A Comparison of Waste Lubricating Oil Treatment Techniques

Motshumi J. Diphare, Edison Muzenda, Tsietsi J. Pilusa and Mansoor Mollagee

***Abstract*—**Waste lubricating oil is a resource that cannot be disposed of randomly due to the presence of pollutants. In response to economic problems and environmental protection, there is a growing trend to regenerate and reuse waste lubricants [1]. The recovery techniques discussed in this paper are reprocessing, re-refining and incineration of waste lubricating oil. The major objective of this paper is to analyze and compare the regenerative technologies, thus creating the foundation for government, the private sector and other stakeholders in policy formation and selection of recovery techniques**.**

***Keywords*—**Regenerative Technologies, Re-refining, Reprocessing, Waste Oil, Waste Management

I. Introduction

MANAGEMENT of waste oils is a growing concern particularly in industrial and urban areas. Generation of waste oils is closely linked with increase in population of automobiles and industries. When additives and foreign substances, such as metal powder, chips and other particles, are mixed with lubricating oil, aging, degrading and failure will likely occur, leading to mechanical fault and degraded performance [1]. In such cases, the oil is replaced to improve the performance. The used, spent or waste oils should be collected and recycled not only to prevent the environment pollution but also to preserve natural resources.

The management of waste oils is particularly important because of the large quantities generated globally through transport and Industrial activities. These Waste Oils may have detrimental effect on the environment if not properly handled, treated or disposed [2]. In recent decades a number of innovative treatment technologies have been developed that promise to solve technical, economic and environmental problems associated with used oil recycling.

Reference [3] further motivates that 1 litre of waste-oil re-processed as fuel contains about 8000 kJ of energy, which is enough to light a 100 W bulb for 24 hours. The efficient recycling of waste lubricant could help reduce both the environmental pollution and gas emission from greenhouses, thus creating an environmental and economic benefit [1].

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II. Characterization of Waste Lubrication Oil

The main constituents of waste lubricating oils are the base oil, degraded additives, metallic debris, oxidation products and carbon soot. A large number of additives are used to impart performance characteristics to the lubricants. The main additives are antioxidants, detergents, anti-wear elements, metal deactivators, corrosion inhibitors, rust inhibitors, friction modifiers, extreme pressure withstanding elements, anti-foaming agents, viscosity index improvers, demulsifying or emulsifying agents and stickiness improver.

During their use, these additives lose their characteristics rendering the lube oil non usable for lubricating purpose. In addition, during their use, the lubricating oils and the metal processing oils pick up fractions of various metals as a result of wearing out of components. The concentration of these impurities depends purely on the application to which the particular oil is put to. Some contaminants, such as chlorinated solvents, water, unburned fuel, carbon and dust are also picked up by the waste oil during use or during storage.

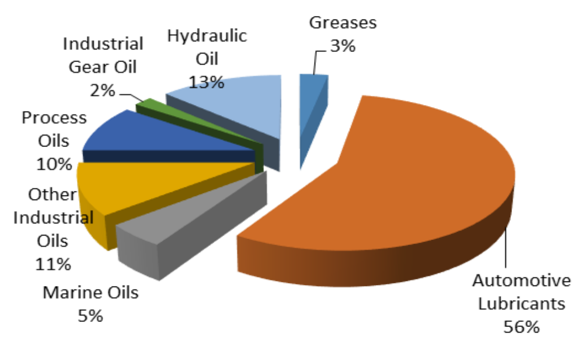

Fig. 1 Percentage contribution of waste oils [2]

III. Environmental Pollution

The contaminants in waste oil have adverse environmental and health impacts. Reference [2] states that the presence of degraded additives, contaminants, and by-products of degradation render waste oils more toxic and harmful to health and environment than virgin base oils. If put into storm water drains or sewers, they can affect waterways and coastal waters [4]. When dumped in soil or sent to landfill, they can migrate into ground and surface waters though numerous land treatment processes. In addition, uncontrolled used oils are a threat to plant and animal life, which can further result in economic losses, for example, recreation and fishing industries. For example, used oil from internal combustion engines generally accumulates a variety of contaminants, which increase the oil's toxicity [5].

