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Waste Oil Management and Recycling Potential in Laguna Province: A Comprehensive Investigation

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ABSTRACT: This study presents a comprehensive analysis of the hazards imposed by automotive waste oils on the environment and human health. Also, the physical and chemical properties of filtered and unfiltered waste oil were analysed using standard test methods conducted at DOST-ITDI. Lastly, comprehensive literature reviews regarding the re-refining techniques on waste oil were also conducted.

It was found that improper disposal of waste oils imposed different dangers in the community and human health. Impurities such as lead, zinc, copper, and iron damage the land, while oil films on water affect the aquatic resources which are detrimental to bodies of water. Also, burning of waste oils produced airborne contaminants that enter the airways of human and cause adverse effects on human health. The results of the study also showed that it is possible to refine automotive waste oils using different treatment processes. The oil's physical and chemical properties greatly affect its performance on the engine, the difference in kinematic viscosity shows that automotive waste oils must be filtered out and be used in other applications instead of disposing it into the environment.

Overall, the findings suggest that treating waste oil is a must instead of disposing it into the environment. Also filtering the oil improved its properties for better engine performance.

KEYWORDS: Re-refining techniques, automotive waste management, kinematic viscosity, viscosity index

I. INTRODUCTION

Waste oil management is crucial in the modern industrialized world since it deals with environmental issues and the sustainable use of resources. Waste oil (WO) from many sources such automobile repair, industrial processes, and cooking presents substantial issues due to its potential for environmental contamination and health risks. Waste oils are disposed improperly and believed that 40% of this material is poured directly into the ground (U.S. Environmental Protection Agency, 2018). It also picks up a variety of hazardous contaminants when used in engines and transmissions such as lead, cadmium, arsenic, dioxins, benzene, and polycyclic aromatics that can harm human, plants, and aquatic animals (Department of the Environment Water Heritage and the Arts, 2013). Yet, this challenge presents a chance for innovation and sustainable methods by implementing effective waste oil recycling processes.

Managing and recycling waste oil is a complex process that includes collecting, transporting, treating, and either reusing or disposing of it. The process of returning waste oil to its original composition, it is important to understand the differences between used motor oil and new motor oil (U.S. Environmental Protection Agency, 2018). Properties such as viscosity, pour point, flash point, acidity, ash content, carbon, water content, contaminants, and cloud point must be analyzed (Abro et al., 2013).

Utilizing cutting-edge technologies and enforcing strict rules can help reduce the negative effects of waste oil and maximize its recycling capabilities. By using efficient management techniques, waste oil can be converted from a problem into a valuable asset, providing many economic and environmental advantages.

This study investigates the property of waste oil, its management system, and its extensive recycling possibilities, emphasizing the significance of sustainable practices and technical progress in creating a more environmentally friendly and resource-efficient future.

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II. OBJECTIVES

The primary objective of the study is to determine the different waste oil management systems, recycling potential, and processes in treating waste oils. Specifically, it aims to:

1. To determine the hazard of waste oil in the community and in the environment.
2. To determine the physical and chemical characteristics of Waste Oils in Laguna.
3. To determine the re-refining techniques and process of converting Waste Oils.

II. METHODOLOGY

Research methodology is essential in a study that seeks to address certain objectives. Adhering to a correct methodology guarantees that the research is carried out in a systematic manner, the data gathered is dependable, and the findings made are sound. Below is the study's outline:

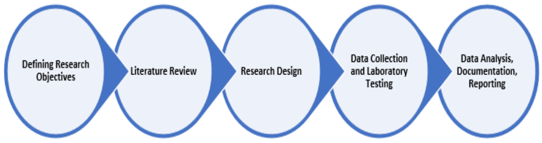

Figure 1. Research Methodology

Define Research Objectives. Investigation into the effects of waste oil disposal on land and water and its influence on the community and environment. Identify the re-refining procedures utilized for treating waste oils and explain how they will be converted into lubricants. Analysis of waste oil characteristics through laboratory testing.

