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Lube Oil Recycling: Environmental and Economic Implications

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Abstract

This study presents a practical investigation on the reuse of spent lubricating oil as its indiscriminate disposal by the various users daily constitutes a serious pollution problem in the environment. In carrying out this work, samples of various used lubricating oil collected at different locations were analyzed for their physical and chemical composition, to ascertain their suitability for use as fuel in the cement factory. The examined parameters gave average values of 9.4686 kcal/kg, 96 ^oC, 18.48, 24 ^oC and 7834.5 kg/m^3 for caloric value, flash point, viscosity, pour point and ash content respectively. The results were compared with those of low fuel oil, used in the cement factories. Consequently, a trial burn was conducted which gave mean values of 133.7 mg/m^3, 1.7 ppm, 112.3 mg/m^3, <25.0 mg/m^3, 20.0 mg/m^3, <0.1 mg/m^3, <6.8 mg/m^3 and 371.2 ppm for SPM, CO, THC, SO_3, NO_3, H_2S, NH_3 and CO_3 respectively. The results obtained clearly showed that the used lubricating oil has chemical composition, calorific value and other physical properties that are comparable to those of low pour fuel oil. The results obtained from the trial burn conducted in the various cement factories, reveal that, the use of used lubricating oil as fuel in cement factories is environmental friendly and economically viable technique of disposing used lubricating oil.

Key words: Lube oil; Indiscriminate disposal; Oil pollution; Recycling; Cement factories

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1. INTRODUCTION

Lubes are high value petroleum products which have a very dominant role in boosting the national economy. Produced in lube refineries, these are actually complex formulations containing highly refined base stocks and specialized additives and are used to perform a variety of static and dynamic functions. In the recent past, major strides have been made in understanding the basic chemistry involved in lube processing and a new quality concept has emerged. Progress has also been made in understanding the role of solvents in lube extraction (Shailendra and Anwar, 1999). When one surface moves over another, there is always some resistance to movement, and the resistance force is called friction. Lrong et al. (2004) found that if the friction is slow and steady, there will be smooth, easy sliding. At the other extreme, the friction may be so great or so uneven, that movement becomes impossible and the surface can overheat or be seriously damaged.

Lubrication is simply the use of a material to improve the smooth movement of one surface over another and the material which is used in this way is called a lubricant. Lubricants are usually liquids or semi-liquids, but may be solids or gases or any combination of solids, liquids and gases (Nigmatullin et al., 2007). In recent years most lubricants are petroleum hydrocarbon base. These are fractions obtained from vacuum distillation of atmospheric residue followed with appropriate treatment, and blending. Additives were then added depending on the type of lubricating oil. These petroleum fractions are separated at various ranges of temperature (300-400, 350-420, 420-450) with carbon atoms of range between 25-35 (Ahmed, 2006).

1.1 Socio Economic Implications of Recycling

The destruction of waste oil has its own share of brighter and darker sides. However, it must be said that notwithstanding some small darker sides of having to live with the hazardous waste, the recycling offers many times more advantages to the individuals, communities and the globe as a whole. Though hazardous, the residues from all the processes can be dealt with adopting appropriate routes and processes for handling them, including secured landfill as a last resort (Chow and Watson, 2006). The underdeveloped countries definitely have an advantageous position as compared to the advanced countries, because the energy intensity (specific energy consumption for recycling) can be brought down by using manual labour in most of the operations, e.g. Handling drums and barrels, Loading and unloading the products, labelling, maintenance of records and other administrative procedures etc., which account for a major portion of energy in the processes. Even some of the technical operations like operating the filter presses can be undertaken by manual labour, through minor modification and appropriate leverage and indigenous designs using local skills. The recycling operation opens up a large and vast canvas of employment opportunities.

1.2 Employment Potential of Waste Oil Recycling

The re-refining industry definitely has good potential for providing jobs in addition to conservation of natural, fast depleting petroleum resources. This industry therefore must be encouraged by the governments of the countries particularly the developing countries and they may even provide financial assistance by way of subsidy, tax rebates or other fiscal measures for environment friendly management of the waste oil.

