



DESIGN OF LOW-COST LUBRICANT RECYCLING SYSTEM FOR AUTOMOTIVE WORKSHOP

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Abstract

This study presents the conceptual design of a low-cost lubricant recycling system intended for a small and medium scale automotive workshops. The system integrates essential units such as a collection chamber, filtration unit, sedimentation tank, heating chamber, additive restoration unit, and storage vessel, arranged to ensure progressive recovery and restoration of degraded oils. A schematic-based design methodology was employed to conceptualize and represent the system, emphasizing affordability, simplicity, and compliance with environmental safety standards. Expected performance analysis indicates a recovery efficiency of 70 – 85%, making the system a feasible alternative to outright disposal or costly re-refining processes. While the study is limited to conceptual design without fabrication, the proposed system provides a sustainable pathway for lubricant reuse, reducing operating costs for workshops and contributing to environmental conservation.

Keywords: Lubricant recycling, automotive workshop, low-cost design, oil recovery, waste management, sustainability.

1. INTRODUCTION

Automotive servicing generates substantial volumes of used lubricating oil (ULO) that, if mismanaged, can contaminate soil and groundwater with heavy metals, polycyclic aromatic hydrocarbons (PAHs), and additive-degradation by-products. In many low- and middle-income settings, informal dumping remains common; recent fieldwork at Lagos' Ladipo and Berger automobile markets, for example, documented significant deterioration of soil physicochemical quality and elevated metals in ULO-impacted plots (Okoya *et al.*, 2024; Obayomi *et al.*, 2021). These findings align with broader evidence of environmental health risks at Nigerian mechanic sites and oil-impacted communities (Onukak *et al.*, 2021).

Within a circular-economy framework, the **re-refining** of ULO to produce re-refined base oils (RRBOs) is widely regarded as the most sustainable end-of-life route compared with energy recovery or disposal. Life-cycle assessments (LCAs) and policy reviews consistently show lower greenhouse-gas emissions and energy use when ULO is re-refined to base oils rather than burned as fuel or landfilled. A national LCA from Serbia and an industry meta-assessment for Europe both conclude that regeneration delivers the best environmental profile per unit of functional lubricant, provided collection systems are effective (Petrovic *et al.*, 2021; Waste Framework Directive, 2023).

Technologically, contemporary ULO re-refining falls along a spectrum from **low-capital, low-temperature** cleanup (e.g., adsorption on activated clays/carbon and solvent extraction) to **high-severity, refinery-style** schemes (vacuum distillation followed by hydrotreating). Recent reviews outline the tradeoffs: adsorption/solvent routes are simpler and cheaper to deploy at small scale but may yield base stocks with higher residual contaminants and color, whereas vacuum distillation with finishing (clay/hydro-treat) achieves higher quality and yields but at higher CAPEX/OPEX and tighter utilities control (Basha *et al.*, 2021; Selvaraj *et al.*, 2020; Patel *et al.*, 2021).

A “design-for-context” opportunity therefore exists for **low-cost workshop-proximate systems** aimed at (i) water and light-ends removal, (ii) removal of particulates, sludge, and polar degradation products, and (iii) viscosity stabilization—producing a cleaned base fraction that can be **re-additized** into serviceable lubricants for non-critical or secondary applications. Recent experimental and review papers show that vacuum distillation operated under modest temperatures with adequate vacuum, optionally followed by clay/activated-carbon polishing, can recover 70–85% oil with substantial sulfur and metal reduction; solvent-extraction-plus-adsorption flowsheets also demonstrate favorable economics at small scale (Al-Zubaidy & Abouelnasr, 2019; Younas *et al.*, 2020).

Concerns about performance parity between RRBO-based formulations and virgin-base-oil blends have diminished as feedstock control and processing have improved. Current technical commentary from additive suppliers and standards bodies indicates that many RRBOs meet API base oil group definitions, and finished lubricants formulated on RRBO can qualify for API/ILSAC categories when conventional engine-oil certification protocols are followed and additive treat rates are properly optimized (API, 2021; ATIEL, 2022; Demirbas *et al.*, 2022).