Literature Review. Perform an extensive literature review to investigate the impact of waste oil disposal on land and water, various re-refining methods for treating waste oils, their potential for conversion into lubricants, and the examination of their physical and chemical properties.

Research Design. For this study, descriptive-quantitative data (e.g., surveys, literature review, data analysis.

Data Collection and Laboratory Testing. Literatures from different studies will be gathered to answer some of objectives. Physical properties such as appearance, viscosity at 40℃ and 100℃, total base number, flash point will be analysed. Also, chemical analysis of the waste oil such as water content and pentane insoluble are also included in the tests which will be conducted at the Department of Energy (DOE).

Data Analysis, Documentation, Reporting. Analysing the collected data and determining the finest re-refining techniques in treating the waste oil as a basis in designing a machine. Comparing the physical and chemical characteristics of used and un-used oil as a basis for evaluating the performance of the machine that will be developed in the next study. Each step in the research process will be methodically recorded, from data gathering to analysis. The research report presented the findings in a straightforward, clear, and structured manner. In the future, the paper may undergo peer review by experts in the field to verify its quality and validity. The research results could be shared through presentations, papers, or other suitable avenues to enhance the field's understanding and perhaps impact waste oil disposal methods.

III. RESULTS AND DISCUSSION

3.1. Waste Oil's Hazard in the Community and Environment

When waste oils are improperly disposed of in the environment, they accumulate numerous hazards in the community. Waste lubricants contained various contaminants, including cadmium, chromium, arsenic, dioxins, benzene, and polycyclic aromatics (Department of the Environment Water Heritage and the Arts, 2013). Additionally, engine oil comprises impurities and supplementary constituents resulting from wear, such as metal particles (e.g., lead, zinc, copper, iron), as well as compounds composed of barium, sulfur, water, dirt, burnt carbon, and ash. Most of these contaminants are exceedingly toxic by nature, necessitating their separation prior to the reutilization of the engine oil (Abro et al., 2013). Oil is an observable impurity in water, existing as a suspended film. The opacity of sunlight and oxygen to the water can be caused by this oil film, which is detrimental to aquatic life and fish. Foam-dwelling animals, including fish and amphibians, are susceptible to its lethal effects. In addition, burning used oil at a low temperature can produce airborne contaminants that can enter the airways of humans and cause adverse health effects (Department of the Environment Water Heritage and the Arts, 2013). In terms of health, improper disposal can cause carcinogenic effect as verified by the European waste catalogue code 13 (Pires, 2012).

3.2. Physical and Chemical characteristics of Waste Oil in Laguna

Sample Code Sample	OCS-2024-0549 Automotive Waste Oil (Used Oil) Filtered	OCS-2024-0550 Automotive Waste Oil (Used Oil) Unfiltered	TEST METHOD
Specific Gravity at 15°C	0.870	0.861	ASTM D1298[a]
Flashpoint, Cleveland Open Cup, °C	240	237	ASTM D92[b]
Kinematic Viscosity at 40°C, mm^2/s	99.0	60.8	ASTM D445[c]
Kinematic Viscosity at 100°C, mm^2/s	13.2	9.96	ASTM D445[c]
Viscosity Index	132	150	ASTM D2270[d]

