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Waste Lubricating Oil Treatment by Adsorption Process Using Different Adsorbents

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***Abstract*—**Waste lubricating oil re-refining adsorption process by different adsorbent materials was investigated. Adsorbent materials such as oil adsorbent, egg shale powder, date palm kernel powder, and acid activated date palm kernel powder were used. The adsorption process over fixed amount of adsorbent at ambient conditions was investigated. The adsorption/extraction process was able to deposit the asphaltenic and metallic contaminants from the waste oil to lower values. It was found that the date palm kernel powder with contact time of 4 h was able to give the best conditions for treating the waste oil. The recovered solvent could be also re-used. It was also found that the activated bentonite gave the best physical properties followed by the date palm kernel powder.

***Keywords*—**activated bentonite, egg shale powder, date palm kernel powder, used oil treatment, used oil characteristics.

I. Introduction

WASTE lubricant oils are generated from vehicles and machineries. This waste lubricating oil has higher values of ash, carbon residue, asphaltenic materials, metals, water, and other dirty materials; which are built during the course of lubrication inside the engine. Wang et al. [1] showed the stability of asphaltene. The addition of compounds with molecules that differ greatly from resins in terms of size and structure, and therefore, solubility parameter, shifts the equilibrium that exists in the non-asphaltene portion of the oil. It is found that normal alkane liquids are often added to oils in an attempt to reduce heavy oil viscosity. The result of this introduction is an alteration in the overall characteristics of the oil making it lighter. Asphaltenes are polar compounds and could be stabilized by the presence of resins. Lichaa [2] showed the critical concentration of resins below which the asphaltene flocculates may precipitate and above which they cannot precipitate regardless of how much the oil mixture is agitated, heated, or pressurized. When the oil is diluted with normal alkane, the amount of asphaltenes precipitated depends on the number of carbons of the solvent. In the normal alkane environment, asphaltenes flocculate and then precipitates into solid phase. The solid phase is a result of particles such as porphyrin, carbon, sulfur, etc. connected to the asphaltene. Vazquez [3] and Juan [4] showed that by introduction of additional alkane, the asphaltenes flocculate because they are swelling until they are breaking down and precipitate out of the solution.

Battalova and Likerova [5] showed that the best adsorbent for the finishing process of lubricating oil is the acid activated bentonite clay, but the mechanism of their action on the components of petroleum oils has not been clarified. They examined the bentonite with and without the addition of 10% sulfuric acid. They showed better properties of the finished lubricating oils. Araujo and Telles [6] showed that the final treatment of the used oil recycling process is the de-colorization and neutralization. The compounds removed at this step are mainly products of the oxidative degradation of base oil, such as organic acids, esters, ketones, etc. They conducted their experiments at controlled temperatures using a batch reactor with a good mixing property. They prepared the oxidized oil and then treated with three different adsorbents at two different temperatures.

Alves and Jeronimo [7] used ketones and alcohols that are miscible with base oils at room temperature. They showed that the flocculating action of polar solvents in waste oils is basically an anti-solvent effect exerted on some non-polar macromolecules, and the addition of KOH in alcoholic solution easily destabilizes the dispersion and increase sludge removal from waste oil. Martins [8] studied the ternary organic solvent (n-hexane, 2-propanol, 1-butanol) on waste oil sludge removal. They showed that 0.25 waste oil, 0.35n-hexane, and 0.4 polar compound (80% 2-propanol, and 20% 1-butanol with 3 gm/l KOH) is an economical aspect for the extraction–flocculation process in the re-refining of waste oils. The waste oil sludges can be reclaimed under the form of asphaltic inks. The used oil is treated with sulfuric acid which preferentially react with oxygen compounds, asphaltic and resinous substances, other nitrogen and sulfur based compounds, and soluble metallic components to form a sludge: paraffinic hydrocarbon are left essentially intact for further refining. Color and odor bodies remaining in the re-refined oil and subsequently removed through treatment with activated clay.

