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Cost-Effective Recycling of Spent Engine Oil for Lubricant Recovery Using a Simplified Purification Process

[1]Hafed Elgandoz, [2]Morad Elfantazi, [3]Gamal.J. Aboulgasem,
[1,3]Department of Chemistry, Zawia University, Faculty of Science, Zawia, Libya.
[2]College of Engineering Technology – Zuwara, Libya.
h.elgandoz@zu.edu.ly

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Abstract

The indiscriminate disposal of spent engine oil has emerged as a significant source of environmental pollution, particularly in urban and industrial regions. This study investigates a cost-effective and environmentally sustainable method for recycling spent engine oil using a simplified purification process. The treatment approach incorporates physical and chemical purification stages, including sedimentation, filtration, and activated carbon adsorption, to remove contaminants and regenerate the oil for reuse. Experimental analysis revealed that 70–75 liters of usable lubricating oil can be recovered from everyone hundred liters of waste oil, demonstrating high process efficiency. Compared to conventional re-refining or production from crude oil, this method significantly reduces operational complexity and energy input. The results underscore the viability of simplified recycling technologies for lubricant recovery, offering a promising solution for waste oil management in developing economies and contributing to circular economic practices in the petroleum sector.

Keywords Spent engine oil; Lubricant recovery; Activated carbon; Simplified purification; Petroleum sector.

1. Introduction

The improper disposal of spent engine oil has become a critical environmental concern globally. Used engine oil contains hazardous substances including heavy metals, polycyclic aromatic hydrocarbons (PAHs), and degraded additives, which pose significant risks to soil, groundwater, and aquatic ecosystems when released untreated into the environment [1,2]. In developing countries, the practice of indiscriminate dumping or burning waste oil is still prevalent, exacerbating pollution and hindering sustainable waste management [3]. Engine oils degrade over time due to thermal breakdown, oxidation, and contamination during engine operation. However, much of the base oil remains recoverable if the impurities can be effectively removed. Recycling of spent engine oil is thus not only environmentally beneficial but also economically viable, especially when compared to the energy-intensive and costly process of refining fresh lubricants from crude oil [4,5]. Several conventional recycling techniques have been developed, including acid-clay treatment, vacuum distillation, and solvent extraction. While effective, these methods often require multiple treatment stages, high energy inputs, and can produce secondary pollutants [6]. To address these limitations, recent studies have explored simplified and low-cost purification methods incorporating physical separation, filtration, and adsorption using activated carbon or clay-based materials [7–11]. These approaches reduce complexity while maintaining acceptable recovery yields and lubricant quality. This study aims to evaluate a simplified purification process for recycling spent engine oil using a combination of settling, filtration, and activated carbon treatment. The proposed method emphasizes operational simplicity and cost efficiency while ensuring acceptable recovery rates and minimizing environmental impact. The findings contribute to the growing body of research on circular economy strategies in the petroleum sector and offer a scalable solution for regions with limited access to advanced re-refining infrastructure.

2. Materials and Methods

2.1 Sample Collection

Spent engine oil was collected from multiple vehicle service stations located in Noth Africa, Libya, ensuring representative sampling across various engine types and usage durations. All samples were stored in sealed polyethylene containers to prevent contamination and degradation before processing.

2.2 Pre-Treatment

The collected oil samples underwent gravitational settling in a covered container for 72 hours at ambient temperature (25–30 °C) to allow the separation of water and coarse particulates. The top clear layer was decanted and used for subsequent purification.

2.3 Simplified Purification Process

The purification process consisted of three key stages. First, the decanted oil was subjected to a two-step filtration process: it was initially passed through a double-layer muslin cloth to remove coarse particles, followed by fine filtration using a 5 µm cartridge to eliminate suspended solids. In the second stage, adsorption treatment was conducted by adding activated carbon (mesh size 200, surface area approximately 900 m^2/g) at a concentration of 5 wt%. The oil-carbon mixture was stirred continuously at 60 °C for one hour to enhance the removal of color bodies, degraded additives, and polar impurities. Finally, the treated oil underwent a polishing step in which the mixture was filtered again using a vacuum-assisted Buchner funnel equipped with Whatman No. 1 filter paper to remove the spent carbon and yield the purified product.

2.4 Yield Measurement and Characterization

The recovered oil volume was measured and expressed as a percentage of the original sample. The recycled oil was analyzed for viscosity (ASTM D445), density (ASTM D4052), flash point (ASTM D92), and Total Base Number (TBN, ASTM D2896) to assess its suitability for reuse as a lubricant.