IV. Importance of Used Oil Recycling

A large range of waste oils can be recycled and recovered in a variety of ways, either directly or after some form of separation and refinement. As per the waste management hierarchy, the first option is to conserve the original properties of the oil allowing for direct reuse. Other options could include recovering its heating value and/or using in other lower level applications. Certain types of waste oils, lubricants in particular, can be reprocessed allowing for their direct reuse. The use of waste oils, after treatment, can be either as a lube base stock comparable to refined virgin base oil or as clean burning fuel.

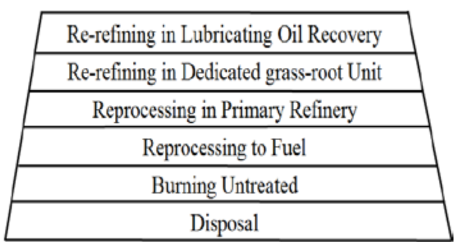

Fig. 2 Waste oil hierarchy [2]

V. Treatment Technologies

The review of waste lubricants treatment techniques were discussed by the author [6]. Used oils have been recycled for the past four decade. The idea of recycling used lubricating oil was presented in the year of 1930. Initially the used lubricating oils were burnt to produce energy, and later these oils were re-blended to engine oils after treatment. Due to the increasing necessity for environmental protection and more stringent environmental legislation, the disposal and recycling of waste oils has become very important [7]. The recycling of waste lubricating oils can be accomplished through three basic methods, which are reprocessing, re-refining and destruction.

A. Reprocessing

The objective of re-processing is to produce a finished fuel oil that is low in basic sediment and water content, and that will not clog burners, foul boiler tubes, or cause sediment build-up in customer tanks. As such, the process requires filtration and removal of coarse solids that can pose environmental hazard or operational problems. Treatment options include mainly physical processes like settling, filtration, or a combination of these operations. Unfortunately, these processes alone are not sufficient to remove all chemical contaminants in the oil, and inclusion of further treatment processes such as clay contacting and distillation would reduce the competitive advantage of waste oil processors [3].

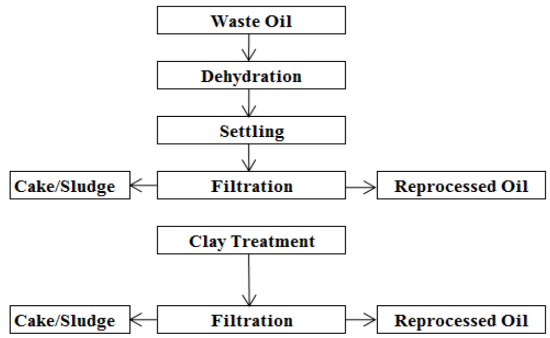

Fig. 3 Block diagram of reprocessing of used lubricating oils [2]

B. Re-refining

Over the years several re-refining technologies have been proposed for waste oil recycling. Re-fining is the use of distilling or refining processes on used lubrication oil to produce high quality base stock for lubricants or other petroleum products. The use of this method has increased tremendously in developed countries, some countries reaching up to 50% of the country's need for lubricating oil [8]. There are various methods developed by different western countries in the treating of used lubricating oil for reuse. It requires the conversion of waste oil to a product with similar characteristics to those of virgin oil. The process typically involves, but is not limited to, pre-treatment by heat or filtration, followed by either vacuum distillation with hydrogen finishing or clay, or solvent extraction with clay and chemical treatment with hydro-heating. Vacuum distillation followed by clay contacting offers a less polluting and more economic solution to the re-refining process, particularly for small-scale plants with a capacity range between 10000 and 30000 tons [3]. The resulting residual by-product is well compacted and baled in thick plastic sheets prior to disposal in landfills. Participation of a reputable recycling company can play an important role in enhancing the trust factor [9].