In this study, adsorption process is investigated for the treatment of waste lubricating oil using different adsorbents such as egg shale powder, date palm kernel powder, acid activated date palm kernel powder, and oil adsorbent. The waste oil is diluted with petroleum hydrocarbon such as BP Amoco, Sharjah, UAE, stabilized condensate with the addition of oil demulsifier to work as diluent as well as an extracting material. All the process is conducted at ambient conditions and constant amount of adsorbent.

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II. MATERIALS AND EXPERIMENTAL PROCEDURE

A. Materials

The stabilized condensate was taken from BP Amoco, Sharjah, United Arab Emirates, with the properties listed in Table 1.

TABLE I
PHYSICAL PROPERTIES OF STABILIZED CONDENSATE

Physical property	Stabilized condensate
specific gravity at 60/60 oF	0.7433
API gravity at 60 oF	58.9
Water and sediment content	Nil
Salt content (NaCl),mg/l	< 1
Reid vapor pressure, psi	10.3
H2S content, mg/l	2

The oil adsorbent material is a multi-sorb top quality small granulated natural adsorbent with high porous surface which is used in wide scope of applications. This oil adsorbent was used in this study as adsorbent. Its properties are listed in Table 2.

TABLE II
PROPERTIES OF OIL ADSORBENT

Physical Properties	Values
Absorption capacity: Oil	≥90%(wt)
Water	≥110%(wt)
Retention capacity	≥ 95%(wt)
Mechanical resistance	5.31 gm/cm2
Granulation	7-35 mesh (0.5-4 mm)

The demulsifying agent was taken from one of the oil services supplying companies. This demulsifying material was used to separate the water and asphaltenic materials from the used oil. The main properties of the demulsifying agent are illustrated in Table 3.

TABLE III
DEMULSIFIER AGENT PHYSICAL PROPERTIES

Physical Properties	Values
Flash point, ºC	69
Specific gravity at 20 ºC	0.87
Boiling point, ºC	185
Appearance/odor	Clears yellow liquid with solvent odor

The date palm kernels were collected, dried, crushed using jaw crusher and disc mill, then sieve analyzed. The date palm kernel powder was used without acid activation and with 15 % (wt) sulfuric acid activation. The egg shale was washed, dried, crushed using ball mill.

B. Contaminants Targeted in Used Oil

Physical properties and metal content in used waste oil are shown in Tables 4 and 5.

TABLE IV
PHYSICAL PROPERTIES OF THE USED LUBRICATING OIL

Physical Properties	Used oil
Specific gravity at 20oC	0.879
Flash point, CCPM, oC	152
Water and sediment, vol. %.	1.3
Water content, Dean and Stark, vol. %	0.8
Viscosity at 37.8oC, cst	209.6
Conradson carbon residue, wt%	1.452
Ash content, wt%	0.99
Sulfated ash, wt%	0.0.76
Asphaltene content, wt%	4.295
TBN (Total base number),mg KOH/gm	4.1
TAN (Total acid number),mg KOH/gm	3.3

C. Experimental Procedure

1. The waste oil was allowed to settle down and all the free water and sediment were separated before using it for the next steps.
2. Specific volume of used oil was mixed properly with stabilized condensate produced from Sharjah BP Amoco, Sharjah, UAE, with solvent to oil ratios of 3:1 with few drops of demulsifier.
3. The mixture was then mixed with a fixed amount of 15%(wt) of different adsorbents.
4. The mixture was stirred properly for different contact time in a batch adsorption process at ambient temperature.
5. The sample was filtered, solvent recovered using simple distillation process, and then analyzed for different physical properties.
6. The sulfuric acid activation procedure of date palm kernels powder was followed by the work done by Jazayeri and Rezaei [9].

