Acetic acid	181.20	16.10	0.8756	215	-11.5

Table 1 also showed that acetic and lactic acids when added to WEO at 40^0C and100^0C, the kinematic viscosity were slightly affected by the acids. Acetic acid had 181.20 centistokes and lactic acids (179.96 cSt) at 40^0C compared to fresh oil (192.71 cSt). Also minimal difference in kinematic viscosity were observed at 100^0C with 16.10 cSt for acetic treated WEO and 15.77 cSt for lactic acid treated WEO compared to the fresh oil (18.35 cSt). This slight difference in the value of the kinematic viscosity treated with acetic and lactic acids showed that these two acids are less destructive to the mixtures and additives of the base oil while refining the WEO. This indicates that acetic and lactic acids are good washing agents in refining WEO.

The specific gravity of the WEO (0.9186) in Table 1 is higher compared to the fresh oil (0.8815) and WEO treated with acetic (0.8756) and lactic acids (0.8745). This is because the WEO contains contaminant such as metals, condensed and oxidized products rich in carbon which increases the specific gravity of the WEO. Specific gravity is known to increase in oil if there is an increase presence of aromatic compounds and solids in the oil and decreases when saturated compounds are present (Abu Elella et al. 2015). Also the specific gravity of WEO treated with acetic (0.8756) and lactic acid (0.8745) is lower than that of the fresh oil (0.8815) because of additives in the fresh oil to aid performance of the fresh oil. The low value of specific gravity of acetic (0.8756) and lactic acid (0.8745) showed that they are good washing agents for WEO in removing contaminants with acetic acid being less destructive to additives in the oil.

The flash points of the oils in Table 1 showed that the fresh oil had highest value of 230^0C due to additives in the oil to enhance performance. Flash point is the lowest temperature for an oil to ignite when heated under certain conditions. And it is used to determine the degree of contamination of oil. Decreasing flash point values of oils is known to be as a result of metallic contents, fuel and oxidation products in oil (Abu Elella et al. 2015). The flash point of WEO in table 1 is 175^0C compared to 230^0C for fresh oil. This shows that the WEO is contaminated. Washing the WEO with acetic and lactic acids increased the flash point of the WEO to 215^0C and 212^0C respectively. This showed that acetic and lactic acids are effective in removing contaminants in WEO and improving its flash point.

Table 1 also showed that treating the WEO with acetic and lactic acid improved the pour point of WEO from -6^0C to -11.5^0C for acetic and -10.9^0C lactic acid treated. The pour point values of -11.5^0C and -10.9^0C are close to the value recorded for fresh oil (-13^0C) with minimal differences of 1.5^0C and 2.1^0C for acetic acid treated and lactic acid treated WEO respectively. This shows that the treated WEO with acetic and lactic acid can enable engine starts at cold weather. This is because pour point is the lowest temperature for engine oil to remain in a flowing state. The pour point values of oils is affected by the viscosity of the oil, thus high viscosity oil have high pour point and contaminants in oil increases oil viscosity.

Fig. 2 shows the FTIR spectrum for the fresh oil. The spectrum shows oxidation of the oil at frequency 1748 cm^{-1} which might be due to the production quality of the oil. Spectral band 1700 to 1750 cm^{-1} indicates oxidation compounds is present in the oil and carbonyl compound (C=O) are easily absorbed in this frequencies. The spectrum also shows the presence of alkenes, aromatics, alkyl halides, alkanes and carbonyl compounds in the fresh oil and their corresponding frequencies explained in table 2.