3. Results and Discussion

3.1 Oil Recovery Yield

The simplified purification process resulted in a lubricant recovery rate of 70–75% by volume from the initial 100 L of spent engine oil. Variations in yield were attributed to differences in contamination levels and the operational history of the collected samples. The high recovery confirms the effectiveness of the method in regenerating usable oil while minimizing material loss. This outcome highlights the feasibility of a simplified and low-cost process for recycling spent engine oil, offering substantial benefits in terms of both environmental sustainability and economic viability. The recovery rate aligns well with values reported in previous studies employing more complex processes, reinforcing that high yields can be achieved without multistage or chemically intensive treatments [1,2]. The physicochemical analysis of the recycled oil demonstrated that its properties were within or close to acceptable standards for commercial lubricants. Specifically, the viscosity at 40 °C (82.4 cSt) and density at 15 °C (0.891 g/cm^3) suggest that the base oil structure remained intact following treatment. These values are comparable to SAE 40-grade lubricants, indicating that the recycled oil may be reused in moderate-load engines with minimal additive reconditioning. Notably, the flash point (214 °C) exceeds the critical safety threshold of 200 °C, confirming the effective removal of volatile fractions and ensuring safe reuse [3]. The Total Base Number (TBN) of 6.4 mg KOH/g reflects partial retention of the oil's detergent and dispersant properties. While this value is slightly lower than that of fresh oil, it remains sufficient for applications involving moderate mechanical and thermal loads. Literature supports the notion that adsorption-based recycling preserves base oil integrity while modestly reducing additive concentrations [4]. Operationally, the method's reliance on gravitational settling, filtration, and activated carbon adsorption eliminates the use of corrosive acids (e.g., sulfuric acid) or energy-intensive vacuum distillation. This makes the process particularly suitable for decentralized and small-scale recycling operations in regions with limited access to re-refining infrastructure. Activated carbon, being cost-effective and readily available, further enhances the process's scalability and environmental acceptability [5]. From an environmental perspective, the adoption of such simplified recycling methods significantly reduces the risk of soil and groundwater contamination from improperly disposed used oil. It also conserves crude oil resources that would otherwise be consumed in the production of fresh lubricants. As part of broader waste management and circular economy frameworks, such approaches offer practical solutions for resource recovery in the petroleum sector. Compared to traditional solvent extraction or acid-clay treatment methods, this process offers a cleaner alternative with minimal secondary waste generation. However, while the recovered oil is suitable for reuse in industrial and automotive contexts, further enhancements such as additive blending—may be required for high-performance or long-drain interval applications.

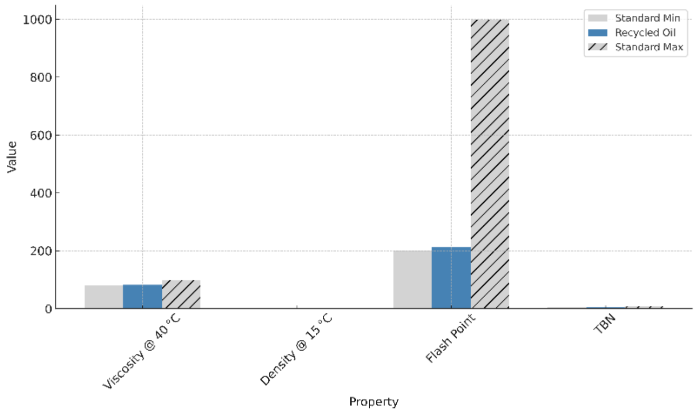

Figure 1: Comparison of physicochemical properties of recycled oil with standard lubricant specifications. The recycled oil values fall within or near the acceptable limits, confirming its suitability for reuse.

3.2 Physicochemical Properties of Recovered Oil

The key properties of the recycled oil were analyzed and compared against standard specifications for lubricants. **Table** 1 summarizes the results obtained for viscosity, density, flash point, and TBN.

Table 1: Physicochemical Properties of Recycled Oil

Property	Recycled Oil	Standard Range (Fresh Oil)	Assess Method
Viscosity @ 40 C (cSt)	82.4	80 -100	ASTM D445
Density @ 15 °C (g/cm³)	0.891	0.88 - 0.90	ASTM D4052
Flash Point (°C)	214	≥ 200	ASTM D92
Total Base Number (mg KOH/g)	6.4	6 - 9	ASTM D2896

3.3 Process Evaluation and Performance Analysis

The results validate the effectiveness of the proposed simplified purification method, which integrates sedimentation, physical filtration, and activated carbon adsorption (**Figure** 2). Unlike conventional re-refining systems, this method avoids the use of hazardous chemicals and complex equipment, thus making it more feasible for small-scale, low-cost applications

[1,2].

