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The Purification of Waste Engine Oil: A Review

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Abstract—*This research is a literature study to examine the problems and utilization of hazardous and toxic waste. What methods can be used to treat waste engine oil, especially to remove metals in waste engine oil? It is known that the waste of hazardous and toxic materials has an impact on environmental hazards, both direct and indirect materials. Recovery of waste engine oil so that it has added value can be utilized by the acid-clay process, solvent extraction, and adsorption or pyrolysis. In principle, these processes have their respective advantages and disadvantages, but the adsorption process is considered an uncomplicated and low-cost process in which this process will use an absorbent medium to adsorb metal components and other impurities in the engine oil waste, but does not change the hydrocarbon structure. Pyrolysis is a technique that is considered expensive, but very good for reducing the value of impurities, especially metals in waste engine oil, but it is not completely the same as the quality of waste engine oil, especially on the viscosity of engine oil. The pyrolysis technique is considered more suitable for converting used engine oil into liquid fuels such as diesel oil or kerosene because there is a break in hydrocarbon bonds due to thermal treatment without air, resulting in a fundamental change in properties where waste engine oil becomes light hydrocarbons and metals will be left in fraction weight as residue.*

Keywords— *Engine oil, pyrolysis, adsorption, solvent extraction, acid clay, removal metals*

I. INTRODUCTION

Many researchers predict that the existence of fuel oil is estimated to only last about 80 more years, fuel gas for 150 years, and coal for 230 years [1]. Fossil fuels are increasingly depleting due to their massive utilization in various industrial and automotive sectors [2]. Its use in the transportation sector is an indication of the impact on the use of engine oil, which in the end will be mostly disposed of as engine oil waste (WEO), engine oil waste is also produced from various sectors such as aviation and marine industries. Lubricating oil or what is called engine oil is a substance used in an engine, which provides a layer between the two surfaces of the rubbing parts of the engine. Only a small portion of WEO is processed for further use, though. Poor environmental management has negative effects on marine life, soil quality, and human health [3]. Based on its name, engine oil's primary function is to lubricate the engine's moving parts to prevent wear and damage to the engine. One of the fractions that practically all machines and vehicles require is WEO. On moving parts, it is utilized to lessen friction between surfaces. When base oil is used in an internal combustion engine, contamination occurs that results in the presence of unsaturated compounds, phenolic compounds, aldehydes, acid compounds, additives, metals, varnishes, gums, and other asphaltic compounds that are caused by bearing surface coatings and base oil component degradation [4].

Various methods have been used to convert waste engine oil into fuel oil, namely: the adsorption process, acid-clay process, solvent extraction process, cracking or pyrolysis method [5]. The acid clay method involves reacting old lubricating oil with sulfuric acid, which then interacts with asphalt and resins, oxygen, nitrogen, sulphur-based compounds, and dissolved metal components to generate sludge [6,7]. Waste motor oil is combined with an aliphatic solvent, such as liquid propane (butane, heptane, or hexane), in a reactor during the solvent extraction procedure. While pyrolysis uses a cut-off mechanism in this unit, the solvent acts selectively to separate the oil fraction while leaving less dissolved contaminants [8]. Cracking is a petroleum refining process in which higher boiling and heavier petroleum fractions are broken down into more valuable products such as gasoline, kerosene, fuel oil, and gas oil, cracking can also be done using microwave waves [9]. However, other studies say that the reduction pyrolysis method is one of the most effective methods for recovering waste oil based on research studies, several pyrolysis methods can be used, namely pyrolysis with thermal assistance, thermal assistance, catalysts, and micro-active assistance [10,11].

II. THE PURFICATION METHOD OF WEO

A. Waste Engine Oil (WEO)

The growth of motorized vehicles today also has an impact on the growth of the use of engine oil. Motorized vehicle engines are lubricated with engine oil to keep them robust during friction. Engine oil will eventually suffer damage from friction, rendering it worthless after a given amount of time. Engine oil has potential to harm the environment because it is occasionally disposed of without being handled. Waste engine oil (WEO) is a dangerous substance that is challenging to naturally degrade. Around 40% of vehicle lubricating oil is discarded without being treated, while 56% of it is used for human use worldwide. While using recovery techniques to provide alternative fuels that are crucial for transportation might boost the economic worth of used engine oil [12]. Engine oil is made from base oil mixed with other chemicals (additives) to improve quality properties. Engine oil is used to lubricate moving engine parts, reduce friction, protect against wear, and remove contaminants. In addition, it can function as a cleaner, anti-corrosion, and refrigerant [13]. Used engine oil or pure oil ranges from C_{16} to C_{20}. The chains in the C_{5-7} region are all light, volatile, and clear naphtha. This compound is used as a solvent, or as a washing liquid. Meanwhile, chains in the C_6H_{14} to $C_{12}H_{26}$ regions can be used for gasoline and other engine fuels. Furthermore, WEO oxidizes (chemically combines with oxygen) to form various compounds [14].

