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# A REVIEW ON TREATMENT METHODS OF USED LUBRICATING OIL

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## ABSTRACT

*Disposing used lubricating oil (ULO) through local means has been found to lead to air, land and water pollution. This pollution lowers the lifespan of inhabitants due to spread of diseases. Treatment of used oil is one of the easiest way to avoid pollution as observed in literatures. Aside preventing pollution, another advantage is majorly turning waste to wealth. In this paper, an indebt review was done on the various methods for treating used lubricating oil. The advantages and shortcomings of each method were highlighted for further study.*

**Keywords:** used lubricating oil, methods, treatment, pollutants.

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## 1. INTRODUCTION

Lubricating oil majorly helps in reducing friction, dust, corrosion, protection against wear and tear and provision of heat transfer medium in various equipment or machineries. (Shri et al., 2014). In the process of usage of lube oil, temperature build up occurs which breaks down the oil and weakens its properties which include pour point, flash point, specific gravity, viscosity etc. (Udonne and Bakare, 2013). The oil becomes unsuited for normal usage due to the build-up of contaminants in the LO such as water, metals, carbon residue, ash, water, gums, varnish, e.t.c. and chemical changes in the oil such as thermal degradation or oxidation. These contaminants are impurities which decrease the lubricating oil performance and turn it into used oil/ Waste oil.

Poor management and careless disposal of used Lube oil can affect the environment negatively (Lam et al., 2016). As reported by UN (2016), about six million deaths resulted from air pollution yearly. The burning of the waste lubricant contributes to the aerosol or green houses in the environment. Scientists have reported that in some geographical region e.g. West Africa, the dispersion of the air pollutants could travel at a speed of 10 -12 m/s (Emetera, 2017). The implication of this report is that air pollution from the burning of waste lubricant is not localized to the source of pollution but could travel with time to other locations. For example, it was recently reported that black soot covered a metropolitan city of Port Harcourt while the remote sources were at the suburb settlement (about 22 km away from city).

Recycling of used oil is therefore important in that; it takes less energy and cost compared to refining of crude oil, it helps to mitigate air, land or water pollutions in the environment. The most preferred option by expert is the reuse of the used oil generated by consumers (Jafari and Hassanpour, 2015). In this study, a detailed review on various treatment methods of used oil starting from the generic methods to the most recent methods and their limitations was discussed; future development of this field was also highlighted.

## 2. CONVENTIONAL/ GENERIC TREATMENT METHODS OF USED LUBRICATING OIL

### 2.1. Acid-clay

Evaluation of the different recycling processes showed that acid-clay process has the highest environmental risk as well as the lowest cost. The process involve treatment of used oil with acid and clay (Udonne and Bakare, 2013; Ellela et al., 2015; Hamawand et al., 2013). The clay serves as an adsorbent to remove the odour and dark colour. Factors which distinguishes acid-clay from other methods include; simple process, low capital investment, low operating cost and requires no skilled operators (Giovanna et al., 2012; Nwachukwu et al., 2012).

To minimize the hazardous waste generated from this process; the acid treatment stage of the process can be conducted under the atmospheric pressure to remove the acidic products, oxidized polar compounds, suspended particles and additives (Falah & Hussien, 2011). Princewill & Sunday (2010) observed that high recovery rate of treated LO from used oil depend largely on the used oil source, pretreatment steps, level of contamination, and grade of acid used. He also added that volume of adsorbent (clay) used could affect the rate at which contaminants are removed and the percentage of recovery of the process.

In Ellela et al., (2015) work, used motor oil was treated with phosphoric acid, sulphuric acid, methanoic acid and acetic acid. Also, methanoic acid, sulphuric acid and acetic acid have great changes on the kinematic viscosity while phosphoric acid is not affected by ULO. Therefore, treatment with acetic showed better results than formic acid- clay.