All developing countries are now having some rules / acts in force on environment, water, air

and soil to keep the pollution under check in the country. The local institutional and regulatory requirements do play a very big role in selecting an appropriate technology for the country also while adopting a particular technology, pros and cons are studied in light of all above points. It may be realised that the labour requirement of any system is inversely proportional to the level of technology deployed. Irrespective of the level and complexity of technologies, there are a major portion of activities in recycling, which are common to all technologies. These are;

- Collection of Waste Oil,
- Transportation to the recycling plant,
- Storage before recycling,
- Transporting waste oil to individual process equipment from stage to stage,
- Periodic mechanical upkeep of different equipment like reactors, pipe lines, motors and pumps etc (Froelund et al., 2001; Yilmaz, 2003).

Nigeria imported a total of 0.332 Million Metric Tons (MMT) per annum of base oils (year 2004) into the country. Assuming that at least 80% of these base oils are blended into different grades of virgin oils, the virgin oil market is estimated at about 0.260 MMT per annum. Assuming that used oil generation could be estimated at 50% of virgin oil while the figure of collectible used oil could be as low as 30%, the volume of used oils in Nigeria is estimated at about 0.130 MMT. Thus, collected oil could be is as low as 0.078 MMT for re-processing or re-refining (Bamiro and Osibanjo, 2004).

1.3 Worldwide Lube Oil Production

Worldwide production of lubricating oil for 2003 was estimated at 41.1 MMT. Figure 1 shows the approximate breakdown by region. The demand projections for the period 2015 are almost the same as those for the 2003 (Researchwikies, Lubricant Market Research, 2011).

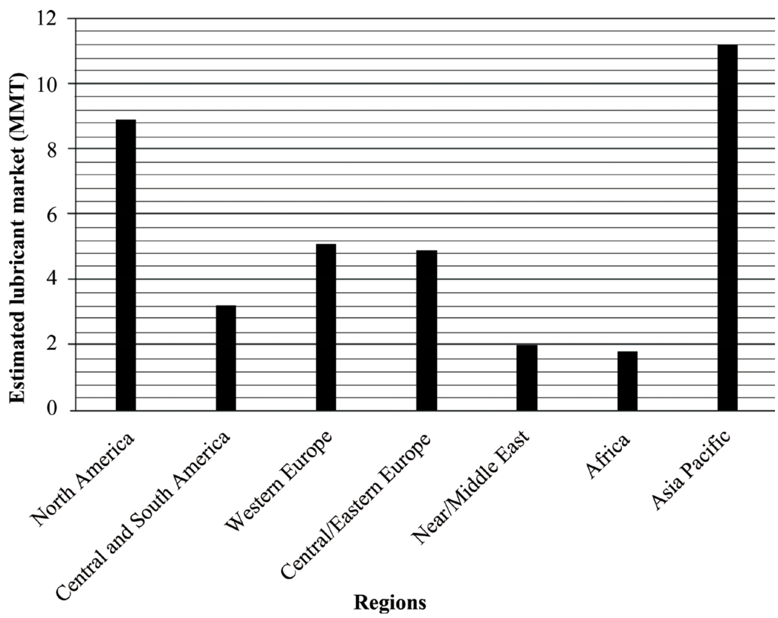

Figure 1
Worldwide Production of Lubricating Oil (2003) (Researchwikies, 2011)

A study by Ogonna and Ovuru (2000) provided a significant contribution to the knowledge database in this area of research. In his research, lubricating oil was used to reduce friction and corrosion of metal. In the lubricating process, the lubricant loses its properties due to heat from the lubricating machine (engine) and the wears that are produced due to the friction of the metal; consequently the lubricating oil is drained from the engine and becomes a waste product. This waste product is found littered in motor mechanic workshops, companies, motor parks and industrial sites. The greatest users of this lubricating oil are the multi-nationals particularly the oil producing companies. These companies send their spent lubricating oil into the crude line, while the motor mechanics and other users liter their spent lubricating oil around their operational areas and this, has resulted to environmental pollution (Ahmed, 2006).