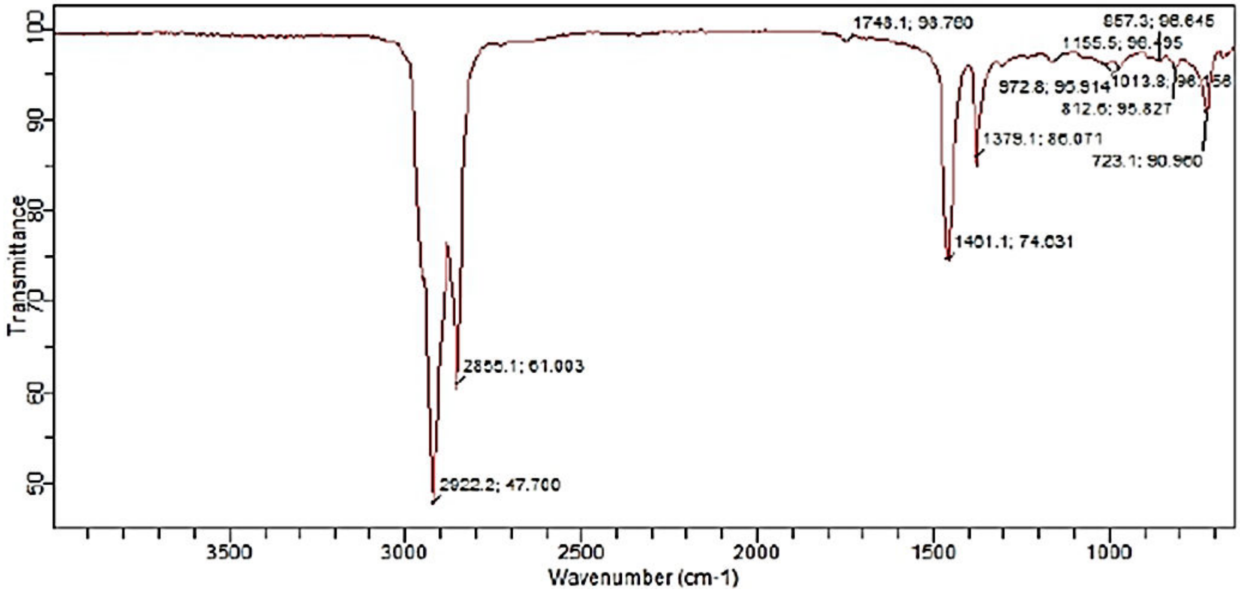

Fig. 2 FTIR spectra of fresh engine oil

Table 2 FTIR Analysis of fresh oil

Frequency cm-1	Bond	Functional Group
723.1	$C-H$	Alkenes
812.0	$C-H$	Alkenes
957.3	$C-H$	Aromatics
972.8	$C-H$	Aromatics
1155.5	CH_2-X	Alkyl Halide
1379.1	$C-H$	Alkanes
1401.1	$C-H$	Alkanes
1748.1	$C=H$	Carbonyl compound
2855.1	$C-H$	Alkanes
2922.2	$C-H$	Alkanes

Fig. 3 shows the FTIR spectra for WEO showing additional peaks at frequencies 1054.8, 1109.2 and 2310 cm^{-1} representing the primary oxidized products at high temperature as analyzed in table 3. These are indications of the oil been used compared to the fresh oil.

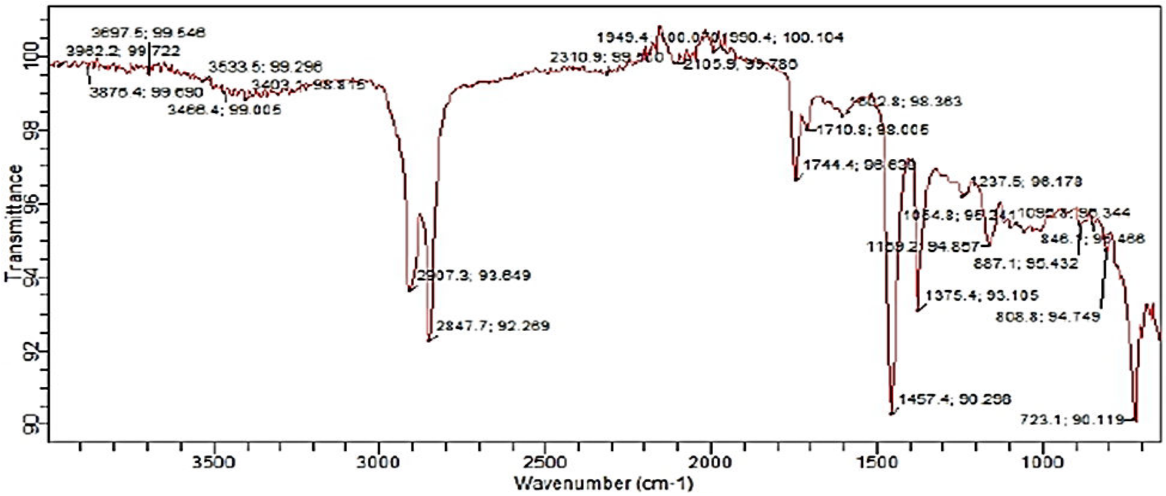
Fig. 3 FTIR spectra of waste engine oil

Table 3 FTIR Analysis of waste oil

Frequency cm-1	Bond	Functional Group
723.1	C − H	Alkenes
808.8	C − H	Alkenes
848.1	C − H	Alkenes
887.1	C − H	Alkenes
1054.8	C − O	Carboxylic acid
1109.2	C − O	Carboxylic acid
1237.6	$CH_2 - X$	Alkyl Halide
1375.4	C − H	Alkanes
1457.4	C − H	Alkanes
1602.8	C = H	Aromatics
1710.8	C = H	Carbonyl compound
1744.4	C = H	Carbonyl compound
2310.9	C − O	Carboxylic acid
2847.7	C − H	Alkanes
2907.3	C − H	Alkanes

Fig. 4 and table 4 are the FTIR spectra for WEO with acetic acid and its analysis respectively. The result shows similarity with the fresh oil with the exception of an oxidized product at frequencies 1054.8 cm^{-1} and 1182.9 cm^{-1} which originates from the waste oil.