C. Incineration

This method is preferable when the waste oil is highly contaminated, particularly with polychlorinated byphenyls (PCB) and polychlorinated terphenyls (PCT). In the absence of hazardous waste incinerators, controlled high-temperature incineration at cement factories is recommended. Temperatures at the flame end of rotating cement kilns ranges between 2000 and 2400°C. This high temperature is adequate to destroy organics and neutralize acid compounds [11]. The heavy metals content is reduced considerably as their concentrations remain very low compared to those found in the natural material used in the cement production process. Note, however, that continuous monitoring of gas emissions at the cement factories would be required to ensure compliance with air quality standards [3].

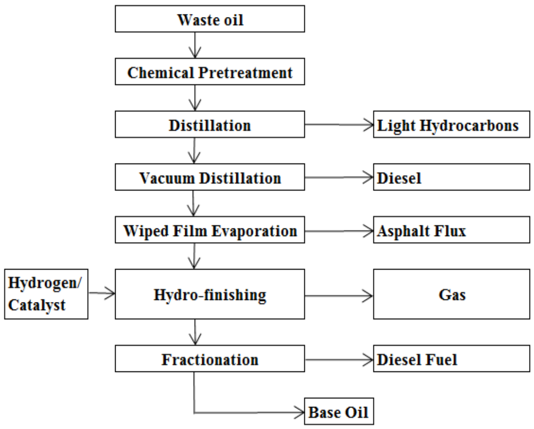

Fig. 4 Block diagram of re-refining of used lubricating oils [2]

TABLE I
COMPARISION OF WASTE OIL MANAGEMENT TECHNIQUES [11]

Technique	Advantage	Disadvantage
Re-refining	Environmentally sound long term solution Creates jobs Reduces the amount of imported lubricant oil	Requires a well-developed collection system. Re-refined lube oil requires well developed market. Requires extensive capital investment. The re-refining option requires a reputable recycling company to ensure the marketability of the product. Proper disposal of end-waste residues are costly
Reprocessing	Good substitute for second grade fuels. Limits the negative effects of the practice of uncontrolled burning of waste. The quality control of the re-processed fuel oil is monitored by the purchaser	Requires a well-developed collection system. Requires extensive capital investment. Proper disposal of end-waste residues are costly
Incineration	Economically feasible at lower processing volumes Cement factories are willing to procure the waste oil Less capital intensive than the previous options Concentrates waste oil disposal to limited sites that can be more easily regulated and controlled	Air emissions, although minimal, still need to be addressed. Opposition by regulatory and government institutions

TABLE II
ENVIRONMENTAL COMPARISON OF TREATMENT TECHNOLOGIES [1]

Regenerative Technology	Re-refining	Reprocessing	Destruction
Acidic sludge	High	Low	-
Residual sludge	High	Low	-
Harmful Chemicals	Sulfuric acid	-	-
Pollution	Low	Low	High
Ash	-	-	Much

TABLE III
ECONOMIC COMPARISON OF TREATMENT TECHNOLOGIES [1]

Regenerative Technology	Re-refining	Reprocessing	Destruction
Technology maturity	Plant scale	Plant Scale	-
Energy demand	High	Low	-
Recovery rate	±63	±74	-
Quality of reclaimed oil	Good	Fair	-
Equipment demand	High	Low	Low
Operating cost	High	Low	-

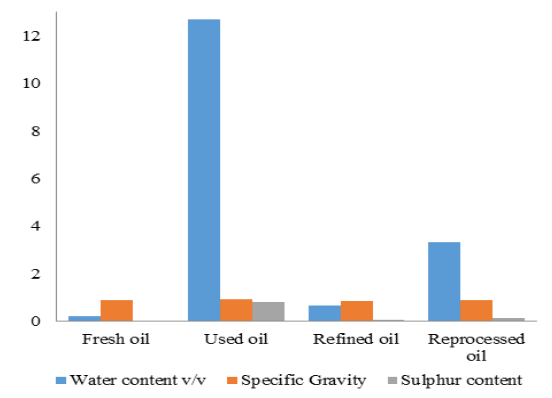

Fig. 5 Comparison of lubricating oil properties before and after treatment [11, 16]