Waste engine oil contains several heavy metals, one study found some metal content in waste engine oil that has been used as a lubricant some of which are Zn, Pb, Fe, and others contained in used engine oil, metal concentrations can vary in WEO [15]. Its existence can be predicted because waste engine oil has experienced friction with motorized vehicle engines and made it damaged so that some metals can be deposited into the waste engine oil, it which results in quality changes during its lifetime. The adsorption process, it will be able to adsorb these metals and if the engine oil waste is pyrolyzed, traces of metal should not be in the non-condensable gas as much as possible to last up to 550^0C [16].

B. Pyrolysis Method

The process of decomposition of hydrocarbons without air or confined air is called pyrolysis. In general, pyrolysis products can be classified into three types, in the form of solid residues rich in carbon content (char), liquid products in the form of (tar, hydrocarbons, and water), gas products (CO, H_2O, CO_2, and hydrocarbons such as paraffin and naphtha) [17]. Pyrolysis can take place in several ways, namely pyrolysis with heat assistance, a combination of heat and catalysts, catalyst assistance, and also micro active assistance. Pyrolysis with thermal assistance can be carried out conventionally with relatively low cost but high energy requirements because a lot of energy may be lost during the process, pyrolysis with the help of microwaves when viewed from energy consumption, this process has lower energy consumption, but is more expensive than the equipment [18]. Pyrolysis can also be used with the help of a catalyst, also called catalytic cracking, which is a thermochemical process that uses Using a catalyst, of course, to lower the activation energy, the catalyst can accelerate the decomposition of compounds with higher molecular weights into products with lower molecular weights [19,20].

Pyrolysis can be used as a waste hydrocarbon recycling technique, where the waste material is broken down to produce hydrocarbon oil, gas and charcoal. Pyrolysis equipment that can be used is a blast furnace or fixed bed reactor heated by a conventional energy source [21]. As previously mentioned, there are several metals or minerals included in waste engine oil by pyrolytic (WEOPC) that have unique properties for each temperature rise treatment. An increase in the value of metals in engine oil is unavoidable in addition to the presence of additives in engine oil as well as oil friction for a certain period. The concentrations of Ba, Ca and Cu in pyrolytic products increased with increasing temperature, while Zn, Pb, Fe, Mn, Ni and Mg decreased. Elemental concentrations tend to be high at increasing pyrolysis temperatures because they are light and stable until 700^0C, the presence of Ca is one of the main additives used in engine oil such as calcium sulfonate which functions as a cleaning detergent [22].

Pyrolysis can also use microwaves, microwave pyrolysis is a thermochemical process that uses a heating source with a microwave heat mode where the principle of energy emission in microwaves is electromagnetic waves that lie between the spectrum of infrared (IR) waves and electromagnetic radio waves. In microwave-assisted pyrolysis, there are microwaves which consist of two mutually perpendicular components, namely electric fields, and magnetic fields [23]. The energy that comes from the microwave tends to bounce back and cannot pass through the conductor. The energy will then completely absorb radiation and microwave heating, which in turn generates microwave heating, also known as dielectric heating [24]. The use of carbon as a microwave absorber, which also provides a reducing chemical environment, promotes the conversion of carbon to CO or CO_2 which then leaves the system in the gaseous phase, during pyrolysis it was noted that most of the metal remained in the carbon sinking in the reactor. The adsorption-desorption effect at higher temperatures is favourable for metal desorption, and the higher evaporation energy at higher temperatures promotes metal evaporation [25].