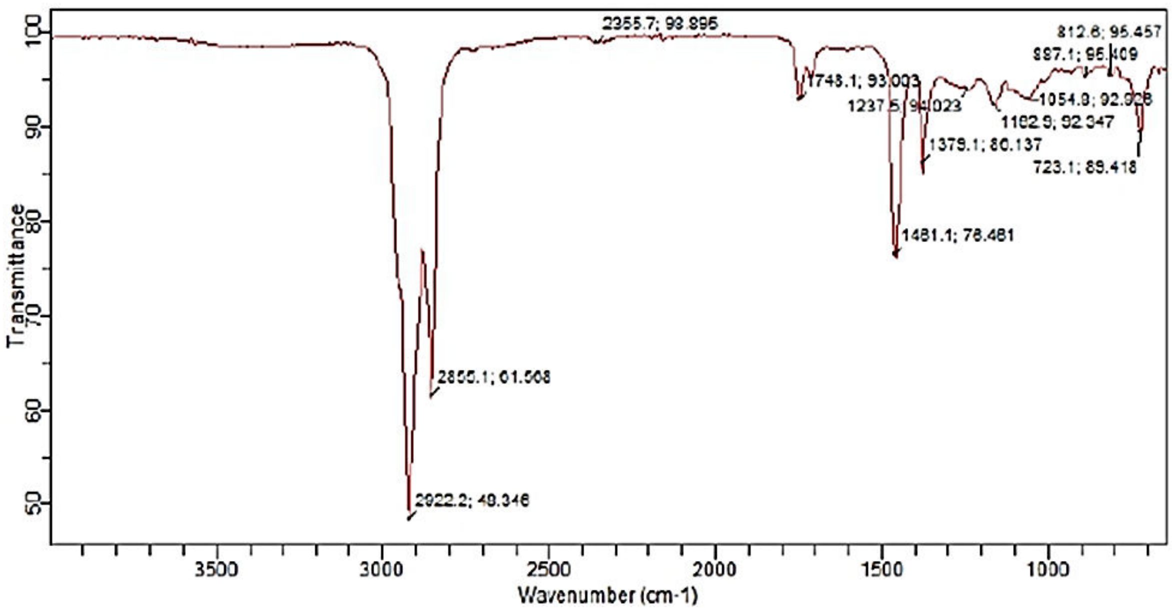

Fig. 4 FTIR spectra of WEO treated with acetic acid

`Table.4 FTIR Analysis of WEO treated with acetic acid

Frequency cm-1	Bond	Functional Group
723.1	C – H	Alkenes
812.6	C – H	Alkenes
1054.8	C – O	Carboxylic acid
1182.9	C – O	Carboxylic acid
1379.1	C – H	Alkyl Halide
1481.1	C – H	Alkanes
1748.1	C = H	Carbonyl compound
2855.1	C – H	Alkanes
2922.2	C – H	Alkanes

The FTIR spectra in Fig 5 for WEO treated with lactic acid and its analysis in table 5 showed similarities with the fresh oil. There were no oxidized products in the treated oil compared to that treated with acetic acid. This might be due to the ability of lactic acid to refine the WEO and remove the oxidized products