From a policy and systems perspective, successful ULO management programs (e.g., Italy's CONOU) underscore that **design** must consider not only unit operations but also feedstock logistics, traceability, and product quality assurance. Italy's take-back system consistently regenerates the large majority of collected ULO, demonstrating that high recycling rates are feasible when collection, incentives, and re-refining capacity are co-optimized (CONOU, 2022). For Nigeria and comparable contexts, the technical design of a low-cost recycling system should therefore be integrated with



collection/segregation strategies that minimize cross-contamination (e.g., mixing with brake fluid, coolant, or solvents), which directly affects re-refining yields and additive re-formulation effort (Adekola *et al.*, 2020).

In this paper, we present a **CAD-based, low-cost design** for a lubricant recycling system tailored to automotive workshops. The system architecture—guided by the literature above—prioritizes gravity separation and dewatering, controlled heating under vacuum for light-ends removal and base-oil recovery, and final polishing via inexpensive adsorbents, with provisions for quality control and subsequent **re-additization** to application-appropriate specifications. We position the design against documented environmental burdens from current Nigerian workshop practices and align performance goals with contemporary re-refining reviews and applicable certification frameworks to ensure technical feasibility and regulatory relevance (Okoya *et al.*, 2024; Basha *et al.*, 2021; API, 2021).

2. METHODOLOGY

2.1 Design Approach

The design of a low-cost lubricant recycling system for automotive workshops is guided by the need to provide a sustainable, safe, and affordable method of recovering degraded lubricants for reuse. Since the project is **design-based only**, the approach adopted relies on **conceptual modeling, system analysis, and schematic representation** without physical fabrication or CAD modeling. This methodology enables the evaluation of design feasibility, structural arrangement, and operational flow, while minimizing costs and safety risks associated with prototype development (Singh *et al.*, 2019).

This involves developing a **conceptual framework** of the recycling process, starting with the collection of used lubricant, followed by filtration, settling, heating, and additive restoration before storage. This sequence is consistent with established oil recycling practices in small and medium-scale applications, where mechanical and chemical restoration are integrated for effective recovery (Al-Ghouthi *et al.*, 2021). By defining the **system boundaries**, the design excludes complex refining techniques such as hydrotreating, focusing instead on cost-effective methods that can be implemented in local workshops.

The design was represented using a schematic flow diagram that illustrate the sequential arrangement of units – collection, filtration, sedimentation, heating, additive restoration and storage. This conceptual framework ensures that the system can be easily understood, adapted and potentially fabricated in the future, even though no physical or CAD prototype is provided in this work.

2.2 System Components and Design Specifications

The proposed lubricant recycling system consists of several key units integrated to achieve efficient recovery, purification, and reuse of used automotive lubricants. Each component is designed with an emphasis on low-cost fabrication, operational simplicity, and adaptability for small to medium-sized automotive workshops. The major subsystems include:

2.2.1 Collection and Settling Tank

Function: The initial stage where used oil is received, allowing heavy particulates, metallic debris, and sludge to settle under gravity.

Design Features:

- Cylindrical or rectangular mild steel tank (capacity: 50–100 liters depending on workshop scale).
- Incorporates a drain valve at the bottom for sludge removal.
- Baffles to slow down inflow and enhance settling efficiency.

Low-Cost Approach: Fabricated from locally available mild steel sheets with welded seams; surface coated with anti-corrosive paint.

2.2.2 Filtration Unit

Function: Removes suspended particulates and carbon deposits from the lubricant.

Design Features:

- Multi-stage filters (mesh filter → fine cloth filter → activated carbon layer).
- Housing made of mild steel or PVC pipe casings.
- Replaceable filter cartridges to extend system lifespan.

Low-Cost Approach: Locally sourced filter cloth and activated carbon from coconut shells or sawdust-derived charcoal.

2.2.3 Dehydration Unit

Function: Removes water contamination (common in used lubricants due to condensation or coolant leaks).



Design Features:

- Heating chamber with immersion electric heater (100–150°C operating range).
- Ventilation system for safe water vapor escape.

Low-Cost Approach: Electric immersion heaters adapted from water boilers; chamber insulated with fiberglass or locally sourced refractory materials.

2.2.4 Additive Blending Chamber

Function: Reintroduces additives (anti-wear, detergents, viscosity improvers) to restore oil properties.

