Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2018, 5(9):168-177

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

A Comparative Study of Recycling used Lubricating Oils using Various Methods

Nooraldeen A. Aljabiri

Chemistry Departement, Polymer Research Center, Basrah University

Abstract Lubricating oils are viscous liquids used to lubricate moving part of different machines which obtains from crude oil. The used lubricating oil collected and regenerated by different ways. When lubricating oils are used, it helps to protect the moving parts. The disposable lubricating oils have now become a major problem and cause severe pollution.

Keywords Recycling, Lubricating Oils

Introduction

Lubricating oils from petroleum consist of a complex mixture of hydrocarbon molecules composed of alkenes, monocycloalkanes and monoaromatic which they have a short and long branch. When lubricating oils are used in services, it help to protect rubbing service and to promote easier motion of moving parts.

Lubricating oils are usually blended with a number of chemical additives to provide products that last longer and allow the machinery to work better under sever operating condition.

However, performance of lubricant deteriorates over time as the additives are chemically changed and the lubricating oil becomes contaminated with various unwanted pollutant as a result of many physical and chemical interaction deteriorate and loss efficiency due to the foreign matters that contain metal powder, filling and other oxidizing lubricating oil as well as additives due to operation conditions of oil.

If these materials deposit on the surface and in the flow passage, it is likely to cause multifunctions of the machine and reduce the overall protective efficiency .At this point, the lubricating oil needs to be changed, so as to increase the work efficiency and the replaced oil will be waste.

With large amount of engine oil used, the disposal of lubricating oils has now a major problem. Many nations are now addressing the problem of environmental pollution posed by waste or used lubricating oils in their countries.

In USA about 2 billion gallons of waste oil are generated annually. This has led industries and governments for find satisfactory solutions that will reduce the contribution of used lubricating oil to pollution and also recover these valuable hydrocarbon resource.

The objective of this study is centered mostly on the different ways waste lubricating oil treatment to reduce environmental pollution and minimized importation of lubricating oil.

Lubricating Oil

Lubricating oil is the very stable, non-volatile and smallest fraction of crude petroleum. As petroleum products are essentially composed of hydrocarbons, lubricating oils have hydrocarbon structures, containing from 20 to 70 carbon atoms per molecule.

The lubricating oil molecules can be divided into three broad groupings i.e. paraffinic naphthenic and aromatic. Paraffinic molecules are predominantly straight chains, tend to be waxy, have a high pour point, good viscosity and better temperature stability. Naphthenic molecules are straight chains with a high proportion of five and to a lesser extent six membered ring structures. They tend to have a low pour point. For this reason they are used as refrigeration oils. They are highly carcinogenic and are little used in engine oil. Aromatics are straight chains with six membered ring benzene structures. In practice, no sharp distinction exists between these various groupings as many lubricating oil molecules are a combination, to varying degrees, of the different types of hydrocarbons [1].

Lubricating oils are fluids such as engine oils, gear, hydraulic oils, turbine oils, etc., used to reduce friction between moving surfaces. They also serve to remove heat from working parts in machinery created by moving surfaces and provide a protective layer on the metal surfaces to avoid corrosion. They also act as a sealant to fill the microscopic ridges and valleys in any metal surfaces to increase the machinery efficiency. In addition, they serve as a cleaning agent to carry away dirt or other debris that may damage the bearings or other parts that are operated in tight tolerance. Debris is removed through the engine oil filter or the transmission filter.

Lubricating oils are usually blended with a number of chemical additives to provide products that last longer and allow the machinery to work better under severe operating conditions.

However, performance of the lubricants deteriorates over time as the additives are chemically changed and the oil becomes contaminated with various unwanted pollutants as a result of many physical and chemical interactions [2].

Used Lubricating Oil

During the usage of lubricating oil, it will age, deteriorate, and lose efficiency due to the mixture with foreign matters that contain metal powder, filings, and other oils as well as additives. If the lubricating oil is oxidized, its colour will become darker, and the acid value increases to generate precipitate, oil sludge, varnish, and hard varnish. If these materials deposit on the surface and in the flow passage and cleaner, it is likely to cause malfunctions of the machine and reduce the overall productive efficiency. At this point, the lubricating oil needs to be changed, so as to increase the work efficiency, and the replaced oil will be waste.