Nguele et al. (2014) identified three main lube oil degradation causes as wear, carbonyl oxidation and sulfate oxidation. The above itemized processes are the principal reasons of additive depletion in lubricants. Hence, the effective way for determining the most effective process for the treatment of used oil can be adopted from known models e.g. activated sludge model 1 (ASM1). ASM1 enables the simulation of the purification of used lubricating oil via the adoption of thirteen process components, eight biochemical processes and nineteen kinetic parameters. The mathematical representation of the ASM1 is shown below

$$r_o = \overbrace{\frac{1 - \gamma_H}{\gamma_H} \mu_H \left( \frac{\rho(S_s)}{K_s + \rho(S_s)} \right) \left( \frac{\rho(S_o)}{K_{O,H} + \rho(S_o)} \right) \rho(X_{B,H})}^{\text{heterotrophs}} - \overbrace{\frac{4.57 - Y_A}{Y_A} \mu_A \left( \frac{\rho(S_{NH})}{K_{NH} + \rho(S_{NH})} \right) \left( \frac{\rho(S_o)}{K_{O,A} + \rho(S_o)} \right) \rho(X_{B,A})}^{\text{autotrophs}}$$

Where  $K_s$ ,  $K_{O,H}$ ,  $K_{NH}$ , and  $K_{O,A}$  are saturation constants for biodegradable organics, oxygen in heterotrophs, ammonia and oxygen in autotrophs respectively.  $\rho(S_s)$ ,  $\rho(S_o)$ ,  $\rho(X_{B,H})$ ,  $\rho(X_{B,A})$  and  $\rho(S_{NH})$  are the densities of biodegradable organics, oxygen, heterotroph biomass, autotroph biomass and ammonia respectively.  $\gamma_H$  And  $Y_A$  are the yield coefficients of heterotroph and autotroph respectively.  $\mu_H$  And  $\mu_A$  are maximum growth rate of the heterotroph and autotroph respectively.

## 2.2. Solvent Extraction (SE)

Solvent Extraction produces good quality base oils and lower rate of pollution. On the contrary, it operates at higher pressure and requires skilled operating systems and personnel. (AERCO, 1995). Several solvent have been used for solvent extraction which include 2-propanol, 1-butanol, MEK, ethanol, Toluene and acetone, Sterpu et al., (2012); Katiyar and Husain (2010) and Hassan et al., (2012) found out that MEK has the highest performance due to its low oil percent losses and high sludge removal while Aremu et al., (2015) and Hussein et al., (2014) stated extraction using butan-1-ol solvent produced the highest sludge removal rate best. In the study of Oladimeji et al., (2018), a composite and single solvent was used. Single solvent used were methyl ethyl ketone (MEK) and propan-2-ol while the composite consist 75% MEK and 25% propan-2-ol. From the result obtained MEK gave the highest yield. It was also discovered that Solvent to oil ratio had a greater effect on the properties of the oil than temperature.

In the findings of Durani et al., 2011; Osman et al., 2017 and Kamal and Khan, 2009, SE and adsorption was confirmed to be more an effective processes for recycling of waste lubricating oils. Osman et al., 2017 examined blends of two or more solvent and activated alumina adsorbent. The higher the solvent - oil ratios, the higher the PSR. Mohammed et al., 2013 investigated the use of adsorbent materials which includes almond shell, eggshell, walnut shell and locally prepared acid activated clay. Khan (2009) added that due to low cost, availability and best adsorbing performance, magnesite can be chosen as a sorbent. Hydrocarbon solvent can also be used which include stabilized and liquefied petroleum gas (LPG) condensate (Hamad et al., 2005). This process reduced asphaltene content, ash content and carbon residue of the lubricating oil. Kamal and Khan (2009) reported that solvents selection can be done using Burrel's classification which says that alcohols are solvents with high capacity, Ketones, solvent with moderate capacity and hydrocarbons are low capacity solvent. These solvents are basically used due to their ability to form hydrogen bond