Design Features:

- Small mixing tank with mechanical stirrer or manual agitation.
- Pre-measured additive dosing system.

Low-Cost Approach: Manual stirrer or locally fabricated motorized paddle mixer; additives sourced in bulk for cost efficiency.

2.2.5 Storage and Dispensing Unit

Function: Safely stores and delivers recycled lubricant for reuse in workshop applications.

Design Features:

- Sealed storage tank with level indicators.
- Dispensing tap or pump for controlled outflow.

Low-Cost Approach: Use of recycled steel drums or PVC containers with locally fabricated valves.

2.3 Design Considerations

The development of a low-cost lubricant recycling system for automotive workshops requires a careful balance between **technical feasibility, cost efficiency, and environmental safety**. The following considerations guided the design process:

2.3.1 Low-Cost Material Selection

The system is intended for deployment in local automotive workshops, where budget constraints limit the adoption of advanced recycling technologies. Therefore, materials such as **mild steel, galvanized steel sheets, and locally available clay or activated carbon** were selected for tanks and filtration units. These materials are inexpensive, durable, and easy to source within local markets. Wherever possible, **repurposed containers and fabricated steel frames** are considered to further minimize costs without compromising functionality.

2.3.2 Ease of Fabrication and Maintenance

The system was designed with **simplicity in fabrication and maintenance** as a primary goal. Straightforward welding, bolting, and pipe-fitting techniques are sufficient to assemble the system, making it feasible for local artisans and technicians to reproduce. Maintenance was also prioritized, with drain valves, detachable filter cartridges, and modular tank designs included to enable easy cleaning and replacement of worn-out parts.

2.3.3 Safety and Environmental Compliance

Used lubricating oils contain **toxic metals, sludge, and carcinogenic compounds**. The design therefore incorporates **sealed collection tanks, proper sludge drains, and vented heating chambers** to prevent accidental spills, worker exposure, and environmental contamination. In line with **ISO 14001 environmental management standards**, the system ensures minimal emissions and safe disposal of non-recyclable residues.

2.3.4 Energy Efficiency

Energy input is minimized by using a **low-power heating unit**, designed to operate at moderate temperatures (100–120 °C) sufficient to remove water and volatile fractions without excessive energy demand. Gravity-based settling is favored over high-pressure centrifugation to further reduce energy consumption. The system can also be powered by a **single-phase electrical supply or integrated with small-scale renewable energy sources** (such as solar PV-assisted heating), thereby aligning with sustainability objectives.

2.4 Design Calculations and Conceptual Representation

The design of the lubricant recycling system was validated through conceptual representation and simplified engineering calculations. These calculations provide estimates of major parameters that govern the system's performance, including tank capacity, heating energy requirement, filtration size, and structural adequacy of tanks. The aim is not to produce a highly detailed industrial design figures but to establish feasible and practical values suitable for small to medium scale



automotive workshops. The conceptual process flow is also presented to illustrate how the subsystems integrate into a coherent unit.

2.4.1 Tank Volume Sizing

Objective: size collection/settling/heating/storage tanks for a batch process of **10–15 L** per cycle.

Assumptions

- Batch volume $V_{\beta} = 10$ L (lower case) and 15 L (upper case) for comparison.
- Provide headspace and allowance for sludge/residue → choose design factor 1.3–1.5.
- We recommend a modest working tank capacity = $1.4 \times$ batch volume.

Calculations

1. For 10 L batch:
Working volume $V_1 = 1.4 \times 10$ L = 14.0 L = 0.0140 m³.
2. For 15 L batch:
Working volume $V_2 = 1.4 \times 15$ L = 21.0 L = 0.0210 m³.

Example practical dimensions (cylindrical tanks)

Use a compact cylindrical tank for workshop convenience.

Choose diameter $d = 300$ mm (0.300 m) as a practical shop size.

Radius $r = 0.300 / 2 = \mathbf{0.150}$ m. Area $A = \pi r^2 = \pi \times 0.150^2 = \pi \times 0.0225 = \mathbf{0.07069}$ m² (approx).