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The table above shows the results of the laboratory test conducted at the Department of Science and Technology- Industrial Technology Development Institute Standards and Division (DOST-ITDI). The result shows the specific gravity, flash point, kinematic viscosity at 40℃ and 100℃, and the viscosity index. The kinematic viscosity of the two samples were different at the same temperature, unfiltered oil has a lower kinematic viscosity compared to the filtered oil. The viscosity of the oil determines the thickness of the oil film. The oil film's resistance to being removed or rubbed from the lubricated surface increases as the viscosity of the oil increases. (Stocks, n.d.). The statement proved that filtering automotive waste oil provides better performance on the engine. The table also shows that as the temperature increases, the viscosity of the oil decreases, the observation was similar to the observations of (Robert et al., 2023) and (Bopche, 2021). In addition, results also showed that the specific gravity and flash point of the two samples were almost the same. The flash point indicates the storage safety of oils at certain temperatures. The table above also shows the viscosity index (VI) of filtered and unfiltered automotive waste oil wherein the VI of the unfiltered oil was higher compared to filtered oil. The viscosity index is a numerical scale that is arbitrary and measures the variation in oil viscosity as a function of temperature. Small variations in oil viscosity with temperature are indicated by a high viscosity index. A viscosity index that is low suggests that the viscosity is high and that it is subject to temperature fluctuations. Consequently, a fluid with a high viscosity index is anticipated to exhibit a relatively low degree of viscosity fluctuation in response to temperature fluctuations and is regarded as having a stable viscosity. It is reasonable to anticipate that a fluid with a low viscosity index will experience a substantial change in viscosity as the temperature fluctuates (Onyeji et al., 2011). Viscosity will not significantly change over this temperature range, and as a result, the most effective lubricants will function optimally. Therefore, an oil that maintains a consistent viscosity despite temperature fluctuations is the most suitable for the majority of applications (Onyeji et al., 2011).

3.3. Re-refining Techniques and Process of converting Waste Oil

Since waste oil was found to be hazardous to the environment, various re-refining techniques and processes were studied to return WO from its original state. The following are the different techniques used in re-refining waste oils:

3.3.1. Waste Lubricant Oil (WLO) Management in Serbia

Based on the current situation in Serbia, a model that combined the available solutions with the models created by (Du đak et al., 2021) was utilized to evaluate the WLO recycling process in the country. A more thorough examination of the effects of waste oils on people and the environment in terms of GHG emissions, acidity, ecotoxicity, etc. was made possible using LCA software during the waste oil treatment process. Figure 2 shows a potential model for management, collection, separation, processing, and disposal of waste lubricating oil in Serbia.

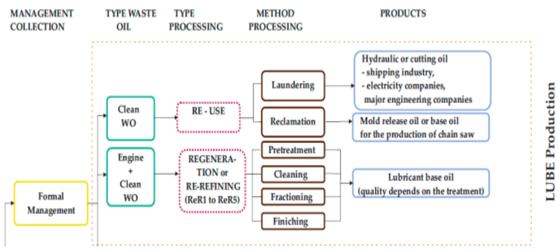

Figure 2. Waste Lubricant Oil Treatment

The figure shows that collected waste oils were sorted into two types (clean WO and Engine plus clean WO). Clean WO has undergone two separate processes such as laundering and reclamation. The WO from the laundering process was used by the shipping industries, electric companies, and engineering companies while the WO from the reclamation process was used for mold release oil or base oil for the production of chain saw. The engine oil has undergone a regeneration or re-refining process to convert it into a lubricating base oil. Processes such as pretreatment, cleaning, fractioning, and finishing were conducted.

3.3.2. Waste Lubricant Oil (WLO) Management in Europe

As environmental consciousness continues to expand on a global scale, numerous nations have enacted regulations to govern the disposal of hazardous materials. Regarding EU Member States, Waste Framework Directive (WFD) 2008/98/EC was amended by Directive (EU) 2018/851, this document establishes the management framework for the WLO. Thus, environmental, and human health protection guidelines are proposed in order to prevent or mitigate the adverse effects of WLO, as well as to improve the efficiency of resource utilization and reduce the resulting consequences (Pinheiro et al., 2021). The overarching objective of the framework is to advance the European Union towards a "society of

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recycling." Therefore, it is imperative that the administration of WLO adheres to the waste hierarchy as outlined below: (1) prevention, (2) reuse, (3) recycling, (4) energy recovery, and (5) disposal. According to the amended Article 21, it is mandated that the Member States undertake actions to ensure that:

A. Oil residue is collected individually, unless doing so would be technically impracticable.

B. Priority is given to regeneration or, alternatively, other equivalent recycling processes when treating used lubricants.