### 2.3. Vacuum distillation (VD)

Several work have been done on VD of used oil which include, Hamawand et al., 2013; Bridjanian and. Sattarin, 2006; Emam and Shoaib, 2013. The basic steps in VD are, pretreatment of oil to remove impurities which can result to fouling and corrosion of the equipment followed by distillation, where water and light hydrocarbons are separated (Gorman, 2005), then vacuum distillation using thin film or a conventional vacuum column. (Assuncao et al., 2010). Vacuum distillation is followed by hydrotreating of distillate with high pressure and temperature in the presence of catalyst for the purpose of removing chlorine, sulphur, nitrogen and organic components. Hydrotreated oil is further fractionated under high vacuum into components of industrial, hydraulic and motor oil. The resulting residue from the VD treatment can be used for road and roof bitumen production (Giovanna et al., 2003).

### 2.4. Hydrogenation

The process involve in hydrogenation can be summarized thus, Used oil and hot hydrogen was heated and mixed in a pressurized mixing chamber. The mixture was transferred to a separator routed to a residue stripper (Basel Convention, 2002). And processed in a catalytic reactor to remove soluble metals and passed through hydro-finishing reactor for dechlorination, desulphurization and other processes. The treated hydrocarbons resulted in products of improved odour, chemical properties and colour. The residue resulting from the process is a high boiling range of hydrocarbon product fractionated into neutral oil products with varying viscosities which can also be used to blend LO (Basel Convention, 2002).

## 3. COMBINED TECHNOLOGIES

These are advanced technology which combines two or more generic methods in its process. Due to the complexity of recycling of used oil, using a single method is difficult to achieve a standard emission controlled process. Some companies developed specific processes for recycling waste oils (Brinkman, 2010; Basel Convention, 2002), these methods require sophisticated equipment and processes. Some of these technologies are detailed below;

KTI process has its first re-refinery plant established in 1992 in Greece. It combines the technology of vacuum distillation and hydrofinishing process (Havemann, 1970ces8). The process involve; atmospheric distillation, for removal of water and light components, vacuum distillation at 250°C temperature and finally hydrogenation which eliminates the sulphur, nitrogen and oxygenated compounds. (Puerto-Ferre and Kajdas, 1994).

STP is another advanced technology which combines vacuum distillation and hydrofinishing process (Basel Convention, 2002). It release less harmful pollutants therefore its environmentally friendly (Khelifi, 2003). The basic steps of the STP process includes; dehydration, vacuum distillation, separation of the lubricating fraction and hydrofinishing base oil is seperation from the residue.

The Vaxon process is one of the treatment process commonly used in Denmark, Germany, Saudi Arabia and Spain. Its advantage over other procesess is the special VD unit called Vacuum Cyclone Flash Evaporator, where less cracking of oil takes place. Vaxon process involves chemical treatment, using alkali-hydroxides which removes metals, chlorides, acidic compounds, acidic compounds and additives and then solvent refining units using solvents such as, dimethyl-formamide, n-methyl-2-pyrrolidone, etc to seperate polycyclic aromatic hydrocarbons and lastly vacuum distillation, where the raffinate are seperated into varying viscosity grade base oils (Brinkman, 2010).

Axen/Viscolube (revivoil) technology is a process that involve high pressure catalytic hydrogenation. It involve three basic steps; dehydration, to seperate water and light hydrocarbon; thermal de-asphalting, where distillation takes place at high temperature to remove asphaltic and bituminous products and hydrofinishing, where chlorine, sulphur and other contaminants are removed (Kajdas, 2006).

IFP Technology/Snamprogetti is the “Institut Français du Petrole”, it combines vacuum distillation and hydrogenation process. IFP process has the following basic steps; the first stage is atmospheric distillation which helps to remove light hydrocarbon and water while the second stage include Vacuum distillation and extraction of the oil-containing part using propane (Kajdas, 2006). Lastly, hydrogenation, where propane, Asphaltic compounds, oxidized hydrocarbons and solids are seperated.

Proterra recycling technology has two major processess which include solvent extraction and vacuum distillation. By-products resulting from this process are, light oils, vacuum residues, extracts, vapour that cannot be condensed and effluent water (Basel Convention, 2002).