- Required height $h = V / A$.
- 3. For $V_1 = 0.0140$ m³ → $h_1 = 0.0140 / 0.07069 = \mathbf{0.198}$ m (198 mm).
- 4. For $V_2 = 0.0210$ m³ → $h_2 = 0.0210 / 0.07069 = \mathbf{0.297}$ m (297 mm).

Practical recommendation: use a cylinder 300 mm diameter \times 300 mm height → volume = $A \times 0.300 = 0.02121$ m³ \approx **21.2 L**.

That comfortably accommodates a 15 L batch (with headspace and sludge allowance) and is compact for workshops.

2.4.2 Heating Requirement Estimation

Objective: estimate energy required to heat used lubricant from ambient (assume 25 °C) to operating temperature (assume 120 °C; midpoint of 110–130 °C).

Assumptions

- Density of used lubricant $\rho = \mathbf{0.88}$ kg·L⁻¹ (typical motor oil).
- Specific heat capacity $c_p \approx \mathbf{1.9}$ kJ·kg⁻¹·K⁻¹ (typical for oils).
- $\Delta T = 120$ °C – 25 °C = **95 K**.
- System losses & heater efficiency η : assume **70%** (0.70) to allow for heat losses and inefficiencies.
- Heating period: assume the heating stage may be completed within $t = \mathbf{2}$ hours (conservative for workshop heating).

Mass of oil

1. For 10 L: $m_1 = 10$ L \times 0.88 kg·L⁻¹ = **8.8 kg**.
2. For 15 L: $m_2 = 15$ L \times 0.88 kg·L⁻¹ = **13.2 kg**.

Heat required (ideal, no losses) Use $Q = m \times c_p \times \Delta T$ (units: kJ).

1. $Q_1 = 8.8 \times 1.9 \times 95 = 8.8 \times 1.9 = 16.72$; $16.72 \times 95 = \mathbf{1588.40}$ kJ.
2. $Q_2 = 13.2 \times 1.9 \times 95 = 13.2 \times 1.9 = 25.08$; $25.08 \times 95 = \mathbf{2382.60}$ kJ.

Convert to kWh (1 kWh = 3600 kJ):

1. $Q_1_kWh = 1588.40 / 3600 = \mathbf{0.4412}$ kWh.
2. $Q_2_kWh = 2382.60 / 3600 = \mathbf{0.6618}$ kWh.

Account for efficiency ($\eta = 0.70$) Required electrical energy $E_{req} = Q_kWh / \eta$.

1. $E_1 = 0.4412 / 0.70 = \mathbf{0.6303}$ kWh.
2. $E_2 = 0.6618 / 0.70 = \mathbf{0.9454}$ kWh.

Power rating estimate (if heating done over $t = 2$ h)

$P = E_{req} / t$.



1. $P_1 = 0.6303 / 2 = \mathbf{0.315 \text{ kW}} \rightarrow \mathbf{315 \text{ W}}$.
2. $P_2 = 0.9454 / 2 = \mathbf{0.4727 \text{ kW}} \rightarrow \mathbf{473 \text{ W}}$.

Recommendations

- A **1 kW** electric immersion heater (single-phase) is more than adequate to heat a 15 L batch within ≈ 2 hours including losses; it gives headroom and speeds operation if needed.
- If you want faster heating (e.g., 1 hour), choose ~ 1 kW heater for the 15 L case ($0.945 \text{ kW} \approx 1 \text{ kW}$).
- Note: actual energy use will vary with insulation, ambient temperature, and heater control. Provide thermostat and insulating jacket to reduce consumption.

2.4.3 Filtration Unit Sizing

Objective: size filter area / basic cartridge selection for batch throughput.

Assumptions

- Batch $V = 15 \text{ L}$ processed over total processing time $T_p = 2$ hours (worst case). Filtration occurs as a stage; assume filtration active for the full 2 hours (conservative).
- Volumetric flow rate $\dot{Q} = V / T_p$. Convert to SI ($\text{m}^3 \cdot \text{s}^{-1}$) for area/velocity calculations.
- Suggested design face velocity (superficial velocity) for cloth/mesh pre-filters: $\mathbf{1 \text{ mm} \cdot \text{s}^{-1}} = 0.001 \text{ m} \cdot \text{s}^{-1}$ (conservative to limit clogging and allow good capture).