Villaueva et al., 2008 worked on the modification of asphalt using used lubricating oil. The research revealed the binding properties of used lubricating oil on asphaltic materials. For the multi-nationals who return the used lubricating oil into the crude line, create greater environment pollution than the later. These used lubricating oils, contain different types of metal particulates depending on the source of spent lubricating oil. There is no doubt that the crude contaminated with the used lubricating oil will be sent for processing for onward transmission for shipment of processing at the refineries. At the tanks the solid particles, the water, and emulsion are separated from the crude in form of sludge which are poorly treated and discharged into the environment. This is a major source of environmental pollution in the petroleum industries. (Kumar et al., 2005).

Jacob, (2000) further reveal that, in the petroleum refining unit the left-over metal components are again separated to prevent their effect in the process equipment. These are again discharged into the environment through the refinery effluent as a major source of pollution in the petroleum refinery. The purpose of this study is to examine the technical and economic feasibility of recycling lube oils in order to eliminate or reduce environmental pollution.

2. MATERIALS AND METHODS

Analyses were carried out for caloric value, flash point, kinematic viscosity, hydrocarbon composition, ash contents, pour point sulphur content and heavy metals. The analyses were conducted in various laboratories using standard equipment as specified by the American Society for Testing and Materials (ASTM). Similarly, the concentration of heavy metals was also determined. Major equipment used includes flash point apparatus, viscometer, gas chromatography, pour point apparatus, sulphur analyzer Atomic absorption spectrometer.

2.1 Sample Collection

Samples for the used lubricating oil were collected from generators, mechanical workshops and various points in SPDC. Samples for the low pour fuel oil were also collected from various cement factories within Nigeria (Obajana, Benue, Sokoto) for similar analysis.

2.2 Laboratory Analysis

Calorimeter was used in the measurement of the calorific value for the used lube oil and low pours fuel oil in accordance with ASTM standard. The pour point was determined using the ASTM standard D129. Viscosity was determined using the viscometer cup with capillary and ball valve at constant temperature both with stirrer and redwood flasks (50 ml). This was done in accordance with ASTM standards D-88.

The flash point determination was carried out with the flash point apparatus, equipped with thermometer, flash cups electric heater and in accordance with the ASTM. Sample of the used lubricating oil and the low pour fuel oil were analysed for the hydrocarbon content using a gas chromatograph Varian 3600 with flame carbonization detector. The heavy metal content of the used lubricating oil was determined using an atomic absorption spectrometer in accordance with the ASTM standard.

3. RESULTS AND DISCUSSIONS

The results of the experimental analysis conducted for the various parameters are presented below (Figure 2 and Tables 1 to 4):

3.1 Calorific Value

The experimental result gave average calorific values of 9.4686 kcal/kg and 9.5000 kcal/kg for used lubricating and low pour fuel oil respectively, which shows that, both oils had almost the same calorific value (Table 1). This is an indication of similarities in the fraction of chemical composition, thus permitting their use for the purpose of energizing furnaces. Both oils showed a high capacity to sustain heat.

3.2 Flash Point

There were variations in flash points of used lubricating oil ranging from 96 ^oC to 112 ^oC for the various collection points and an average value of 94 ^oC for the low pour fuel oil as shown in Table 1. This is likely to be attributed to the blending suspected to have been carried out by the various companies to suit their plant requirement.

3.3 Viscosity

The results of the analysis of both used lubricating oil and low pour fuel oil ranged from 14.29 to 22.67 and 13.88 to 16.47 respectively, which were within the same range with slight differences (Table 1). This could be as a result of grease or other petroleum with higher molecular weight. The slightly low viscosity of the low pour fuel oil may be as a result of blending.

3.4 Pour Point

The pour points for all the oils were initially similar at average value of 140 °C but changes from -6 to +30 with time (Table 1). This implies that the used lubricating oil can be stored under tropical temperature without solidification.

3.5 Ash Content

The ash content was quite low in the low pour fuel oil samples with average value of 44.97 kg/m^3 as compared to the used lubricating oil samples with 7834.5 kg/m^3 (Table 2). This is likely due to the heavy metal and other contaminants in the used lubricating oil.