Generally lubricating oil becomes unfit for further use for two main reasons: accumulation of contaminants in the oil and chemical changes in the oil. These effects interfere with the basic properties of lubricating oil which are peculiar for their effective performance during application [3].

Lubricating oil Properties

In simple terms, the function of lubricating oil is to control friction and wear in a given system. The basic requirements therefore relate to the performance of the lubricant, i.e. its influence upon friction and wear characteristics of a system. Another important aspect is the oil quality which reflects its resistance to degradation in service. Most of the present day lubricant research is dedicated to the study, prevention and monitoring of oil degradation since the life-time of oil is as important as its initial level of performance. Apart from suffering degradation in service, which may cause damage to the operating machinery, oil may cause corrosion of contacting surfaces.

The fundamental physical properties such as viscosity, viscosity temperature dependence, viscosity index, pour point, flash point, volatility, oxidation stability, thermal stability, and etc., are the factors which determine the level of performance and quality of lubricating oil. During the oil application period, these properties may be lost or degraded [4].

Oil Viscosity

The parameter which plays a fundamental role in lubrication is oil viscosity. Different oils exhibit different viscosities. In addition, oil viscosity changes with temperature, shear rate and pressure and the thickness of the generated oil film is usually proportional to it. For engineering applications the oil viscosity is usually chosen to give optimum performance at the required temperature.

The viscosity of lubricating oils is extremely sensitive to the operating temperature. With increasing temperature the viscosity of oils fall quite rapidly. In some cases the viscosity of oil can fall by about 80% with a temperature increase of 25°C.

From the engineering viewpoint there was a need for a parameter which would accurately describe the viscosity-temperature characteristics of the oils. The viscosity index is an entirely empirical parameter which

compares the kinematic viscosity of the oil of interest to the viscosities of two reference oils which have a considerable difference in sensitivity of viscosity to temperature.
Lubricant viscosity is also affected by pressure and increases with pressure. For most lubricants this effect is considerably larger than the effect of temperature or shear when the pressure is significantly above atmospheric.
There are several widely used oil viscosity classifications. The most commonly used are SAE (Society of Automotive Engineers), ISO (International Organization for Standardization) and military specifications [4].

Lubricant Density and Specific Gravity

Lubricant density is important in engineering calculations and sometimes offers a simple way of identifying lubricants. Density or specific gravity is often used to characterize crude oils. It gives a rough idea of the amount of gasoline and kerosene present in the oil. The oil density, however, is often confused with specific gravity.
Specific gravity is defined as the ratio of the mass of a given volume of oil at temperature 't1' to the mass of an equal volume of pure water at temperature 't2'. Density, on the other hand, is the mass of a given volume of oil [kg/m^3].
The density of a typical mineral oil is about 850 [kg/m^3] and, since the density of water is about 1000 [kg/m^3], the specific gravity of mineral oils is typically 0.85 [4].

Temperature Related Characteristics of Lubricating Oil

The temperature characteristics are important in the selection of lubricating oil for a specific application. In addition the temperature range over which the lubricating oil can be used is of extreme importance. At high temperatures, oils decompose or degrade, while at low temperatures oils may become near solid or even freeze. Oils can be degraded by thermal decomposition and oxidation. During service, oils may release deposits and lacquers on contacting surfaces, form emulsions with water, or produce foam when vigorously churned. These effects are undesirable and have been the subject of intensive research. The degradation of oil does not just affect the oil, but more importantly leads to damage of the lubricated equipment. It may also cause detrimental secondary effects to the operating machinery. A prime example of secondary damage is corrosion caused by the acidity of oxidized oils. The most important properties of lubricating oils and other lubricants, which are related to operating conditions, are its pour point, flash point, volatility, oxidation and thermal stability, neutralization number and carbon residue [4].