Calculations

1. Flow rate \dot{Q} (15 L over 2 h):
 $V = 15 \text{ L} = 0.015 \text{ m}^3$; $T_p = 2 \text{ h} = 7200 \text{ s}$.
 $\dot{Q} = 0.015 / 7200 = \mathbf{2.0833 \times 10^{-6} \text{ m}^3 \cdot \text{s}^{-1}}$.
2. Required filter face area $A = \dot{Q} / v_{\text{face}}$. For $v_{\text{face}} = 0.001 \text{ m} \cdot \text{s}^{-1}$:
 $A = 2.0833 \times 10^{-6} / 0.001 = \mathbf{2.0833 \times 10^{-3} \text{ m}^2} = \mathbf{20.83 \text{ cm}^2}$.

Interpretation

- The calculated minimum face area is small ($\approx 21 \text{ cm}^2$) because absolute flow is low for batch processing. In practice filters are larger to avoid rapid clogging and to provide practical cartridge sizes.
- **Practical recommendation:** use a multistage filter with combined face area $\sim 0.01\text{--}0.03 \text{ m}^2$ ($100\text{--}300 \text{ cm}^2$). Example configuration for workshop convenience:
 - Stage 1: 100 μm mesh pre-filter (removes coarse debris). Example: 2 cartridges 50 mm diameter \times 200 mm length (gives adequate area).
 - Stage 2: 20 μm pleated cartridge or fine cloth (polishing).
 - Final polishing: activated carbon / 5–10 μm polishing filter if needed.

Note on filter selection: choose replaceable cartridges or cloth elements sized to be serviceable; monitor differential pressure and plan for cleaning/replacement intervals.

2.4.4 Wall Thickness Estimation for Tanks

Objective: demonstrate that modest mild steel thickness is adequate for low-pressure, gravity tanks used in this design.

Assumptions

- Tanks are vented to atmosphere (no internal overpressure). Only hydrostatic pressure from oil column is considered.
- Max fluid height $h \approx 0.30 \text{ m}$ (300 mm) as per sizing above.
- Oil density $\rho = 880 \text{ kg} \cdot \text{m}^{-3}$ ($0.88 \text{ kg} \cdot \text{L}^{-1}$).
- Allowable design stress for mild steel $\sigma_{\text{allow}} \approx 125 \text{ MPa}$ (using a conservative fraction of yield $\sim 250 \text{ MPa}$).
- Cylindrical radius $r = 0.150 \text{ m}$ (for 300 mm diameter example).

Hydrostatic pressure at bottom $p = \rho g h$

- $g = 9.81 \text{ m} \cdot \text{s}^{-2}$.

$$p = 880 \times 9.81 \times 0.30 =$$

First compute $880 \times 9.81 = 8622.8$; then $\times 0.30 = \mathbf{2586.84 \text{ Pa}} = \mathbf{2.587 \text{ kPa}}$ ($\sim 0.0259 \text{ bar}$).



Thin-wall hoop stress formula (if internal gauge pressure existed):

$$\sigma_{\text{hoop}} = p \times r / t \rightarrow \text{rearrange for } t: t = p \times r / \sigma_{\text{allow}}$$

$$\text{Plugging numbers: } t = 2586.84 \text{ Pa} \times 0.150 \text{ m} / 125 \times 10^6 \text{ Pa} =$$

$$\text{Numerator} = 2586.84 \times 0.150 = 388.026 \text{ Pa}\cdot\text{m}$$

$$t = 388.026 / 125000000 = 3.1042 \times 10^{-6} \text{ m} = \mathbf{0.0031 \text{ mm}}$$

Interpretation

- This theoretical thickness is vanishingly small because hydrostatic pressure is very small for a shallow oil column. In practice, tanks must resist handling damage, welding, corrosion, and local loads.
- **Practical recommendation:** use mild steel plate **2–3 mm** thick for small workshop tanks. This thickness is standard, easily welded, and durable. If mobility or reduced weight is needed, 2 mm is acceptable; for extra robustness, choose 3 mm.