C. Acid-Clay method

This technique begins with the waste engine oil being filtered to remove metal particles and dirt. The filtered waste engine oil is reacted with a solution of acid and clay at a process temperature $(200 - 400)^0$C in a reactor to produce fuel. The resulting fuel is stored after being filtered and cooled. In the acid-clay process, used lubricating oil is reacted with an acidic solution, which reacts with oxygen, nitrogen and sulphur-based compounds, bitumen, and resinous substances to cause dissolved metal components to form sludge. The colour and smell remain in the oil treatment. The main problem with the acid-clay process is how to dispose of it properly. Safe for removing large amounts of sludge and containing residual acid solutions. Various types of acids (sulfuric acid, formic acid, acetic acid), can be used as acid solutions [26.27]. Sulfuric acid is by far the most popular method for lubricating oil recovery. This process produces aromatic compounds which are structurally oil soluble in sulfuric acid, similar to soot and other impurities and form precipitates that are easy to remove. After this process is complete, the obtained oil is treated with clay (usually bentonite clay) to clarify the liquid. However, the waste from this process is toxic and difficult to remove and manage, [28].

The acid-clay method is perfect for removing metal content, but it is necessary to consider the type of acid solution used. The effect of the type of acid on the cleaning of metal content in WEO has a sequential order of ability, The order of removal percentages from sulfuric acid using different acid-modified clay materials does not follow a definite pattern, however, the same order of percentage removal seen between nitric acid and sulfuric acid contrasts with the order of metal removal percentages of phosphoric acid [29].

D. Solvent Extraction

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The extraction technique using a solvent is an easy and inexpensive process. In this process, contaminants are removed in the process of mixing with the solvent where better results are obtained compared to using sulfuric acid. In the reactor, used engine oil is combined with an aliphatic solvent such as liquid propane (butane, heptane, or hexane). In this system, the solvent separates the oil fraction while leaving behind some dissolved contaminants. In a distillation column that runs at atmospheric pressure and condenses the solvent vapor from the top of the column without using refrigerant, the solvent is recovered from the solvent-lubricating oil combination. The solvent treatment process's sludge byproduct can be sold as an asphalt additive and disposed of as non-hazardous trash. The extraction process using hydrocarbon solvents is used for the processing of waste engine oil. The solvent used is liquefied petroleum gas (LPG) condensate and stabilized condensate. This procedure yields a sizable amount of liquid product with relatively little metal contamination [30]. Several types of solvents that can be used are MEA, butanol, and methyl ethyl ketone. The solvents can also be mixed with a certain ratio. Research ever conducted by Ghassan Rokan Daham in 2017, Shows that mixing mono ethyl amine (MEA) + 1-butanol produces the best metal removal results compared to 1-butanol and methyl ethyl ketone (MEK). In principle MEK, 1-butanol + MEA, and 1-butanol can be used to remove metals in WEO, the average percentage of removal is around (50 – 90) %. The solubility of the solvent and its ratio in WEO, greatly determines the amount of metal that can be cleaned, the higher the solubility the better. The ability of the solvent to separate contaminants from waste engine oil is closely related to the solubility parameter of the solvent [31].

E. Adsorption

The adsorption is a process or phenomenon physical and chemical of accumulation of substances on the surface of the two adsorbed phases called adsorbates (solute and adsorbent phases are called adsorbents [32]. Such events are usually referred to as the adsorption of adsorbate molecules to the adsorbent surface. The physical adsorption process is an adsorption process that is the result of attractive forces. Intermolecular between solid molecules and substances. Chemical adsorption or active adsorption is the result of the interaction between the solid and the adsorbed substance. The process of chemical adsorbs often does not go back and forth and the desorption of substances is often found to have undergone a chemical change [33]. There are several main factors that affect the adsorption including pH, temperature, metal concentration, and surface area [34].

In general, adsorbents are very porous materials. Because the pores are usually very small, they can be referred to as nanoparticles with large surface areas. Many adsorbents that can be used including low-cost ones, including natural materials, bio-sorbents, and industrial and agricultural waste materials can be used because they have a high carbon content and also a low inorganic content [35]. Besides the purity of the adsorbent is also the main characterization wherein the adsorbent functions the purer the more desirable because of its adsorption ability good. Nabil M. Abdel Jaber In 2020 has investigated the effect of the type of adsorbent on the adsorption of dissolved metals in engine oil waste. In his research, he compared bentonite that had not been activated and after it was activated using an acid solution, he also made comparisons with activated carbon derived from palm shells [36]. The results obtained in this research turned out that the type of adsorbent greatly influenced the adsorption process, in which there was a very significant effect of the type and activation treatment on the active bentonite adsorbent. Activated bentonite adsorbent has better adsorption power than non-activated treatment, and when compared to activated carbon derived from palm shells, activated bentonite is even better at adsorbing certain metals, such as Na, Ca, Mg, P, Zn [22].