Degradation of Lubricating oil

Oils have a finite lifetime. As it is stated earlier, they will eventually degrade and/or become contaminated and will need to be changed. Lubricants consist of a base stock that can either be mineral or synthetic. In the case of synthetic base stocks, these are a family of compounds that are manufactured in a laboratory to have precisely the properties that the chemists and engineers want. Mineral base stocks are derived from crude oil that comes out of the ground and is refined to produce a base stock that can do the desired job. Synthetic bases are superior to mineral ones but are much more expensive.
The other component of a lubricant is the additive package. This is a range of twenty or more chemicals that the refinery blends with the base stock so that it can do its job. The additives are used to enhance the natural properties of the lubricating oil and to prevent some undesirable properties. The main additives for lubricating oil are oxidation inhibitor, detergent & dispersants, viscosity index improvers, pour point depressants, anti-foam agents, rust inhibitors, corrosion inhibitors and anti-wear additives.
Most additives are sacrificial in nature and this means that they get used up during the lifetime of the oil. As the oil is used to lubricate a piece of machinery, the additives become depleted and deactivated and eventually the oil will wear out and will need to be replaced.
Why oils degrade has been covered in numerous technical bulletins but this issue deals with how lubricants degrade, in other words, what are the mechanisms for additive depletion and degradation. The important mechanisms include oxidation, thermal degradation, neutralisation, shearing, hydrolysis, water washing, particle

scrubbing, surface adsorption, rubbing contact, condensation settling, filtration, aggregate adsorption, evaporation, centrifugation and contamination.

Degradation of oil is also a complex web with many competing processes taking place at the same time. Even the best oil, in the best equipment, operating in an ideal environment with perfect maintenance practices will eventually degrade, wear out and need to be changed.

The next sub-sections will address the specifics of exactly what happens to motor oil during use in an internal combustion engine and what properties are violated.

Oxidation

Oxidation is the most important form of chemical breakdown of motor oil and its additives. The chemicals in motor oil are continuously reacting with oxygen inside an engine. The effects of oxidation due to this reaction as well as the by-products of combustion produce very acidic compounds inside an engine. These acidic compounds cause corrosion of internal engine components, deposits, varnish, sludge and other insoluble oxidation products that can cause a performance and durability degradation of an engine over a period of time. The products of oxidation are less stable than the original base hydrocarbon molecular structure and as they continue to be attacked by these acidic compounds can produce varnish and sludge.

Oxidation can cause changes in almost all properties of lubricating oils, especially on viscosity, pour point, flash point, volatility, and neutralization number.

Thermal Degradation

When motor oil is heated beyond a certain temperature it will start to degrade, even if there is no oxygen present. This is called thermal degradation and causes the oil to change viscosity. The thermal stability of motor oil cannot be improved by use of additives but it can be improved by refining out the same compounds that decrease the oxidation resistance. As temperatures increase, thermal degradation increases. In order for an oil to provide proper service and protection at high operating temperatures highly refined oils with plenty of anti-oxidants should be used. For average service less highly refined oils can be used.

In addition to changes on viscosity and oxidation stability, thermal degradation can significantly affect volatility and evaporation rate of lubricating oil and also increase carbon residue.

Corrosion

Petroleum oil that is new or kept clean by proper filtration is generally non-corrosive and will provide good protection against corrosion caused by the atmosphere. However, inside an engine oil oxidation by-products will attack internal engine steel and bearing materials that are typically manufactured with aluminium, copper, lead and tin.

Water present due to condensation caused by temperature and humidity changes or short ‘stop and go’ driving where the engine never reaches the proper operating temperature, although still hotter than the ambient temperature, can also cause corrosion. The hotter the oil is when water is present the more severe the chemical reaction is and corrosion related damage could definitely occur. In addition, water present in oil for an extended period of time can emulsify the oil and form a mixture which is much more corrosive than the two components alone and can then form sludge which may block oil filters or small passages.

Corrosion can accelerate oxidation & thermal instability, and further infringe all lubricating oil properties.

Contamination

Motor oil contamination also causes deterioration of the oil. Some of the more common contaminant sources include dirt, sand and dust from the air, soot, unburned fuel in the oil, water from condensation of the combustion process, wear metal particulates that the oil filter cannot trap and hold, corrosion by-products and additive elements that have degraded. In addition dirt, sand and dust can continue to enter the engine and, in addition to creating more wear debris, combine with other contaminants and cause more damage than they would separately.

One of the many by-products of combustion is soot. Soot can be highly abrasive as well as cause filters to become filled and/or plugged in extreme cases. Another contaminant is acidic by-products of combustion, which can produce a highly corrosive mixture and cause corrosion and pitting of internal engine components and additional generation of wear debris. These same acidic solutions can also mix with water inside the engine and form an emulsion that can cause problems with oil filters and passageways [5].

Yet another source of contamination is fuel. A charge of fuel is rarely 100% burned during the combustion process. This unburned fuel can mix with the oil present in the cylinders. Fuel contamination can also be caused by worn sealing components such as excessive piston ring to cylinder clearances allowing unburned fuel to blow-by the rings.