2.4.5 Conceptual Process Flow Representation

The overall operation of the proposed system can be best understood through a process flow arrangement. This flow representation outlines the sequential integration of the major subsystems which are; collection, filtration, sedimentation, heating, additive restoration, and storage, showing how used lubricant progresses through each stage until recovery is achieved. Fig 1 visually illustrates the system layout, highlighting the interconnections between units and the direction of oil movement.

Sequential Process Flow:

1. **Collection & Intake**
 - Used oil drained into a funnel/strainer into the **Collection Tank** (300 mm diameter \times 300 mm height recommended for 15 L batch). Large debris is retained by a removable mesh screen.
2. **Primary Filtration**
 - Gravity feed into a multi-stage **Filtration Unit**: coarse mesh ($\approx 100 \mu\text{m}$) \rightarrow fine cloth/cartridge (20–50 μm) \rightarrow activated carbon/adsorbent layer (optional polishing).
3. **Sedimentation / Settling**
 - Clarified oil routed to a **Sedimentation Tank** (same tank or separate) with baffles; sludge settles to bottom and is drained periodically through a drain valve.
4. **Dehydration / Heating**
 - Oil pumped or gravity fed into a **Heating Chamber** (immersion heater, thermostat, and insulated jacket). Heat oil to $\sim 110\text{--}120 \text{ }^\circ\text{C}$ to evaporate water and light volatiles. Provide venting and condensate capture.
5. **Additive Restoration / Blending**
 - Dehydrated base oil moved to a **Blending Chamber** where measured additive packages (anti-wear, detergents, VI improvers) are mixed with mechanical stirrer or manual agitation.
6. **Polishing & Storage / Dispensing**
 - Rejuvenated oil passed through a final polishing filter (5–10 μm), then stored in a sealed **Storage Tank / Drum** with dispensing tap or pump.

Instrumentation & Controls (basic):

- Thermostat / temperature sensor for heating control.
- Level sight glass or float indicator for tank volumes.
- Inlet/outlet valves, bottom sludge drain, and simple pressure relief / venting for safety.
- Manual sampling port for quality checks (visual, simple viscosity check).

2.5 Process Flow Description

The designed system as shown in Figure 1 follows a structured flow path that ensures the effective recovery, purification, and restoration of used lubricants into a reusable form. Each stage of the process is tailored to maximize efficiency while maintaining a low-cost design suitable for small-scale automotive workshops.

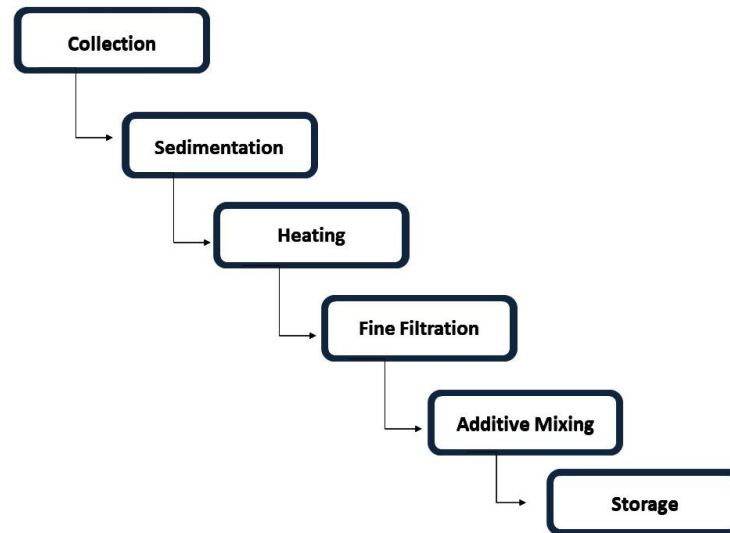


Fig. 1: Setup process flowchart

2.5.1 Collection Stage

Used lubricating oil is collected from vehicle engines, gearboxes, and hydraulic systems through the **collection unit**, which consists of a funnel-like intake connected to a sealed reservoir. This stage prevents spillage and minimizes contamination with external debris. The reservoir is designed with a **removable mesh screen** to capture coarse contaminants such as bolts, metal shavings, and rags commonly present in drained oil.