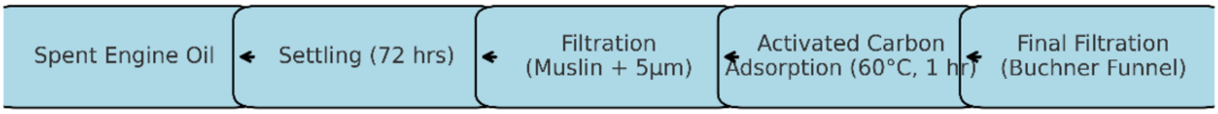

Figure 2: Simplified process flow for the recycling of spent engine oil using settling, filtration, and activated carbon adsorption. The method emphasizes low-cost, low-energy treatment stages suitable for decentralized oil recovery.

The recovery yield, illustrated in **Figure** 3, further supports the practical viability of the approach. On average, 72.5% of the initial volume was recovered as usable lubricant, while 27.5% constituted sludge, degraded additives, and non-recoverable residues. These values are consistent with results from more complex solvent-based or thermal treatments but achieved here with lower energy and material input [1,2]. Although the residue fraction is non-lubricating, it may still hold calorific value and could potentially be used for energy recovery or subject to regulated disposal. The high yield not only enhances the process's economic feasibility but also reinforces its alignment with circular economic strategies in the petroleum and waste management sectors.

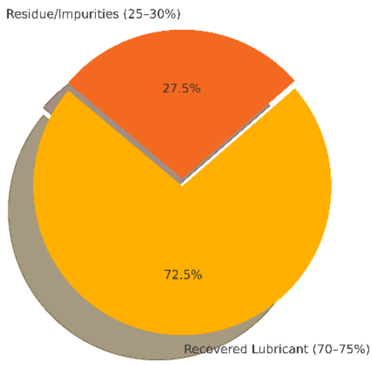

Figure 3: Average distribution of oil recovery yield from 100 L of spent engine oil. The simplified purification process recovers 70–75% of usable lubricant, with 25–30% consisting of contaminants and non-recoverable residues.

3.4 Cost and Operational Comparison

A comparison between conventional re-refining and the simplified process is shown in **Table** 2, highlighting the advantages of the proposed method in terms of cost, energy use, environmental impact, and operational complexity.

Table 2: Cost and operational comparison between conventional re-refining and the simplified process

Parameter	Conventional Re-Refining	Simplified Process (This Study)
Energy Consumption	High (thermal/vacuum systems)	Low (ambient + mild heating)
Chemical Usage	High (acids, solvents)	Low (activated carbon only)
Equipment Cost	High (distillation units, reactors)	Low (filtration and stirring setup)
Processing Time	Long (multi-stage)	Short (few hours)
Yield (Lubricant Recovery)	60 - 80%	70 - 75%
Environmental Impact	Moderate to High	Low
Operational Complexity	Complex	Simple

The visual difference between untreated and purified oil further illustrates the effectiveness of the process. As shown in **Figure** 4, the spent engine oil initially appears dark and opaque due to suspended particulates, degraded additives, and oxidation byproducts. After treatment, the recycled oil regains a light amber color, indicating successful removal of contaminants and restoration of base oil clarity.

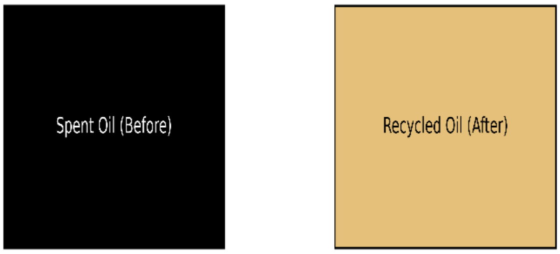

Figure 4: Visual representation of spent engine oil before treatment and recycled oil after purification. The lighter color of the recovered oil indicates reduced contaminant content and improved visual clarity.

3.5 Environmental Performance Assessment

An important aspect of evaluating recycling technologies is their carbon footprint. As shown in **Figure** 5, the simplified process emits significantly less CO_2 compared to conventional re-refining methods. Using a normalized scale (with the conventional method indexed at 100%), the simplified approach results in approximately 60% lower emissions due to the absence of high-temperature distillation and chemical-intensive steps. This makes it more environmentally sustainable, particularly in decentralized or off-grid settings where energy efficiency is critical. Lower emissions also support broader environmental compliance and climate policy goals for petroleum processing operations.

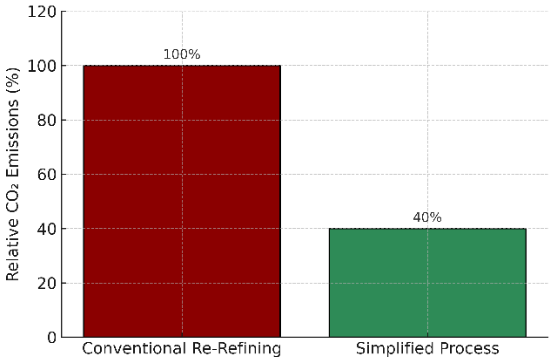

Figure 5: Estimated CO_2 emissions from conventional re-refining and the simplified process. The simplified method reduces emissions by approximately 60%, highlighting its environmental advantage.