When motor oil is diluted with fuel the viscosity is lowered. If this reaches extremes of contamination excessive wear and engine damage can take place and may lead to significant deterioration of the different properties of the oil [4].

Contaminants in Used Lubricating 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, antifoaming 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 [6].

Generally, lubricating oil loses its effectiveness during operation due to the presence of certain types of contaminants. These contaminants can be divided into extraneous contaminants and products of oil deterioration.

Table 1: Typical contaminants found in used oils

Metals	Chlorinated hydrocarbons	Other organic compounds
Cadmium	Dichlorodifluoromethane	Benzene
Chromium	Trichlorotrifluoroethane	Toluene
Arsenic	Tetrachloroethylene	Xylene
Barium	1,1,1- Trichloroethane	Benzo(a)anthracene
Zinc	Trichloroethene	Benzo(a)pyrene
Lead	Total Chlorine	Naphthalene
		PCB’s

Extraneous Contaminants

Extraneous contaminants are introduced from the surrounding air and from the engine during combustion. Contaminants from the air are dust, dirt, and moisture. These contaminants pass into the engine through the air-cleaner and may be composed of small particles of silicates. Air itself may be considered as a contaminant since it might cause foaming of the oil. The contaminants from the engine are:

(1) Metallic particles resulting from wear of the engine: Iron, copper and aluminium are released due to normal engine wear.

(2) Carbonaceous particles: soot and carbon originate due to incomplete fuel combustion especially during warm-up with a rich mixture.

(3) Metallic oxides present as corrosion products of metals,

(4) Water from leakage of the cooling system,

(5) Water as a product of fuel combustion: Fuel burns to CO2 and H2O. For every liter of fuel burnt, a liter of water is created. This normally passes out through the exhaust when the engine is hot, but when cold it can run down and collect in the oil.

(6) Fuel or fuel additives or their by-products, which might enter the crankcase of engines. Unburnt gasoline or diesel can pass into the lubricant, especially during start-up. Tetraethyl lead, which is used as an anti-knock agent in petrol, passes into the oil. Typical used engine oil may have contained up to 2% lead, but today any lead comes from bearing wear and is likely to be in the 2 - 12 ppm range.

Products of Oil Deterioration

Many products are formed during oil deterioration. Some of these important products are:

(1) Sludge: a mixture of oil, water, dust, dirt, and carbon particles that results from the incomplete combustion of the fuels and as result of oxidation. Sludge may deposit on various parts of the engine or remain in colloidal dispersion in the oil.

(2) Lacquer: a hard or gummy substance that deposits on engine parts as a result of subjecting sludge in the oil to high temperature operation.

(3) Oil-soluble products: result of oil oxidation products that remain in the oil and cannot be filtered out and deposit on the engine parts. The quantity and distribution of engine deposits vary widely depending on the conditions at which the engine is operated. At low crankcase temperatures, carbonaceous deposits originate mainly from incomplete combustion products of the fuel and not from the lubricating oil. While, at high temperature, increased lacquer and sludge deposits may be caused by the lubricating oil. Some oil molecules, at elevated temperatures, will oxidize to complex and corrosive organic acids [3].

Effects of Oil Contaminants

The lubricating oil properties are affected by any contaminants that may occur during motor operation. The effects of the contaminants are as follows:

(1) Water: Even in small amounts, water causes rusting of iron or steel. The water also results in forming water sludge (emulsions), which may clog oil passages, pump, valves and other oil handling equipment. Water also contributes to foaming problems.

(2) Solid particles of dirt, dust, grit and metallic fragments, which were circulated by the lubricant: these contaminants cause excessive wear, scoring of bearing surface, and possible failure due to seizing of metal fatigue. Soot and carbon make the oil go black.

(3) Sludge and lacquers: sludge deposits clog small oil passages and clearances. Lacquers or varnishes can cause sticking of valves, and resist against the continuous operation of oil pump.

(4) *Liquid contaminants:* such as unburned fuel from engines dilute lubricating oil and possibly reduce their viscosity beyond a safe load. Contaminants of the lubricant with heavier oil increase viscosity and interfere with the oil circulation. This affects the lubricating value and heat transfer capacity [3].