E. Comparison of Waste Engine Oil Recovery Methods

Several methods can be used to recycle waste engine oil. waste engine oil can be recycled into different products such as liquid fuel, making waste engine oil into liquid fuel more effective if you recycle the waste to become lubricants because when engine oil has been used, the composition of chemical compounds will change. Due to the heat factor and the friction of the engine oil with the motorcycle engine, the amount of dissolved metal will also increase. An overview of the comparison of several engine oil waste recovery techniques may be found in Table 1.

TABLE 1.

No	Method of recovery	Critical reviews	Ref.
1	Distillation Pyrolytic	This method is less effective in reducing a number of metals, but very effective in reducing sulfur	21
2	Acid/Clay method	This research shows that this method is more effective for removing all metals, but further treatment is needed to separate the acid+clay from WEO.	17
3	Adsorption	This research shows that the adsorption process is able to remove some metals, such as; zinc, chromium, cadmium and also magnesium, but is unable to adsorb copper and iron metals.	32
4	Microwives pyrolysis	This study shows that the use of microwaves is very significant in obtaining yields, namely being able to reach 90%, but the viscosity and metal content are far from the expected standards.	24
5	Solvent Extraction	This method shows that solvent extraction is the most effective for reducing the amount of metal present in WEO, but further treatment is required for solvent separation.	28

The recovery methods described above in principle can be used to reduce the amount of metal content in engine oil waste, the ability of each method is very different as shown in Figure 1 below.

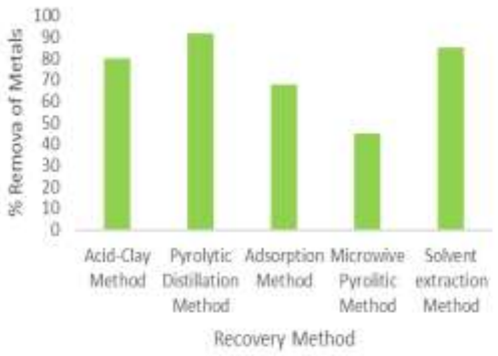

Figure 1. The comparison recovery method on %removal

Figure 1 above shows that the percent removal of metals in engine oil waste expressed in % removal is in pyrolytic distillation followed by solvent extraction, acid-clay, and adsorption methods, but the lowest removal of the five methods is the microwave pyrolytic method. However, different things appear in the evaluation of yield gains, the five methods give different results as shown in the Figure 2 below

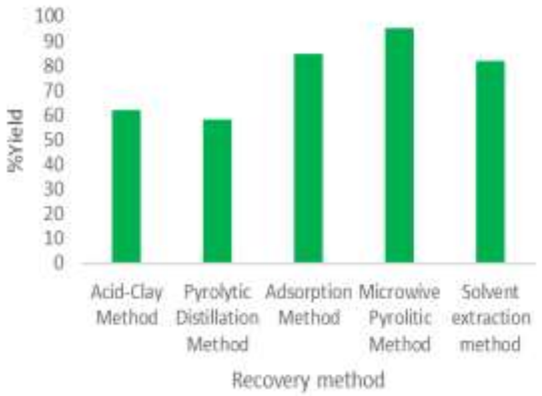

Figure 2. The comparison recovery method on % yield

Figure 2 above shows that after WEO was processed by this method, the best yield obtained was the microwave pyrolysis method which was able to reach 90% yield, followed by adsorption and solvent extraction in the range of 80% yield, while acid-clay and distillation pyrolysis were the lowest in obtaining results.

III. CONCLUSION

Hazardous and toxic waste, especially engine oil waste, is very harmful to the environment, either directly or indirectly, based on a literature review. It can be concluded that the most dangerous material contained in engine oil waste is metal content. In used oil, the metal contained in used engine oil waste can come from additives added to improve the quality of the lubricating oil or it can also form after the engine oil waste process occurs during the lubrication process so that the engine oil becomes damaged and useless like the initial state. To overcome waste engine oil that causes environmental problems, efforts can be made to increase the added value of engine oil waste.

The pyrolytic distillation method is more advanced, efficient, and good for recycling waste engine oil. This method is very good for removing metal deposited in waste engine oil by combustion. The adsorption method is quite feasible because the cost is lower than others, but the ability to remove metals is lower than the pyrolytic distillation method, acid-clay, solvent extraction, and other methods. The pyrolytic distillation process is not only good for reducing the amount of metal but also converting waste engine oil into fuel that resembles diesel by cracking, which is breaking the long chain of hydrocarbons in WEO into short chains or light hydrocarbons.

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