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COMPARATIVE STUDY OF DIFFERENT MEDIA IN REDUCTION OF POLLUTANTS IN USED LUBRICATING OIL, NIGERIA-A CASE STUDY

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ABSTRACT

Nigeria is about the 6th largest producer of crude oil in the world and in recent times averages about 500,000,000 litres yearly of total consumption of lubricating oil. Significant qualities of these used lube oil are frequently disposed in the country by means which pollute the water, land, air, and in turn endanger the public health. In order to address this problem, this experiment was undertaken to recycle the used lube oil by filtration process. This was done by first conducting analysis of used lubricating oil from different types of vehicles and then subjected to various treatment options. Experimental results indicated that result from the use of glass beads was more feasible, has low operating potential hazards and most effective in pollutant reduction compared with others. The concentrations of various ions like Fe^{2+}, NO_3, Ca^{2+} among others in the samples investigated was more than 100% higher in the used oil compared with results in the unused sample. The experiment was able to provide efficient waste management treatment and acceptable compressive strength of 350 psi in 12 hours using 12.5 pounds per gallon (ppg) recipe was obtained.

Keywords: used lubricating oil, Nigeria, comparison, pollutants.

INTRODUCTION

Chemistry of petroleum lubricants

The first step in producing lubricating oil involves distillation of the crude petroleum. The lower boiling gasoline, kerosene and fuel oils are removed first, and the lubricating oil fractions are then separated by boiling point into several grades of neutral distillates and a final more viscous residuum. Subsequent refining steps remove undesirable aromatics and the minor portion of sulphur, nitrogen and oxygen compounds. Finished lubricating oils are then made by blending these refined stocks to the desired viscosity, followed by introducing additives needed for optimal performance. Petroleum base lubricating oils are present in the residue boiling above 370˚C (680˚F) from atmospheric distillation selected oils of both paraffinic and naphthenic types. Lubricating oils are tested either to identify them as regards source, refining or blending or to determine their suitability for a particular use. The viscosity of lubricating oil is a measure of its flow characteristics to meet a particular application. Viscosity is generally the most important controlling property for manufacture, differences in speed, and the pressure between the surfaces to be lubricated (Hall, E., *et al.,* 1983).

Lubricants and its constituents

Experts have defined engine oil "as a lubricant which interposes between moving parts of the engine and preventing the engine from seizure while at the same time protecting the engine against problems of friction and wear, oxidation and heat stress, deposit and corrosion as well as sludge. The most commonly selected fluid today is oil derived from petroleum. Despite problems arising from friction, the engine gives rise to various problems. This severe engine oil operating environment exposes the lubricating oil in use to thin film, high temperature and extreme pressure and engenders decomposition of the oil degradation, oxidation, ring sticking, sludge and piston ring wear (The Editor, 1999). Consequently loss of power, higher consumption of fuel and engine oil, excessive running and maintenance costs result. For an engine oil to be classified as sound and appropriate, it must be able to cope with the menace of friction, wear, oil contamination, oxidation, sludge formation, harmful deposits, temperature, pressure, impurities and deterioration. To achieve desired oil characteristics, certain chemical substances called additives are incorporated into a fully formulated oil. These additives handle wear, friction, oxidation, rust, sludge, pressure, valve sticking, volatility, degradation and loss of power.

Additives in petroleum lubricants

Many petroleum products have their qualities improved upon through the utilization of chemical additives. The additives help to suppress inevitable but undesirable properties, enhanced desired qualities or even help to broaden the areas of product suitability. The common additives are as outlined: oxidation inhibitor, corrosion inhibitor, viscosity index improvers, pour-point depressants, antifoam, detergent, dispersants, anti-wear (PTI, 1991).

What is used lubricating oil?

Used lube oil is oil that has been used for lubricating or other purposes, and has become unsuitable for its original use because of the presence of impurities or loss of original properties. It is not "waste oil" but it is a

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recoverable, recyclable resource. Oil doesn't wear out; it just gets dirty. Used lube oil can be re-refined into lubricating oil that is equal in quality to lubricating oil made from crude oil. Used oil includes engine, turbine or gear lubricating oils, hydraulic and transmission fluid. (www.seawifs.gsfc.nasa.gov/html).

Pollutants in used lubricating oil

During use, the constituents present in virgin oil undergo physical and chemical changes and the oil also comes in contact with bearings, seals and other engine parts, which add heavy metals and other contaminants considered hazardous to humans. These contaminants result from chemical action among the oil constituents or from a breakdown of lead compounds from engine blow by, dirt, dust and rust particles. These contaminants are hazardous to humans and constitute one of the greatest pollutants and significant quantities are wastefully disposed by means, which pollute the water, land and air, and in turn endanger the public health.