Physical and Chemical Tests of Used Lubricating Oil

Standard chemical and physical tests are used to evaluate the properties of the oil and the extent of the contaminants in the used automotive oils. These tests involve the following measurements:

(1) Viscosity: viscosity testing can indicate the presence of contamination in used lubricating oil. The oxidation and polymerization products that were dissolved and suspended in the oil cause the increase of oil viscosity. While a decrease in the viscosity of lubricating oil indicates the fuel contamination.

(2) Pour point: pour point is the lowest temperature at which the oil will flow. Low pour point indicates good lubricating oil.

(3) Flash point: flash point is the lowest temperature at which the vapours in air will burn momentarily if ignited by flame or spark. A decrease in flash point indicates contamination by dilution of lubricating oils with unburned fuel. Increasing of flash point indicates evaporation of the light components from the lubricating oil.

(4) Acidity or neutralization number: this is a measure of the amount of alkali required to neutralize one gram of the oil. An increase in acid number indicates the extent in oxidation of lubricating oil.

(5) Ash content: the remaining solid ash, when the oil is completely burned, is a measure of oil purity and indicates contamination with metals.

(6) Carbon or coking test: this evaluates the solid residue obtained when the oil is heated to complete vaporization and it refers to the amount of deposit formed.
(7) Water content: this test is done by distillation and indicates the amount of water emulsified in the oil.
(8) Fuel contaminants: this test indicates the amount of fuel diluting in the lubricating oil during operation [3].
Refractive index, oil colour, sulphur content, chlorine content and metal contents of lubricating oils are tested through different techniques to characterize oil properties.

Table 2: Comparison of fresh base engine oil and used oil

Samples	**Base engine oil (Ravenol, VSi SAE 5W-40)**	**Used engine oil (being in use for 2000–3000 km)**
Flash point °C	232	158
Pour point °C	−13	−5
Kinematic viscosity@ (40 °C)	195.62	136.6
Kinematic viscosity@ (100 °C)	18	13.5
Viscosity index	100.27	89.11
Refractive index	1.4886	1.4763
Specific gravity	0.8818	0.9261
Water and Sediment (mL)	-	0.9
Carbon residue (wt %)	0.55	1.82
(TAN) mg KOH/ g(sample)	-	4.5
(TBN) mg KOH/ g(sample)	3.55	-
Metal Contents (ppm)		
Cu	0	4.6
Mg	72	81
Cr	0	1.5
Sn	0	1.6
Pb	0	14.6
Fe	0	72
Zn	1200	1280

Impacts of Used Lubricating Oil

The contaminants in used oil have adverse environmental and health impacts. 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. 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, i.e. recreation and fishing industries. For example, used oil from internal combustion engines generally accumulates a variety of contaminants which increase the oil's toxicity [6].

Improper application of used oil for multiple customary purposes also leads to various environmental degradations and health effects. Some local uses of changed oil and its direct and indirect adverse effects are shown in Table 3 [7].

According to EPA, just one quart of used oil is able to make one million gallons of water undrinkable. When used oil enters surface water, oil films will block sunlight, impair Photosynthesis, and prevent the replenishment of dissolved oxygen, which lead to the death of aquatic plants and animals. When used oil is dumped down the drain and enters a sewage treatment plant, very small concentrations of oil in the wastewater (50 to 100 ppm) can foul sewage treatment processes. Used oil drainage has been reported to account for more than 40% of the total oil pollution (the largest single source) to American waterways. Used oil filters are not even regulated as hazardous waste for most states and are allowed to be disposed in municipal landfills. Serious problems for the groundwater supplies surrounding the landfills are caused by residual oils from the filters that leach into the ground. Hence, practicing a good used oil recycling management is an important step for municipal solid waste reduction [4].

Used oil that is dumped onto soil can be washed into surface water by rain or snow, or it can seep through the soil into groundwater to contaminate our water sources. Used oil in the soil can also evaporate into the air.