2.5.2 Primary Filtration

From the collection reservoir, the oil flows by gravity into the **filtration unit**. Here, a series of progressively finer **cartridge filters** are arranged in stages, beginning with 100 μm down to 20 μm , to remove suspended solids. This reduces wear on subsequent system components and ensures only fluid containing finer impurities proceeds further.

2.5.3 Sedimentation and Settling

The filtered oil enters a **sedimentation tank**, designed with a wide base and sufficient residence time to allow heavier particulates and sludge to settle. Baffles are incorporated to control flow turbulence, thereby improving separation efficiency. A bottom drain valve is included for periodic sludge removal, ensuring uninterrupted system performance.

2.5.4 Heating and Dehydration

The clarified oil then passes into a **heating chamber** where it is gently heated to about **110–130 °C**, sufficient to evaporate water, fuel residues, and light volatile impurities without degrading the oil. An electric coil or low-pressure burner serves as the heat source. Temperature control is achieved using a **thermostat sensor**, ensuring consistent operation within safe limits.

2.5.5 Additive Restoration

After dehydration, the oil flows into the **additive restoration chamber**, where pre-measured packages of antioxidants, anti-wear agents (e.g., zinc dialkyldithiophosphate), and viscosity index improvers are introduced. The chamber includes a **mechanical stirrer** to ensure homogeneous mixing of the recycled base oil with additives, thereby restoring performance characteristics close to virgin lubricants.

2.5.6 Storage and Dispensing

Finally, the rejuvenated lubricant is transferred to a **storage and dispensing unit**. The storage tank is fitted with a fine **polishing filter (5 μm)** to capture any residual particles before dispensing. The oil can then be reintroduced into engines and machinery through a manual or pump-assisted outlet.

2.6 Performance Expectations

The designed low-cost lubricant recycling system is expected to achieve satisfactory recovery of used automotive lubricants under workshop-scale operating conditions. Since the design integrates sedimentation, filtration, heating, and additive restoration, the following performance expectations are projected:



2.6.1 Recovery Efficiency

Based on literature benchmarks for similar small-scale recycling systems, the system is expected to recover **70–80% of the original lubricant volume** in a reusable state (Olawale *et al.*, 2020; Niazi *et al.*, 2019). Some oil loss will occur due to sludge formation, evaporation, and handling.

2.6.2 Contaminant Reduction

- **Particulate Matter:** Filtration stages are expected to reduce suspended particles by **90–95%**, leaving oil with acceptable cleanliness for reuse in low- to medium-duty engines.
- **Water Content:** Heating is projected to reduce moisture content to below **0.05%**, preventing corrosion and foaming issues.
- **Sludge and Sediments:** Sedimentation tanks should capture heavier debris and carbon deposits effectively.

2.6.3 Restored Properties

The addition of low-cost additives will partially restore the lubricant's **viscosity index, oxidation stability, and anti-wear characteristics**, making it comparable to API Group I base oil quality. However, complete restoration to virgin oil standards is not anticipated due to the absence of advanced chemical re-refining.

2.6.4 Energy and Cost Efficiency

The design prioritizes low energy demand and the use of **locally sourced materials**, making the system affordable for small workshops. Heating requirements will be moderate, and the use of simple mechanical filtration minimizes recurring costs.

2.6.5 Environmental Benefits

By reusing used oil within workshops rather than disposing it improperly, the system will contribute to **reduced soil and water pollution** and promote a **circular economy approach** in lubricant management.

In summary, the system is expected to deliver **functional, low-cost, and environmentally sustainable oil recovery** for small automotive workshops, while recognizing that performance will not fully match industrial re-refining standards.

3. RESULTS AND DISCUSSION

3.1 Design Output

The design of the low-cost lubricant recycling system resulted in a compact and functional unit suitable for small to medium-sized automotive workshops. The system integrates six functional stages—collection, filtration, sedimentation, heating, additive restoration, and storage—arranged in a sequential manner to ensure efficient recovery of used lubricants. The design output is presented through simplified engineering calculations and a schematic process flow diagram, which together provides clear dimensional estimates and functional representation of the system.