Recycling of used oil

In general, the earlier in the life of a lubricant that it is exposed to recycling technology, the easier the job and the better the results (Emmerson, 1980). When used oils have suffered substantial dilution, contamination, and deterioration, effective recycling requires the application of a number of unit operation processes. Among the commonly used physical methods are settling, filtration, centrifugation, and in some cases, thermal processing for removal of light ends and water. Recycling of used oil entails acquisition and processing of oil that has become unsuitable for its intended use in order to regain useful material. In this recycling process, a number of stages are possible depending on original source of the used oil, the level of contamination, and the sophistication of the technology utilized. Once oil has been used, it can be collected, recycled, and used over and over again. Recycled used oil can sometimes be used again for the same job or can take on a completely different task. It takes just one gallon of used oil compared with 42 gallons of crude oil to produce 2.5 quarts of lubricating oil (www.gov.pe.ca/te/tips/oil.asp, 1998).

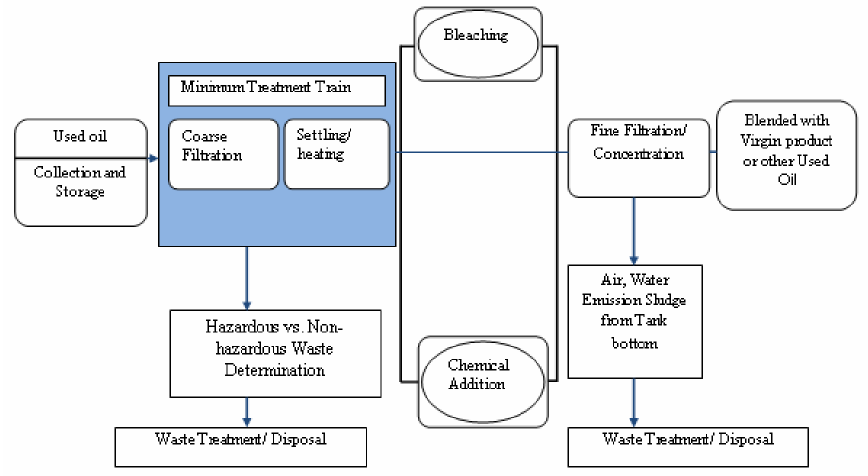

Figure-1. A simplified used oil recycling system.

Disposal

Although recycling is the best used oil management option, recycling is not always feasible. Some used oils are too contaminated, generated too far away from recycling facilities, or generated in quantities too small to be economically recycled in certain cases; therefore, disposal is an appropriate option, as long as the used oil is disposed off in a way that does not harm human health or the environment. For used oil that is not deemed a hazardous waste, appropriate disposal options include incineration by a facility that accepts industrial liquids or placement of the used oil in a properly designed and constructed landfill that accepts industrial wastes. The major problem of dumping used oils into landfills is contamination of groundwater supplies. This contamination usually occurs when refuse leachate from landfill penetrates groundwater sources in deep sandstone or shallow aquifers. The potential harms are greater for used oil than with unused oil because the former contains hazardous contaminants which may migrate to ground water along with the oil component.

Filtration principle

Although the filtration equipment takes several forms, its operation is basically the same. The Solid-Liquid feed stream passes through a porous screen that retains the solids but passes the liquid. As the flow continues, a cake builds up the screen. The cake has a complex pore structure determined by the nature of the solid particles. The structure removes additional particles by a simple straining mechanism (Holdich, 1994).

Considering operating parameters, two special cases are industrially important. One is constant cake filtration wherein the cake of feed delivery to the filter stays the same during the filtration cycle. The other is constant pressure filtration, where the feed is delivered

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under a pressure that does not vary over the cycle. In filtration, the flow resistances increase with time as the filter medium becomes clogged or filters cake builds up. The chief quantities of interest are the flow rate through the filter and the pressure drop across the unit. As time passes during filtration, either the flow rate diminishes or the pressure drop rises. In what is called constant – pressure filtration, the pressure drop is constant and the flow rate allowed to fall with time, less commonly, the pressure drop is progressively increased to give what is called constant-rate filtration.