#### **4. CURRENT TREATMENT METHODS**

Used oil tends to have a high concentration of potentially hazardous pollutants and heavy metals which could be deleterious to the earth. Therefore, development of environmentally safe, sustainable and cost-effective solution is required for recycling of used lubricant (Stehlík, 2009). Some of the current methods are discussed;

In the study of Arpal et al., (2010), a fuel named as diesel-like fuel (DLF) was produced by applying pyrolytic distillation method. Filtration of the waste engine oil sample was done using a qualitative filter. Three additives known as  $\text{Na}_2\text{CO}_3$ , zeolite and CaO were blended with the purified oil at different ratios and were exposed to thermal and pyrolytic treatment to convert them into a DLF. Conclusively, effects of DLF on the oil properties shows a closer range to that of diesel fuel.

Another current method is Membrane technology, this is a technology that uses various polymer hollow fiber membranes to treat waste oils by filtration to remove metal particles and carbon soot present in the waste oil and to regain some lubricating properties of the oil. Ecamples of polymer used for membrane filters are polyethersulphone(PES), polyvinylidene fluoride (PVDF)and polyacrylonitrile(PAN) (Lam et al., 2016).

In recent times, Pyrolysis process (PP) has been used as an alternative means of effective conversion of used lubricants to a refined one (Lam et al., 2016; Manasomboonphan and Junyapoon, 2012). Lam et al., 2016, describe pyrolysis as a thermal process that heats and decomposes substance at high temperature (300–1000 °C) in an inert environment without oxygen. PP is not yet widespread but it has been receiving attentions nowadays due to its potential to produce energy-dense products from waste materials. Types of PP include; Microwave PP (MPP) and conventional PP (CPP). The MPP is a thermo-chemical process applied to waste to wealth process of electrical power input of 7.5kW at a flow rate of 5kg/h.

**Table 1:** Advantages and Disadvantages of some all the methods

Recycling methods	Advantages	Disadvantages
Acid-clay (Udonne, 2011)	<ol style="list-style-type: none"> <li>1. It is a commonly used method.</li> <li>2. Lower cost of production</li> <li>3. Simple and Non-sophisticated in process and operation, and skilled operators required.</li> </ol>	<ol style="list-style-type: none"> <li>1. It generates waste leading to pollution</li> <li>2. Causes corrosion of equipment and reduces its life.</li> <li>3. Low oil recovery</li> </ol>
Vacuum Distillation (Hamawand et al., 2013)	<ol style="list-style-type: none"> <li>1. Suitable for high capacity plants</li> <li>2. It does not result in pollution.</li> <li>3. It requires Sophisticated equipment 4. Produces good quality base oils.</li> </ol>	<ol style="list-style-type: none"> <li>1. Requires high capital investment.</li> <li>2. Due to sophisticated equipment, requires highly skilled operators</li> </ol>
Solvent Extraction (Sterpu et al., 2012; Hussein et al., 2014;	<ol style="list-style-type: none"> <li>1. Solvent is recyclable.</li> <li>2. It does not result in pollution.</li> <li>3. Good base oils recovery.</li> </ol>	<ol style="list-style-type: none"> <li>1. Economical only for high capacity plants.</li> <li>2. It requires highly skilled operators</li> </ol>

## 5. CONCLUSION

The combined technology processes are commonly used in developed countries but not available in developing countries. Processes involved in these technologies generates a reduced level of pollutant but require sophisticated and expensive equipment. The convectional /generic treatment method have shown much improvement over the years, however the environmental hazards that emanates from the process remains a major disadvantage. The solvent extraction method is environmentally controllable but the high cost and low yield (compared to the convectional /generic treatment method) is its shortcoming. The challenge of cost cuts across the vacuum distillation and hydrogenation technique. Hence, the viability of efficient, environmentally friendly and cheaper treatment technique has not been achieved till date. The combined treatment technology have shown a great deal on treatment efficiency and environmental friendliness. However, the issue of cost remains a major gap in used lubricant oil treatment.

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