C. Waste oils with distinct properties are not combined, nor are they combined with other types of waste or substances, unless such a mixture occurs during a recycling process such as regeneration.

Following the accumulation of WLOs, several regulated routes for the treatment and disposal of waste oil were evaluated. In Europe, regeneration, laundering, reclaiming, direct burning, mild and severe reprocessing, and thermal cracking are the most pertinent disposal methods.

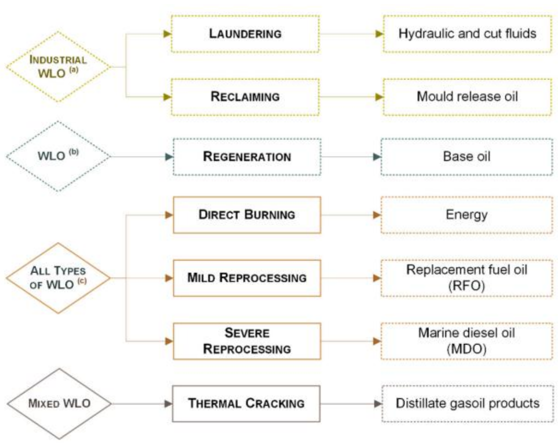

Figure 3. Treatments and Disposal Routes Available in Europe

The various treatment and disposal systems in Europe are illustrated in Figure 3. Laundering and reclamation procedures have been applied to industrial waste oils prior to their application as cut and hydraulic fluids, as well as mold release oil. Waste oils subject to limitations on chlorine content, PCB content, and saponification number are subjected to a regeneration process that transforms them back into base oil. On the other hand, heavily polluted oils undergo direct burning, mild reprocessing, and severe reprocessing processes to render them suitable for applications such as energy generation, replacement fuel oil, and marine diesel oil.

Reclaiming and laundering are viable methods for the recovery of industrial lubricants. A closed-loop process, laundering is particularly designed for hydraulic and cutting fluids. Solids are eliminated via filtration, deionization is achieved via vacuum distillation, and new additives are introduced during the procedure. For reuse, the purified oil is returned to the same company. Reclaiming is an alternative method for treating hydraulic fluids in which the lubricant is reclaimed after being centrifuged and/or filtered (Pinheiro et al., 2021).

For the recuperation of energy, WLO can be burned directly without any pre-treatment. The level of notoriety that Europeans accord to this route fluctuates significantly due to local regulations. Mild reprocessing is a straightforward treatment method utilized in space heaters, cement kilns, or waste incinerators to eliminate water and sediments from heavily polluted WLO. Metals, halogen, and sulfur may remain in the treated oil; however, it remains suitable for utilization as replacement fuel oil (RFO) in road stone plants, fuel oil blends, or power stations. The objective of severe reprocessing is to distinguish the combustible portion of heavy polluted WLO from the non-combustible ash, soil, and metal-containing bottom fractions, which are less desirable. Heavy distillate, or demetallized heavy fuel oil (HFO), is produced through the application of chemical or thermal processes. This by products can be utilized as marine diesel oil (MDO) (Pinheiro et al., 2021).

Regeneration entails the extraction of additives, contaminants, and oxidation by products from WLO to produce base oil that can be utilized in the production of additional lubricant products. The procedure is more intricate than those delineated earlier and encompasses multiple treatment technologies to attain a base oil of comparable quality to that produced during crude oil refinement. WLO contaminated with chlorine, PCB, or a chemical composition that impedes regeneration treatment must be managed via an alternative disposal or treatment method, in accordance with local regulations. Thermal cracking operates on the principle of utilizing elevated pressure within a pressurized vessel to fracture larger hydrocarbon molecules, which consist of approximately 30 carbon atoms, into hydrocarbons containing 10–18 carbon atoms. Products of superior quality, including demetallized HFO and gasoil by products, are acquired (Pinheiro et al., 2021).