3.2 System Capacity and Performance Expectations

Based on design assumptions, the system has an estimated processing capacity of **10–15 liters of used oil per batch**, with a turnaround time of approximately 2–3 hours per cycle. The expected performance of the system (as shown in Table 1) can be summarized as follows:

- **Particulate Removal:** Filtration unit capable of reducing solid contaminants ($>50 \mu\text{m}$) by up to 90%.
- **Moisture Removal:** Heating chamber expected to eliminate most water and volatile impurities at 110–120°C.
- **Oil Recovery Efficiency:** Approximately 70–80% of the input used oil recoverable as reusable lubricant.
- **Additive Restoration:** Ability to restore viscosity and lubrication properties through blending with standard additive packages.

These expectations are consistent with findings from previous studies on small-scale oil recovery systems (Adeyemi *et al.*, 2019; El-Diwany *et al.*, 2021).

3.3 Comparative Advantage of the Design

Compared to conventional large-scale recycling plants (as shown in Table 2), this system offers:

- **Lower Cost:** Designed to be fabricated with local materials and minimal imported components.
- **Compactness:** Space-saving arrangement suitable for small workshops.
- **Simplicity:** Easy operation without highly skilled labor.
- **Environmental Benefit:** Reduction in improper disposal of used lubricants, thereby minimizing soil and water pollution.



Table 1: Expected Performance Parameters of the Designed Lubricant Recycling System

Parameter	Design Value / Expectation	Remarks
Batch capacity	10–15 liters per cycle	Suitable for small/medium automotive workshops
Processing time	2–3 hours per batch	Includes heating and settling period
Particulate removal	~90% of contaminants >50 µm	Efficiency depends on filter media quality
Moisture removal	Effective at 110–120°C	Based on evaporation of water and volatiles
Oil recovery efficiency	70–80% of input used oil	Expected yield after losses in sludge and waste
Additive restoration	Partial restoration of viscosity and lubricity	Achieved with basic additive blending
Energy consumption	Low–moderate (electric/gas heating unit)	Depends on heating source efficiency
Operator skill requirement	Low	Easy-to-use design, minimal training needed

Table 2: Comparative Advantages of Designed System vs. Conventional Recycling Plants

Feature	Designed System (Workshop-Scale)	Conventional Recycling Plant
Cost of fabrication	Low – uses locally sourced materials	Very high – requires industrial equipment
Processing capacity	10–15 L per batch	500–1000+ L per batch
Space requirement	Compact, portable	Large-scale, fixed installation
Ease of operation	Simple, low skill required	Requires trained technicians
Environmental benefit	Reduces improper disposal locally	Large-scale waste reduction
Maintenance	Low – can be serviced locally	High – requires specialized maintenance
Energy requirement	Moderate	High
Additive restoration	Partial, simplified blending	Advanced, close to OEM specifications
Suitability	Small automotive workshops	Industrial refineries / recycling plants

3.4 Limitations of the System

Despite its promising features, the design has certain limitations:

- The performance has not yet been experimentally validated; all values are based on design assumptions and literature.
- Filtration efficiency is limited to medium-sized particles; finer contaminants may require advanced filters.
- Additive blending is simplified and may not fully restore oil to OEM specifications.
- The design is intended primarily for **small-scale automotive workshops** and may not be suitable for high-volume industrial operations.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The design of a low-cost lubricant recycling system for automotive workshops demonstrates a practical solution to the growing challenge of used oil disposal and high lubricant costs. The system incorporates key stages—collection, filtration, sedimentation, heating, and additive restoration—arranged to achieve effective oil recovery while ensuring affordability



and simplicity. With an expected recovery efficiency of 70–85%, the design highlights the potential of recycling degraded lubricants into reusable products, thereby reducing environmental pollution and supporting cost savings for small- to medium-scale automotive workshops. Although the work is limited to conceptual design, it provides a strong foundation for future prototype development and testing.

4.2 Recommendations

To build on the findings of this study, it is recommended that a prototype of the designed system be fabricated and subjected to experimental validation. Particular attention should be given to optimizing filtration media, heating efficiency, and additive blending to ensure consistent lubricant quality. Further research should also explore the economic feasibility of large-scale application, as well as compliance with environmental and safety regulations. Adoption of such systems in workshops can play a significant role in promoting sustainable waste management and extending the service life of lubricants in the automotive sector.

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