3.6 Heavy Metals

The heavy metals concentration measured in ppm varied considerably across the used lubricating oil samples ranging from 0.05 ppm to 1300.0 ppm, and were slightly lower in the low pour fuel oil samples with a range of 0.02 ppm to 81.6 ppm. This is apparently due to friction and engine wear (Table 2).

3.7 Sulphur Content

The sulphur content in the samples is of significant importance in terms of gaseous emissions in the burning process but not in terms of engine corrosion because it is to be burnt in a furnace. Hence, an air quality analysis was carried out during a trial burn. The results gave mean values of 133.7 mg/m^3, 1.7 ppm, 112.3 mg/m^3, <25.0 mg/m^3, 20.0 mg/m^3, <0.1 mg/m^3, <6.8 mg/m^3 and 371.2 ppm for SPM, CO, THC, SO_3, NO_3, H_2S, NH_3 and CO_3 respectively as presented in Figure 2, Table 3 and Table 4.

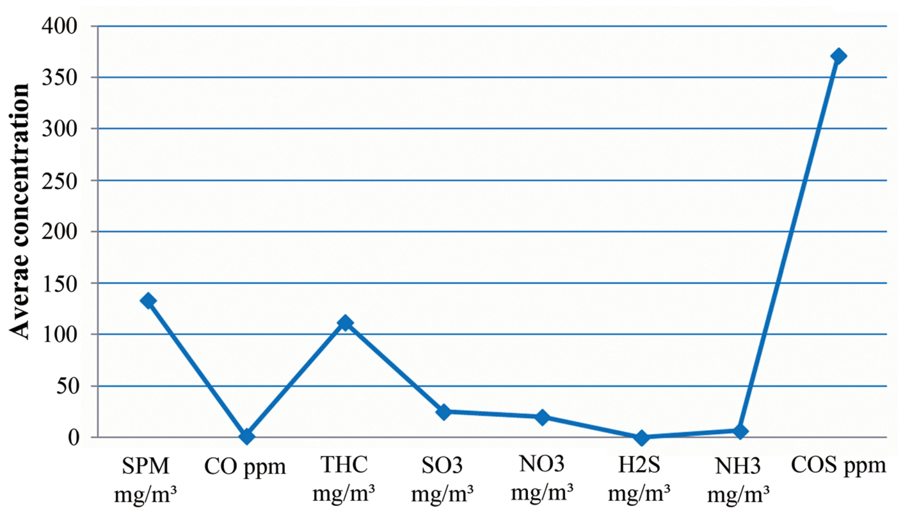

Figure 2

Average Concentration of Air Pollutants Measured at Trial Burn

A comparative analysis was conducted with FEPA standard and International standards, where all the level of pollutants were within the accepted limits (Table 4).

Table 1
Physical Properties of the Various Samples

S/N	Used lube oil (ULO)						Low pour fuel oil (LPFO)		
	Parameter	Mechanic workshop	Bonny	Mandilas	Kidney island	Hajaig w/shop	Obajana	Benue	Sokoto
1.	Kinematic Viscosity 82 °C	15.60	14.97	22.67	16.68	14.29	16.47	15.02	13.88
2.	Pour point °C	-8	-6	-12	-6	-14	-9	-6	+30
3.	Calorific value Kcal/kg	9.480	9.416	9.462	9.548	9.437	9.462	9.412	9.626
4.	Flash point °C	96	104	112	101	100	90	96	96

Table 2
Concentration of Heavy Metals (PPM)