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3.3.3. Recycling of Used Engine Oil Using Extraction by Composite Solvent, Single Solvent, and Acid Treatment Methods.

Used engine oils were collected from the transport office of PCSIR-KLC Karachi in Pakistan. Two different were considered in recycling the used oil such as extraction and acid treatment after the dehydration and removal of light fuels by vacuum distillation of waste engine oil at 2-8mBar (Abro et al., 2013). The vacuum apparatus was shown below:

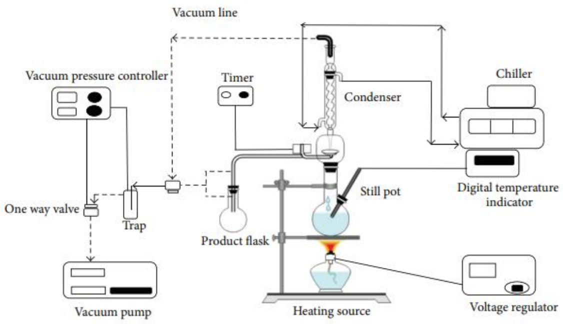

Figure 4. Vacuum Distillation of water and light fuels

The first approach considered the function of solvent extraction that was divided into two subfunctions; single solvent extraction and multicomponent solvent extraction butanol 38%, propanol 37%, and butanone 25% were used to form a composite solvent then that was mixed with oil in the ratio (oil: composite solvent) of 1: 2, 1: 3, and 1: 4 in that order. The obtained sludge was separated after 12 hours. Solvents were recovered by vacuum distillation and remaining materials as required products completely analysed. The second approach was consisting of mixing the raw material and sulfuric acid with the ratio of 10: 1 (oil: acid) at 60∘ C. That acidified material was neutralized with caustic soda of 20% solution and filtered to remove precipitate as the result of neutralization. The filtration gave clear liquid containing the required product that was analysed (Abro et al., 2013). To gather data pertaining to products manufactured using two distinct approaches in chemical process engineering, samples were dispatched to the PCSIR laboratories Complex Karachi for the purpose of validating and verifying the obtained results. Consequently, the iron contamination in the composite solvent decreased from 50 ppm to 13 ppm, while in the propane solvent and acid treatment it decreased by up to 30 ppm and 15 ppm, respectively. Variable degrees of improvement were observed in the flash point, pour point, viscosity, specific gravity, and ash percentage; however, the most optimal outcomes were achieved through the utilization of the composite solvent, albeit at the expense of increased cost.

IV. CONCLUSIONS AND RECOMMENDATIONS

In summary, the community and the environment are at substantial risk due to the illegal disposal of waste oils. Waste lubricants and engine oils are contaminated with a variety of toxic substances, including heavy metals and organic compounds, which have the potential to significantly impact aquatic ecosystems and Human health. Before oil can be reliably repurposed, it is necessary to conduct a comprehensive separation due to the presence of these contaminants. The physical properties of filtered and unfiltered waste oil samples are significantly different, as evidenced by laboratory experiments. Filtered oil exhibits a higher kinematic viscosity than unfiltered oil, which suggests a more resistant and denser oil film that improves engine performance. Nevertheless, the viscosity of both samples decreases as the temperature rises, a common trend that has been observed in previous investigations. The results of the specific gravity and flash point experiments are consistent for both filtered and unfiltered oils, indicating that they are of comparable storage safety. The viscosity index (VI), which quantifies the oil's resistance to temperature-induced variations in viscosity, is higher in unfiltered oil, suggesting that it is more stable. Nevertheless, refined oil is more appropriate for most applications, as it maintains a consistent viscosity despite temperature fluctuations. In terms of re-refining automotive waste oils, different methods and processes must be considered. In general, the optimal performance of waste oils in their reuse is contingent upon the appropriate filtration and disposal of waste oils, which are essential for minimizing environmental and health risks. For the recommendation, search for other sources on how to treat or refine automotive waste oils to determine the proper method and equipment in designing and developing a waste oil filtration system.

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