Table 3: Environmental impact assessment of local uses of changed engine oil

Local uses of used oil	Application	Environmental effect
Road construction	On the ground	Soil pollution
Rust prevention	On a metal device	Stains on contact
Old engines emergency lubricant	Automobiles, generators	Air pollution, waste
Wood preservation	Timber; roofing, fencing	Land pollution
Mixed with grease for gear oil	Gear box lubricant	Spills; Soil pollution
Production of grease	Automobile lubricant	Stain on contact
Burning, Boilers, furnaces	Burners, bakery, incinerators	Off-gas, air pollution
For pest, weed, and dust control	Garden, workshops	Soil pollution
Hydraulic oil	Props, Lifts, Jacks	Spills
Ball joint oil and nuts loosing oil	Ball and socket joints, nuts	Stains on contact
Block and Balustrade mold lubricant	Block, bricks, balustrade molds	Spills
Medication	Wound and cuts	Additional Health effect
Dust and tick control	Land, floor	Land pollution, Stains
Road construction	On the ground	Soil pollution

The contaminants in used oil that enter the air through evaporation or improper burning can then settle, or be washed by rain or melting snow, into surface water or onto soil. The only way to make sure that used oil will not contaminate either water, soil, or air is to make sure that it is not released into the environment at all.

Since used oil is generated in such large quantities, for example more than 1.5 billion gallons per year estimated in the U.S., the associated impact to the environment is tremendously serious when there is uncontrolled dumping and land filling of used oil in the environment. EPA data show that more than 33% of used oils generated each year in the U.S. are illegally dumped. The most uncontrollable used oil source is those do-it-yourself oil changers (DIYers). According to EPA, only 5 percent of used oil generated by DIYers is recycled, and the rest is either burned onsite (4 percent), disposed of in trash (30 percent) or illegally dumped (61 percent). Lack of public education and awareness and shortage of convenient recycling centres are main reasons why many DIYers do not participate in the used oil collection program [8]. As shown in Table 4, there are many harmful constituents in used oil that may cause cancer or other health problems if they are inhaled or ingested. For example, it was reported that burning used oil tagged as the top source of airborne lead emissions, especially in those states where used oil is not listed as hazardous waste and lead concentration in used oil is not regulated. Used oil, therefore, is not prohibited for open burning even if lead is present at high concentrations. Typical levels of contaminants found in used oils are also summarized in Table 4.

Table 4: Typical levels of contaminants in used oils (Yang, 2008)

Category	Compounds	Automotive Used Oil Concentrations [ppm]	Industrial Used Oil Concentrations [ppm]
Metals	Cadmium	5 – 25	NG
	Chromium	50 – 500	NG
	Arsenic	2	NG
	Barium	3 – 30	NG
	Zinc	100 – 1200	NG
	Lead	100 - 1200	NG
Chlorinated hydrocarbons	Dichlorodifluoromethane	1000 – 4000	NG
	Trichlorotrifluoroethane		NG
	Tetrachloroethylene		1000 – 6000
	1,1,1- Trichloroethane		
	Trichloroethene		
	Total Chlorine	1000 – 4000	1000 – 6000
Other organic compounds	Benzene	100 – 300	100 – 300
	Toluene	500 – 5000	500 – 5000
	Xylene	500 – 5000	500 – 5000
	Benzo(a)anthracene	10 – 50	NG
	Benzo(a)pyrene	5 – 20	NG
	Naphthalene	100 – 1400	NG
	PCB’s	NG – 20	100 – 1000

These contaminants not only cause problems when they are released into the environment through improper management, but sometimes also interfere with the recycling operations of used oils. At other times, they are found to be concentrated in the waste streams of the reprocessing or re-refining plants and can cause further disposal problems [4].

Used Oil Recycling and Reuse

A large range of used 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 used oils, after treatment, can be either as a lube base stock comparable to refined virgin base oil or as clean burning fuel.