III. RESULTS & DISCUSSION

The waste oil was treated over different adsorbents such as bentonite, activated bentonite, date palm kernels powder with and without acid activation, oil adsorbent material, and egg shale powder, with a contact time of 1-6 h. The treated oil was filtered, solvent recovered. The treated oil was analyzed for Conradson carbon residue, ash content, sulfated ash, and asphaltene content as heptane insoluble. These properties were compared with previous work done over bentonite and acid activated bentonite which are used in many commercial recycling processes to improve mainly the color of the finished oil product. These properties of the treated oil are shown in Figures 1-6. From these figures, it can be seen that the 4-h contact time over different adsorbent gave the best physical properties of the treated oil as shown in Figure 7. From these figures, it can be seen properly that the acid activated bentonite has the best performance in treating the waste oil in an adsorption process followed by the date palm kernel powder.

The recovered stabilized condensate solvent was analyzed using the standard ASTM distillation test and other important physical properties to check the changes in boiling points with different collected volumes. The specific gravity of the stabilized condensate was changed from 0.7236 to 0.7316 at 15°C and the kinematic viscosity was changed from 0.7254 to 0.751 cst. at 37.8°C. The vapor pressure (DVPE) was changed from 48.209 to 40. 12 KPa absolute. The recovered solvent has slightly higher specific gravity, viscosity and boiling point than fresh solvent. This showed that some of the light hydrocarbons from the used oil were distilled with the recovered stabilized condensate solvent. These hydrocarbons can be classified as heavy ends of the gasoline fraction.

The metal content of the treated oil from 3:1 solvent to oil ratio with demulsifier after contact hour of four hours over 15% bentonite material, acid activated bentonite and date palm kernels powder are shown in Table 5. The treated oil showed low levels of contaminated iron and lead.

TABLE V
METAL CONTENT OF WASTE OIL, AND TREATED OIL OVER DATE PALM KERNEL POWDER AND OTHER ADSORBENTS

Metal	Waste oil (mg/kg)	Oil after Bentonite treatment (mg/kg)	Oil treated over activated acid bentonite (mg/kg)	date palm kernel (mg/kg)
Iron (Fe)	15	4	4	5
Aluminum (Al)	4	1	1	2
Chromium (Cr)	4	<1	<1	<1
Copper (Cu)	7	5	4	6
Lead (Pb)	138	101	9	75
Tin (Sn)	<1	<1	<1	<1
Silver (Ag)	7	<1	<1	<1
Nickel (Ni)	<1	<1	<1	<1
Vanadium (V)	<1	<1	<1	<1
Titanium (Ti)	<1	<1	<1	<1
Cadmium (Cd)	<1	<1	<1	<1
Manganese (Mn)	1	1	1	1
Molybdenum (Mo)	7	5	3	6
Silicon (Si)	11	<1	<1	2
Boron (B)	3	4	<1	4
Sodium (Na)	13	29	43	9
Barium (BA)	<1	<1	<1	<1
Calcium (Ca)	1667	1272	1104	973
Magnesium (Mg)	51	45	33	34
Phosphorus (P)	632	409	381	489
Zinc (Zn)	780	408	77	531

IV. CONCLUSION

The precipitation of the asphaltenic materials and other contaminants over different adsorbents was studied to get rid of these contaminants. The process of adsorption of waste oil using natural adsorbents such as date palm kernels powder, oil adsorbent, egg shale powder with the addition of stabilized condensate and demulsifier were achieved. It was found that the date palm kernels powder looks attractive process for treating waste oil. The carbon residue, ash content, and aspheltene content were decreased up to 68.2 wt%, 72.9wt%, and 92.3wt% respectively. This process also decreases the amount of heavy metals in treated oil. The solvent recovered from the process can be recovered and reuse again.