In cake filtration, the liquid passes through two resistances in series: that of the cake and that of the filter medium. The filter medium resistance, which is the only resistance in clarifying filters, is normally important only during the early stages of cake filtration. The cake resistance is zero at the start and increases with time as filtration proceeds (Wakeman, 1981; Stamatakis and Tien, 1991)

Filtration theory

In order to understand the mechanism of cake filtration, the cake may be modeled as a fixed bed of spherical particles; this means it will have a porosity, or fraction of voids within the cake (Holdich, 1990). The origins of the theory used in these compressible cake simulations are due primarily to the work of Tiller and Shirato and are documented (Shirato, *et al.*, 1970; Holdich, 1996; Tiller and Cooper, 1962; Shirato, *et al.*, 1971).

A higher porosity will result in a lower resistance through the cake. The modified Darcy's Law describes the relationship between the driving force (DP) and the permeability (K).

$$\frac{\Delta P}{L} = \frac{\mu(dV)}{KAdt} \quad (1)$$

From Eq. (1) it can be seen that as the pressure drop across the cake increases the volume of filtration collected also increases.

When applying Eq. (1) to cake filtration, the modified Darcy's Law becomes,

$$\frac{dV}{dt} = \frac{A^2 \Delta PK}{\beta V \mu} \quad (2)$$

The permeability is the conductive property of the medium, (which is the reciprocal of the resistance of the medium). This is related to the porosity by the equation,

$$\alpha = \frac{1}{(1-\varepsilon)PsK} \quad (3)$$

Where α is average specific resistance?

From Eq. (2), β can also be related to the porosity, since β is the ratio of the cake volume to filtrate volume,

$$C = \beta(1-\varepsilon)\rho \quad (4)$$

Where C is average dry cake mass per unit volume filtration

Equation (2) can therefore be rearranged, and the values of β and K can be substituted from Eq. (3) and integrated to give equation (5):

$$t = \frac{\mu \alpha c}{2A^2 \Delta P} V^2 \quad (5)$$

However, the resistance due to the filter medium must be taken into account and added to equation (5), to produce the constant pressure filtration equation,

$$t = \left(\frac{\mu \alpha c}{2A^2 \Delta P}\right) V^2 + \left(\frac{\mu Rm}{A \Delta P}\right) V \quad (6)$$

Using the general filtration equation (6) for compressible cake filtration and dividing the equation by volume gives what is known as the linearised parabolic rate law.

$$\frac{dt}{dV} = \left(\frac{\mu \alpha c}{A^2 \Delta P}\right) V + \left(\frac{\mu Rm}{A \Delta P}\right) \quad (7)$$

RESEARCH METHODOLOGY

In order to fulfill the objectives of this project, the following steps were taken:

- Samples of used lubricating oil from three different sources and unused samples were collected;
- Carried out laboratory analysis to characterize the nature and extent of contamination using recommended test equipment and procedures;
- Designed a treatment process to achieve reduction in the pollutants;
- Evaluated results to determine conformance or deviation with results of the unused sample;
- Attempt was also made to regenerate the treatment medium with the best option;
- Treatment of waste for disposal in a manner that will not pollute the environment; and
- Determined the compressive strength for effective disposal.

Compressive strength test

The used glass beads and effluent water used in the regeneration process were mixed with treatment additive at specified ratio. The mixture was put in 2" by 2" brass cube and placed in water bath at room temperature. The specimens were allowed for 12hours and 24hours respectively, after which the compressive strength results were determined for various compositions, using Hydraulic press machine.

Regeneration of used glass beads

After initial utilization of glass beads for filtration of the used oil, it was found not to be very effective in reduction of the pollutants at subsequent use. Therefore, there was need for regeneration so as to enhance the propertied for further utilization. The used glass beads (about 500g) was mixed (about 250g) of water in a beaker and placed on a hot plate and heated to attain a temperature of 190˚F. Test period was about 30 minutes. The effluent water was decanted and compositions were

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determined. The regenerated glass beads were heated in an oven to a temperature of about 300˚F to dry up any moisture and later allowed to cool for further utilization.

Sample identification and description

Sample-A: Used lubricating oil sample from Peugeot car, estimated period of use was about 3 months
Sample-B: Used oil sample from Mercedes car, estimated period of use was about 3 months
Sample-C: Used oil sample from pick-up van, estimated period of use was about 3 months
Sample-D: Clean oil (unused) sample
Sample-E: Filtered sample from sample A, filtration medium was 20/40 sand
Sample-F: Sample B was passed through a filter bed using glass beads

RECYCLING OPTIONS ADOPTED

The basic treatment options adopted are represented by schematic as shown in Figure-1.

Settling

This involved pumping the used oil into a large holding tank, where in sufficient time large solid particles separated out and accumulated at the bottom of the tank.

Heating

Heating was undertaken to decrease the oil's viscosity and improve gravity settling. This was used to evaporate the water and other light fuel fractions.