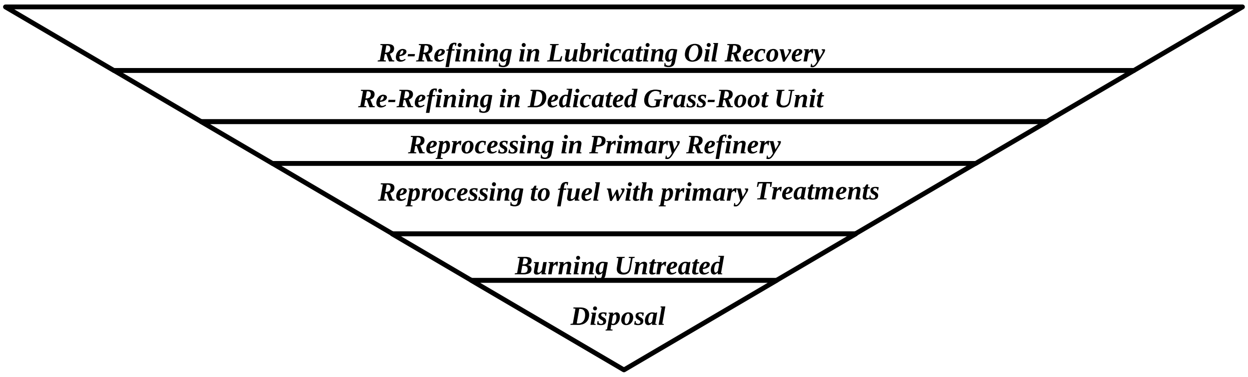

Figure 1: Waste oil treatment hierarchy

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 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. The reuse of used lubricating oils can be accomplished through three basic methods, which are incineration, reprocessing, and re-refining.

Used oil can be thermally destroyed by incineration or combusted for energy utilization. Due to the economic benefit of recycling used oil, only a very small quantity of used oil is currently incinerated. Used oil that is incinerated generally has high concentrations of toxic contaminants that make recycling impractical or unsafe [6].

Reprocessing technology provides a means where the waste oil is processed and burned for energy recovery. It involves removal of water and particulates so that used oil can be burned as fuel to generate heat or to power industrial operations. This form of recycling is not as preferable as methods that reuse the material because it only enables the oil to be reused once. Nonetheless, it is one of the economically attractive ways of managing used oil providing valuable energy i.e. about the same as provided by normal heating oil [4]. A litre of used oil re-processed as fuel contains about 8,000 Kcal of energy, which is enough energy to light a 100 W bulb for one day or to operate a 1000W electric heater for 2 hrs. [7]. Compared to direct burning, the major advantage from reprocessing used oil is that it improves the burning quality of used oil by removing/reducing some contaminants [9].

Used oil can also be re-refined back into base lube oil. Lube oil is a premium substance that can be re-refined and reused again and again. In general, water and dissolved low boiling point organic are removed by atmospheric or moderate vacuum distillation. Lube oil is then recovered using different treatments and/ or unit operations. Light end by-products are commonly used for plant combustion fuels. Diesel fraction and gas oil fractions can be recovered as high quality by-products after further advanced treatment. Residual streams from distillation can be used by asphalt industry as an asphalt flux to produce roofing asphalt, paving asphalt, insulating materials, and other asphalt based products. Re- refining involves treating used oil to remove impurities so that it can be used as a base stock for new lubricating oil. Re- refining prolongs the life of the oil resource indefinitely. This form of recycling is the preferred option because it closes the recycling loop by reusing the oil to make the same product that it was when it started out, and therefore uses less energy and less virgin oil [6].

References

[1]. Yu-Lung Hsu & Chun-Chu Liu. (2010). Evaluation and Selection of Regeneration of Waste Lubricating Oil Technology. Environ Monit Assess.

[2]. Dennis W. Brinkman. (2010). "Used oil: resource or pollutant?". Technology Review, 46-52.

[3]. Firas Awaja & Dumitru Pavel. (2006). Design Aspects of Used Lubricating Oil Re-Refining. Amsterdam, The Netherlands: Elsevier.

[4]. Chia-Yu (Iris) Yang (PhD). (2008, December 20). The Feasibility Studies On Sonochemical Processes For Treating Used Oil: Toxin Reduction For Eliminating Recycle Interference. California, University Of Southern California, USA.

[5]. Layzell, D. (2010). The Re-Refining of used Lubricating Oils. VII-Energy-B-Rerefining Used Oils-1, 54-68.

[6]. Motshumi J. Diphare, Edison Muzenda, Tsietsi J. Pilusa and Mansoor Mollagee. (2013). A Comparison of Waste Lubricating Oil Treatment Techniques. 2nd International Conference on Environment, Agriculture and Food Sciences (ICEAFS'2013), 106-109.

[7]. Michael A. Nwachukwu, Jude Alinnor, and Huan Feng. (2012). Review and assessment of mechanic village potentials for small scale used engine oil recycling business. African Journal of Environmental Science and Technology Vol. 6(12), pp. 464-475.

[8]. F. Dalla Giovanna, O. Khlebinskaia, A Lodolo and S. Miertus. (2012). Compendium of Used Oil Regeneration Technologies. Trieste: United Nations Industrial Development Organization.

[9]. Isah, A. G. (2013). Regeneration of Used Engine Oil. Proceedings of the World Congress on Engineering 2013 Vol I. London: World Congress on Engineering.