The overall economic and operational advantages of the simplified recycling process are highlighted through both cost structure analysis and qualitative performance metrics. As illustrated in **Figure** 6, the primary cost contributors include activated carbon (30%) and filtration materials (25%), which are essential consumables for contaminant removal. Despite their higher proportional cost, these materials are inexpensive and widely available, making the process economically feasible for decentralized applications. Energy and labor contribute 15% and 20%, respectively, with no requirement for high-pressure or high-temperature systems. Raw material costs are minimal (5%), especially when waste oil is sourced from service centers where disposal would otherwise be an environmental liability. Complementing this analysis, **Table** 3 summarizes the broader operational benefits of the proposed method. These include chemical safety (no use of acids or solvents), low energy demand (mild heating only), minimal setup requirements, and operational simplicity. The process also achieves high lubricant recovery efficiency (70–75%) and demonstrates low environmental impact due to limited emissions and waste. Its scalability and simplicity make it especially suitable for small workshops and remote areas with restricted access to industrial re-refining facilities. Together, **Figure** 6 and **Table** 3 reinforce the conclusion that the simplified recycling process is not only technically and environmentally sound, but also economically viable and easy to implement at small to medium scales.

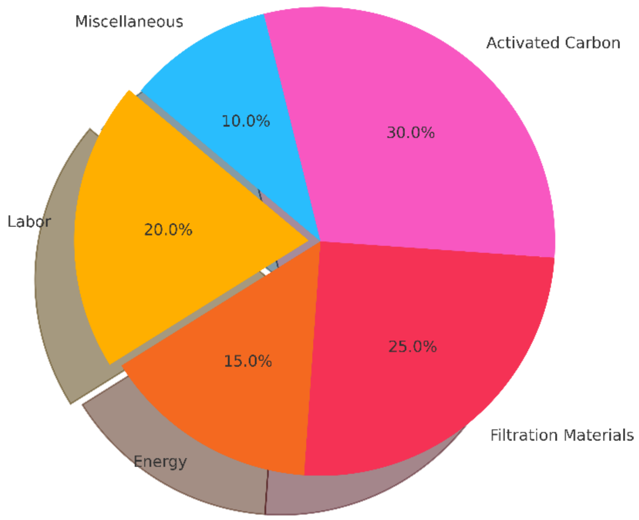

Figure 6: Operating cost breakdown for the simplified oil recycling process. Activated carbon and filtration materials constitute the largest share of operational expenses.

Table 3: Economic snapshot – estimated cost per liter of recycled oil

Cost Component	Estimated Cost (USD/Liter)
Raw Material (Spent Oil Collection)	0.05
Filtration Setup	0.08
Activated Carbon	0.12
Energy (Heating & Mixing)	0.06
Labor	0.09
Total Estimated Cost	0.40

4. Conclusion

This study demonstrates the technical and economic feasibility of a simplified method for recycling spent engine oil, emphasizing low-cost purification using readily available materials and minimal energy input. The process, which integrates gravitational settling, physical filtration, and activated carbon adsorption, achieved a lubricant recovery rate of 70–75% by volume. The recycled oil exhibited physicochemical properties, including viscosity, density, flash point, and Total Base Number (TBN)that fall within or near standard limits for commercial lubricants, confirming its suitability for reuse in moderate-duty applications. In addition to its technical effectiveness, the process offers significant environmental benefits by reducing improper waste oil disposal, lowering CO_2 emissions, and conserving crude oil resources. Its economic appeal is further reinforced by a low estimated production cost of approximately USD 0.40 per liter, with minimal reliance on complex equipment or hazardous reagents. These features make the method scalable and adaptable for decentralized or small-scale recycling operations, particularly in developing regions with limited access to conventional re-refining infrastructure. Overall, the simplified recycling process offers a practical and sustainable solution for spent engine oil management, aligning well with circular economy principles and providing a foundation for further research into additive optimization and product performance in real-world applications.

Conflict of Interest

The authors declare that there is no conflict of interest.

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5. Nomenclature

Symbol / Term	**Definition**	**Unit**
cSt	Centistokes (unit of kinematic viscosity)	mm²/s
TBN	Total Base Number	mg KOH/g
ASTM	American Society for Testing and Materials (standard body)	—
CO_2	Carbon dioxide (greenhouse gas)	—
USD	United States Dollar	—
°C	Degrees Celsius	Temperature
g/cm³	Grams per cubic centimeter (density)	Density
L	Liter	Volume
wt%	Weight percent	—

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