Filtration

Since small suspended particles usually do not accumulate or settle out in a settling tank, they can be separated by a filtration system.

Centrifugal separation

Centrifugal separation involved the separation of the different specific gravity materials by centrifugal force

Solidification

The waste was solidified by appropriate water to cement ratios. The solidified mixtures was subjected to hardness (compressive strength) test.

THE PROPOSED LAYOUT/ PROCESS

Description

Used oil was stored in the storage tanks with valves as indicated. A pump for easy transport of used oil from the tank to the filtration cell was also installed. The filtering medium was glass beads. After treatment in the cell, the filtered oil was either withdrawn for direct use or sent to a settling tank for fine/impurities to settle and eventually withdrawn for use. The glass beads are periodically sent for regeneration and could be reused. When it could no longer be used due to high level of contamination of pollutants, it was sent for waste treatment together with the effluent water and finally disposed in an environmentally sound manner

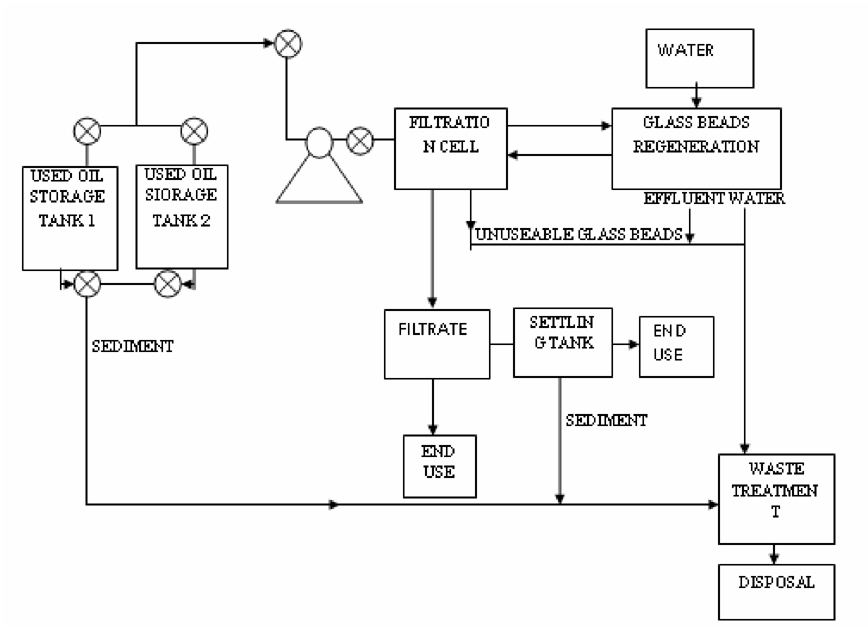

Figure-2. Proposed plant layout using glass beads treatment.

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RESULTS AND DISCUSSIONS

Results for all the processes adopted are reflected below:

Filtration treatment option

The two treatment media were 20/40 sand and glass beads. Test results obtained experimenting with these two media are indicated as shown in Tables 1 and 2, respectively.

Filtration with 20/40 sand

Volume of oil sample: 600ml
Weight of sand/volume of filter column: 1500g/1800ml
Residence time: 50 minutes

Table-1. Results of filtration with 20/40 sand.

Time (seconds)	**Volume collected** (ml)	**% yield**
3600	50	8.33
7200	220	36.67
10800	330	55.83
14400	400	66.67
18000	420	70.00
21600	430	71.67

Filtration with glass beads

Volume of glass beads: 200ml
Volume of oil sample (b): 500ml
Residence time: 10 minutes

Table-2. Results with glass beads as filtration medium.

Time (seconds)	**Volume collected** (ml)	**% yield**
100	50	10
320	100	20
1120	200	40
1800	260	52
2400	300	60
3770	380	76
5400	460	92
7200	490	98

Table-3. Results from used oil/clean/treated oil analysis.

#	**Test parameters**	**Used oil**			**Unused oil**	**Treated oil**	
		A	**B**	**C**	**D**	**E (20/40 Sand)**	**F (Glass Beads)**
1	SG@15.6/15.6˚C	0.901	0.8952	0.8992	0.8782	0.9022	0.8784
2	AP@15.6˚C	25.55	26.57	25.86	29.63	25.34	29.59
3	B. S. & H_20	0	0	0	0	0	0
4	Copper (mg/l)	1.09	1.18	1.06	1.01	0.88	1.18
5	Chromium(mg/l)	0.06	0.07	0.15	0.04	0.25	0.15
6	Nitrate (mg/l)	10	4	8	4	2.5	2
7	Calcium (mg/l)	80.6	80.6	49.6	28.75	280	25
8	Iron (mg/l)	81.8	72.7	36	14.1	98.04	14.5
9	Barium (mg/l)	4	4	2	2	4	4
10	Magnesium(mg/l)	0	0	0	0	0	0
11	Phosphorous	0.36	0.58	0.44	0.34	1.27	0.39
12	300rpm reading	346	252	430	380	260	262

Table-4. Results from used and regenerated glass beads.