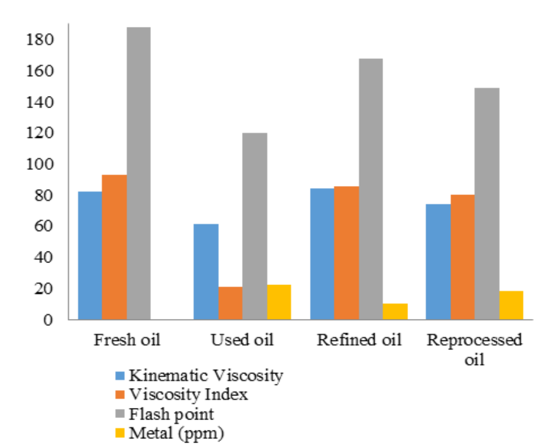

Fig. 6 Comparison of lubricating oil properties before and after treatment [11, 16]

VI. DISCUSSION

The management of used oil is particularly important because of the large quantities generated globally, the potential for direct re-use, reprocessing, regeneration and detrimental effects on the environment if not properly handled, treated or disposed of [12]. Though dirty, used oil still contains the same properties that make it a valuable lubricant as well as an ideal product for recycling [13]. Three different oil treatment technologies were studied and evaluated environmentally and economically.

Re-refining by distillation, reprocessing by simple dehydration/filtration, and lastly destruction by burning in furnaces. The treated oil's properties such as water content, specific gravity, viscosity, flash point, pour point, sulphur content and metal content were obtained from previous work [11-15] and were analyzed and compared to those of virgin oil. The properties of treated oil using different techniques are presented in Fig. 5 and Fig 6.

Viscosity is the most important consideration when choosing lubricating oils. The strength of the oil film is approximately proportional to its viscosity, thus a higher viscosity indicates the stronger strength of the oil film.

Increasing viscosity of used oil can occur due to oxidation or contamination [14]. Figure 6 shows that, after use, lubricating oil experience a change in viscosity due to either contamination or oxidation. Fig 6 further illustrates that re-refining is the most effective technique as it yields oil with viscosity of 85.8 which is close to 92.8 that of virgin oil as compared to 80.2 from reprocessing.

Water contamination may cause various problems in lubricating oils, such as corrosion which is directly associated with water ingress. During application, water can displace the oil at contacting surfaces, reducing the amount of lubrication and activating surfaces which may themselves act as catalysts for degradation of the oil [15].

Fig. 5 shows that re-refining is the best technique to removes water from waste oil. This is mainly due to distillation at temperatures above the boiling point of water. Fig. 5 shows the values of sulphur content for the treated oils by the two methods. The sulphur in used oil is due to wear caused by moving parts. Sulphur reacts with the metal to form compounds of low melting point that are readily sheared. Corrosion in engines is caused by mineral acids formed by the oxidation of sulphur compounds in fuel in internal combustion engines with lubricating oils [14]. Sulphur content was found to be 0.042wt % and 0.13 wt % through re-refining and reprocessing respectively.

Fig. 5 also shows that the specific gravity of the virgin oil is higher than the treated oils and lower than the used oil. The results for the used and re-refined and reprocessed oils are 0.91, 0.86 and 0.89, respectively. The specific gravity of contaminated oil could be lower or higher than that of its virgin base oil depending on the type of contamination. If the used oil was contaminated due to fuel dilution and/or water originating from fuel combustion in the engine, its specific gravity will be lower than that of fresh oil or re-refined one.

VII. Conclusion

Recycling of waste lubricants could result in both environmental and economic benefits. Re-refining of waste oil to manufacture base oil conserves more energy than reprocessing the waste oil for use as a fuel. The energy required to manufacture re-refined oil from used oil is only one-third of the energy required to refine crude oil to produce virgin base oil. Therefore, re-refining is considered by many as a preferred option in terms of conserving resources, as well as minimizing waste and reducing damage to the environment [11].

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