Type of oil	Sample name	Ash content	Fe	Zo	As	Ni	Pb	Cr	Ca	Mg	Mn	%H20	Viscosity@ 4 °C centislokes	Specific gravity
LPFO	BENUE	8.9	4.0	1.7	0.02	11.6	<0.9	<0.9	4.8	0.4	<0.9	<0.01	67.5909	0.9264
	SOKOTO	81.6	4.9	4.9	0.02	10.2	1.9	<0.9	5.0	1.0	<0.9	<0.01	72.0592	0.9264
	OBAJANA	44.4	24.6	23.2	0.2	59.1	4.9	<0.9	39.9	6.0	<0.9	<0.01	0.5206	0.9036
ULO	BONNY	8271.0	74.7	9.0	0.05	2.5	7.5	1.49	1300.0	421.0	0.9	0.01	57.5412	0.8915
	MANDILLAS	8271.0	98.5	6.50	0.10	<0.9	57.0	3.9	936.0	165.0	1.4	<0.01	73.4406	0.8943
	KIDNEY ISLAND	7231.0	74.4	56.5	0.10	4.0	4.0	8.4	1270.0	2.85	1.4	<0.01	119.6722	0.8987
	HAJAIG W/ SHOP	7539.0	70.1	49.0	0.10	2.3	3.0	9.2	1074..0	8.72	1.4	<0.01	91.8677	0.8998

Table 3
Concentration of Air Pollutants Measured at Trial Burning

Station	Time	SPM mg/m^3	CO mg/m^3	THC mg/m^3	SO_3 mg/m^3	NO_3 mg/m^3	H_2S mg/m^3	NH_3 /m^3	CO_3 ppm
ONE	11-12	229.3	2.0	44.6	<25.0	17.9	<0.1	<6.8	340.0
	12-1pm	45.1	2.5	37.2	<25.0	23.2	<0.1	<6.8	340.0
	1-2	63.9	2.0	156.3	<25.0	23.2	<0.1	<6.8	340.0
	5-6	162.9	1.0	160.0	<25.0	20.5	<0.1	<6.8	379.0
	6-7	167.4	1.0	163.2	<25.0	22.1	<0.1	<6.8	437.0
TWO	9-10am	53.9	1.0	29.8	<25.0	13.8	<0.1	<6.8	340.0
	10-11	31.3	1.5	22.3	<25.0	5.0	<0.1	<6.8	340.0
	2-3pm	23.1	1.0	22.7	<25.0	10.2	<0.1	<6.8	340.0
	3-4	25.0	1.0	26.1	<25.0	8.5	<0.1	<6.8	340.0
	4-5	22.3	1.0	25.2	<25.0	9.7	<0.1	<6.8	325.0

Table 4
Comparison of Mean Air Pollutant levels with FEPA and International Standards

Pollutant	Mean concentration	FEPA standard	International standard
SPM mg/m^3	133.7	250	260
CO ppm	1.7	10	13
THC mg/m^3	112.3	5,000	-
SO_3 mg/m^3	<25.0	260	1300
NO_3 mg/m^3	20.0	75-113	100
H_2S mg/m^3	<0.1	8	-
NH_3 mg/m^3	<6.8	138,776	-
CO_3 ppm	371.2	100,000	-

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The results of the analysis carried out on used lube oil (ULO) and low pour fuel oil (LPFO) are all presented. It was established that most of the values of the basic parameters (Calorific Value, Point, Kinematic Viscosity, Flash Point) were similar for ULO and LPFO. This shows that ULO could be blended with LPFO at certain ratios, depending on the usage of substitute for LPFO. The study conducted showed that:

- Used lubricating oil is potentially hazardous and improper disposal is capable of polluting the soil, surface and subsurface waters and damage to the ecosystem.
- Used lubricating oil has economic value because it can effectively replace the LPFO currently used in the cement factory.
- Used lube oil is a cheap source of energy as compared to other sources.
- Used lube oil is in abundant quantity in Nigeria. It is being generated by all the major oil companies at the rate of approximately 20m^3/day. Because the society is not aware of the use of this waste, the oil companies re-inject it into the crude oil system (pipe lines) which in turn carries it to the oil terminals for export and part to the existing refineries. Studies have shown that this is not very healthy for the running of the refineries as a result of its heavy metal content.

4.2 Recommendations

From the research conclusions, it is recommended that:

- Collection centres for used lube oil be set up at suitable areas;
- Used lube oil be properly stored to prevent contamination;

- Government should enact a law prohibiting indiscriminating dumping of used lube oil.

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