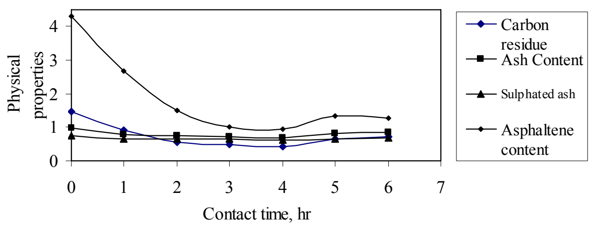

Figure 1: Physical Properties of treated oil with 15% bentonite material(No acid activation)

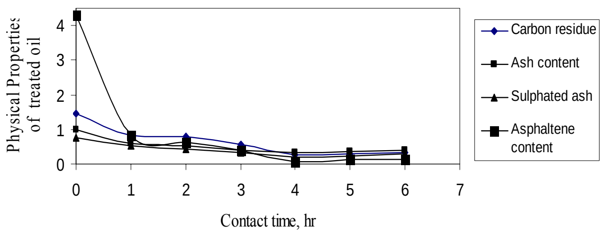

Figure 2: Physical Properties of treated oil with contact time at 15% acid treated clay

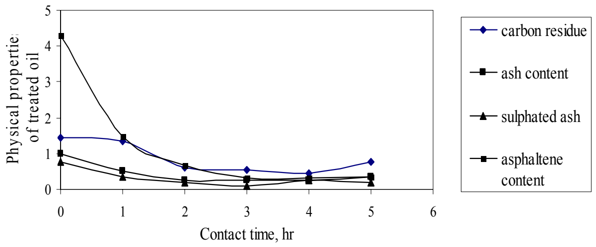

Figure 3: physical properties of treated oil with contact time over 15% date stone powder

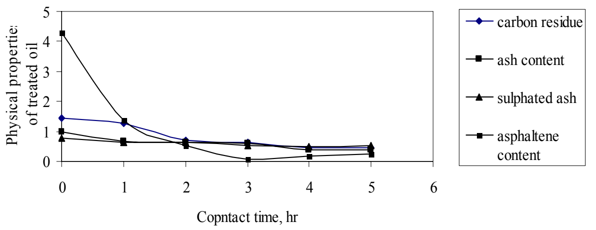

Figure 4: Physical Properties of treated oil with contact time over 15% acid activated of date stone powder

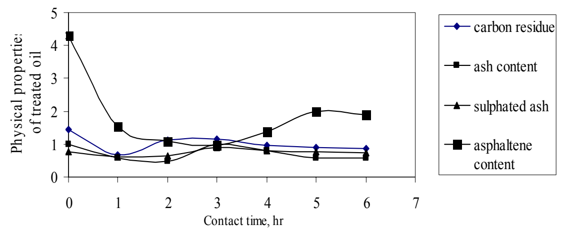

Figure 5: Physical properties of treated oil with contact time over 15% egg shale powder

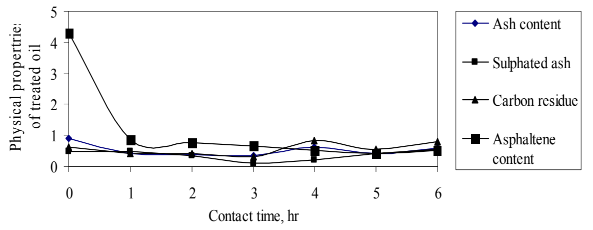

Figure 6: Physical properties of treated oil with contact time over 15% oil adsorbent material

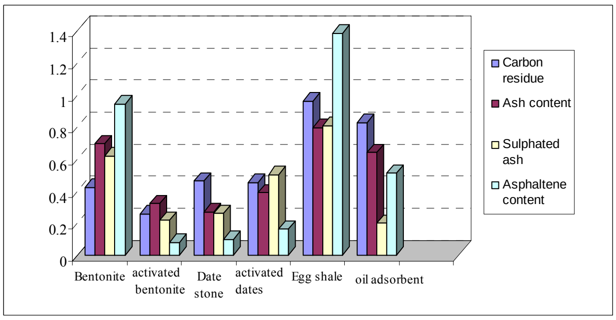

Fig. 7 Physical properties of treated oil over 15% of different adsorbents

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