#	Test parameters	Unused oil (A)	Used oil (B)	(B) With unused glass beads	(B)With used glass beads	(A) With regenerated glass beads
1	SG@15.6/15.6˚C	0.8782	0.8952	0.8784	0.8964	0.8784
2	AP GR@15.6˚C	29.63	26.57	29.59	26.40	29.59
3	B. S. & H_20	0	0	0	0	0
4	Copper (mg/l)	1.01	1.18	1.18	0.72	0.80
5	Chromium(mg/l)	0.04	0.07	0.15	0.1	0
6	Nitrate (mg/l)	4	4	2	2	-
7	Calcium (mg/l)	28.75	80.6	25	126	31.25
8	Iron (mg/l)	14.10	72.70	14.50	196.07	67.33
9	Barium (mg/l)	2	4	4	1	4
10	Magnesium(mg/l)	0	0	0	0	0
11	Phosphorous	0.34	0.58	0.39	1.14	0.63
12	300rpm reading	380	252	262	-	-

Table-5. Results of analysis of effluent water from regenerated glass beads.

Parameters	Test results
Calcium	125mg/l
Iron	24.5mg/l
Nitrate	0.0mg/l
Phosphorous	0.0mg/l
Copper	0.0mg/l
Barium	0.0mg/l
Chromium	0.08mg/l
Bicarbonate	61mg/l
Chloride	1029mg/l
S.G @ 15.6/15.6˚C	1.02
pH	7.6
Colour	Yellow

Table-6. Results of compressive strength with glass beads.

#	Composition	Compressive strength results
1.	12.5ppg slurry: 75%CMT: 25% Glass Beads Cement: 375.00g Used Glass Beads: 125.00g Effluent Water: 361.26g	350psi at 12hours 550psi at 24hours
2.	13.5ppg slurry: 75%CMT: 25% Glass Beads Cement: 450.00g Used Glass Beads: 150.00g Effluent Water: 299.65	400psi at 12hours 650psi at 24hours
3	14.5ppg slurry: 75%CMT: 25% Glass Beads Cement: 600.00g Used Glass Beads: 200.00g Effluent Water: 279.05g	450psi at 12hours 700psi at 24hours

As reflected in test results in Table-3, A-C was for result from used oil samples. Test result indicated that there was remarkable increase in calcium and iron concentrations in all the used oil samples compared with the result from the clean oil. The differences in concentrations of other metals determined (Copper, Chromium, Nitrate, Barium, Magnesium and Phosphorous) compared favourably with that of the unused oil and do not call for great concern. As a result of the remarkable increase in concentrations of some of the ions, there was need for treatment. The effectiveness of this treatment procedure will be defined in terms of contaminants removed.

Test D

This was with unused oil sample. Te results as shown will be used as a basis to compare the degree of contamination.

Test E

Samples A and B was passed through 20/40 sand bed. Test results indicated that the concentrations of Calcium, Iron and Phosphorous were on the increase. There was no remediation and thus treatment was not effective.

Test F

Sample-B was passed through a filter bed using glass beads. There was reduction in the Calcium, Iron and Phosphorous ions and results compared very favourably with that of the clean oil. Treatment appeared to be effective because there was considerable reduction in the concentrations of the ions.

Table-4 indicated the effects of used and regenerated glass beads on the treatment process. Test results indicated that reasonable increase in some of the ions was observed when reusing the glass beads without regeneration. Test results obtained using regenerated glass beads indicated that a reasonable reduction in the ions was achieved, affirming the effectiveness of the process.

Results of analysis of effluent water obtained after regeneration of glass beads as indicated in Table-5 appear not to be of great concern in terms of the various ions concentrations.

Table-6 indicated the various compressive strength results obtained with different ratios of the cement, used glass beads and effluent water. As reflected in test results, all recipes tested appeared to attain minimum strength required for safe disposal after solidification.

CONCLUSIONS

Treatment using glass beads gave the best result in terms of reduction of the pollutants and development of early compressive strength. The process and treatment medium adopted is very simple to design and environmentally friendly, cost less and very effective in pollutant reduction compared with previous processes in use.

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