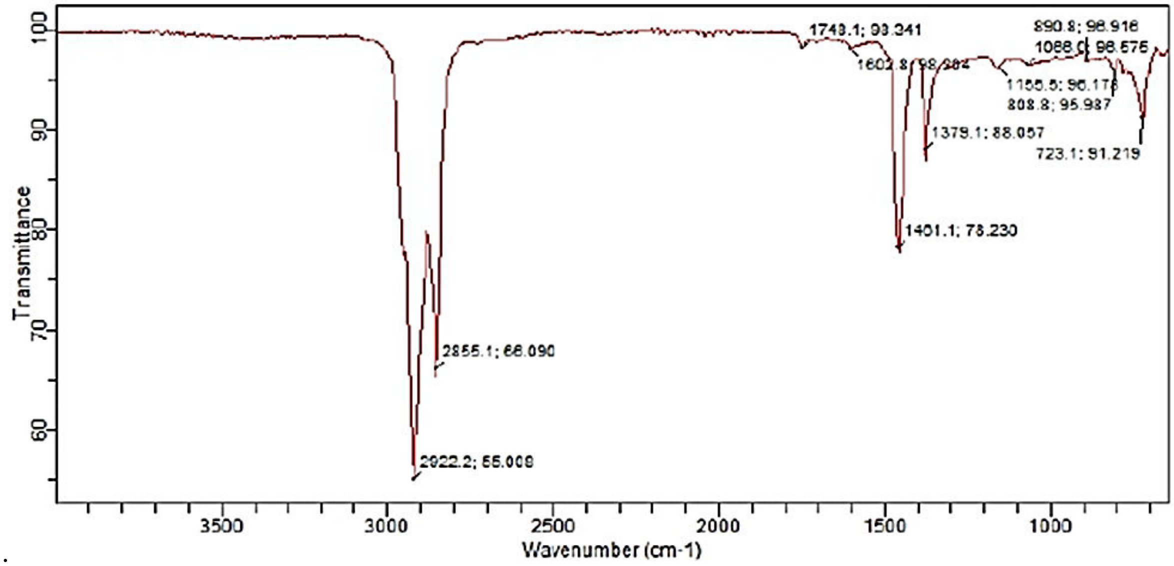

Fig. 5 FTIR analysis of WEO treated with lactic acid

Table 5 FTIR Analysis of Waste oil treated with lactic acid

Frequency cm-1	Bond	Functional Group
723.1	C – H	Alkenes
808.8	C – H	Alkenes
1155.5	$CH_2 - X$	Alkyl Halide
1379.1	C – H	Alkyl Halide
1401.1	C – H	Alkanes
1602.8	C = H	Aromatics
1748.1	C = H	Carbonyl compound
2855.1	C – H	Alkanes
2922.2	C – H	Alkanes

IV. CONCLUSION

In conclusion the FTIR analysis and oil parameters such as kinematic viscosity at 40ºC and 100ºC, flash and pour point, specific gravity, showed that acetic and lactic acids are good refining agents for WEO. The results for acetic and lactic acids are close to the fresh oil values with no oxidized products found in lactic acid treated WEO but acetic acid treated WEO results are closer to fresh oil values.

REFERENCES

Ugwele, F.O, Aninwede, C.S, , T.O, Christian, O.A, Innocent, S.I. (2020). Application of response surface methodology in optimizing the process conditions for the regeneration of used mobil oil using different kinds of acids. *Heliyon*. 6 (10), :e05062.

Kwao-Boateng, E., Terza, A. P., Anthony, N. P. A., Michael, K. F. (2022). "Re-refining Used Engine Oil in Ghana Using Solvent Extraction and Acid-Clay Treatment", *International Journal of Chemical Engineering*, 2022, Article ID 6344409, 8 pages,

Abro, R., Xiaochun ,C., Khanji , H., Zulifqar, A. D., Muhammad, "A. (2013). Comparative Study of Recycling of Used Engine Oil Using Extraction by Composite Solvent, Single Solvent, and Acid Treatment Methods", *International Scholarly Research Notices*, 2013, Article ID 952589, 5 pages.

Sardasht, T., Hamawand, I., Yusaf, T.F. (2013). Recycling of Waste Engine Oils Using a New Washing Agent, *Energies*., 6. 10.3390/en6021023.

Udonne, J. D. (2011). A comparative study of recycling of used lubrication oils using distillation, acid and activated charcoal with clay methods. *Journal of Petroleum and Gas Engineering,* 2(2), 12-19.

S Anisuzzaman, S .M., Jumaidi, M. H., Nasir , N. N .M. (2021). Used lubricating oil recovery process and treatment methods: A review *IOP Conference Series.: Material Science Engineering*. 1195 012031

Boadu, K. O., Joel, O. F., Essumang, D. K., Evbuomwan B. O. (2019). A Review of Methods for Removal of Contaminants in Used Lubricating Oil, *Chemical Science International Journal*, *26*(4): 1-11,

Salah, E.F., Hegazi, Y.A., Mohamd, M.I.H. (2017). Recycling of Waste Engine Oils Using Different Acids as Washing Agents, *International Journal of Oil, Gas and Coal Engineering*, *5*, (5), pp. 69-74.

Stan, C., Cristian, A., Marius, T. (2018). Some aspects of the regeneration of used motor oil, *Procedia Manufacturing, 22*, *709-713*

Abu-Elella, R., Ossman, M., Farouq, R., Abdel, F.M. (2015). Used Motor Oil Treatment: Turning Waste Oil Into Valuable Products, *International Journal of Chemical and Biochemical Sciences, 7*, 57-67.