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The Environmental and Socio-Economic Imperative for Waste Lubricating Oil Re-Refining in Developing Economies: A Case Study of Nigeria

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ABSTRACT: The exponential growth in motorized transport and industrial machinery has led to a significant rise in the consumption of lubricating oils globally, with developing nations such as Nigeria contributing substantially. As lubricating oils reach the end of their service life, they transform into hazardous waste lubricating oils (WLOs), posing significant threats to the environment and public health when improperly disposed. The rapid industrialization and urbanization of developing economies have precipitated a surge in lubricant consumption, generating substantial volumes of hazardous waste lubricating oil (WLO). This study examines Nigeria as a critical case study, where 287.465 million liters of WLO are projected for 2025 amidst inadequate management infrastructure. Annually, approximately 35 million metric tons of lubricants are consumed worldwide, with about 17.5 million metric tons returning as waste. Through integrated analysis of environmental science, circular economy principles, and policy frameworks, we demonstrate that WLO re-refining presents a triple-win solution: mitigating severe ecological contamination, reducing dependence on imported base oils, and unlocking significant socio-economic value. Our findings reveal that implementing re-refining could satisfy 40% of Nigeria's lubricant base oil demand, create jobs, reduce CO_2 emissions by 1.8 million tons annually, and contribute to GDP growth. We propose a phased implementation roadmap integrating technology selection, policy incentives, and stakeholder collaboration, providing a transferable model for resource constrained economies grappling with hazardous waste management.

It explores the environmental consequences of indiscriminate disposal, highlights the potential of re-refining as a circular economy strategy, and evaluates the opportunities for energy savings, economic diversification, job creation, and import substitution. The paper also compares Nigeria’s current policies with global best practices and proposes a framework for sustainable WLO management, emphasizing the need for investment, regulation, and awareness to transform waste into wealth.

KEYWORDS: Waste Lubricating Oil, Re-refining, Circular Economy, Environmental Pollution, Socio-Economic Development, Sustainable Development Goals, Resource Conservation, Import Dependence. Hazardous waste management.

INTRODUCTION

Lubricating oils are essential for reducing friction and wear in automotive and industrial machinery, but their disposal after use presents significant environmental challenges. In Nigeria, a major oil-producing nation, the generation of waste lubricating oil (WLO) is substantial due to widespread vehicle and industrial activities. Improper disposal of WLO, such as dumping into water bodies or soil, leads to soil contamination, water pollution, and health risks from toxic compounds like polycyclic aromatic hydrocarbons (PAHs) and heavy metals.

The global industrial landscape is characterized by an ever-increasing demand for lubricants, essential for the smooth operation and maintenance of machinery across diverse sectors, from automotive and manufacturing to power generation and aviation. The annual global requirement for lubricating oil is approximately 35 million metric tons, a market valued at over $142 billion, projected to grow to over $206 billion by 2032 with a Compound Annual Growth Rate (CAGR) of 4.30% (Statista et al., 2023). This robust demand, particularly propelled by rapid industrialization and urbanization in emerging markets, inevitably leads to a significant generation of waste lubricating oil (WLO). It is estimated that about 50% of consumed lubricating oil, equating to roughly 17.5 million metric tons globally, is returned as waste annually (Mohammed et al., 2013).

The management of this colossal volume of WLO poses a formidable global challenge. Historically, the linear "take-make-dispose" model of resource utilization has dominated, leading to resource depletion and widespread environmental degradation. WLO, a complex mixture of base oil, water, sludge, worn metals, and oxidation compounds, accumulates hazardous substances such as heavy metals (e.g., lead, cadmium, chromium, arsenic, zinc, copper, sulfur) and toxic organic compounds (e.g., polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), benzene, chlorinated solvents) during its lifecycle (Emam and Shoaib, 2013; Kashif et al., 2018; Saleem and Karim, 2020).

Indiscriminate disposal of WLO, a common practice in many developing nations, results in severe contamination of water bodies, soil, and air, with profound adverse effects on ecosystems and human health. A single volume of WLO, for instance, can contaminate at least 250,000 volumes of water, highlighting its potent mutagenic potential in aquatic environments (Saleem and Karim, 2020; Bridjanian and Sattarin, 2006).

In response to these pressing environmental and resource concerns, a paradigm shift towards a circular economy approach in WLO management has become imperative. Re-refining emerges as a direct and potent solution, embodying the core tenets of sustainability by transforming a hazardous waste into a valuable resource. This process not only mitigates widespread environmental pollution but also conserves finite crude oil resources, requiring significantly less energy than producing virgin base oil (Speight & Exall, 2014).

This research delves into the critical environmental and socio-economic imperative for waste lubricating oil re-refining, with a particular focus on Nigeria as a compelling case study. It aims to provide a comprehensive analysis of the challenges posed by WLO in a developing economy context, the transformative benefits of re-refining, its alignment with global sustainable development goals, and the policy and practical considerations for its successful implementation and scaling up.

The Escalating Problem of Waste Lubricating Oil in Developing Economies

WLO is classified as a hazardous waste due to its content of heavy metals (e.g., lead, cadmium), sulfur, chlorine, and PAHs, which are harmful to human health and the environment. In Nigeria, the lack of adequate waste management infrastructure exacerbates the problem, with WLO often disposed of in open dumps, rivers, or burned, releasing toxic pollutants into the air and soil. For instance, improper disposal in Kaduna Metropolis has been linked to soil degradation and groundwater contamination, threatening agricultural productivity and public health. The Niger Delta region, a hub for oil-related activities, faces additional challenges from WLO pollution, compounding the environmental degradation caused by crude oil spills. These practices contribute to biodiversity loss, reduced soil fertility, and increased health risks, including respiratory issues and cancer, particularly in communities near disposal sites.

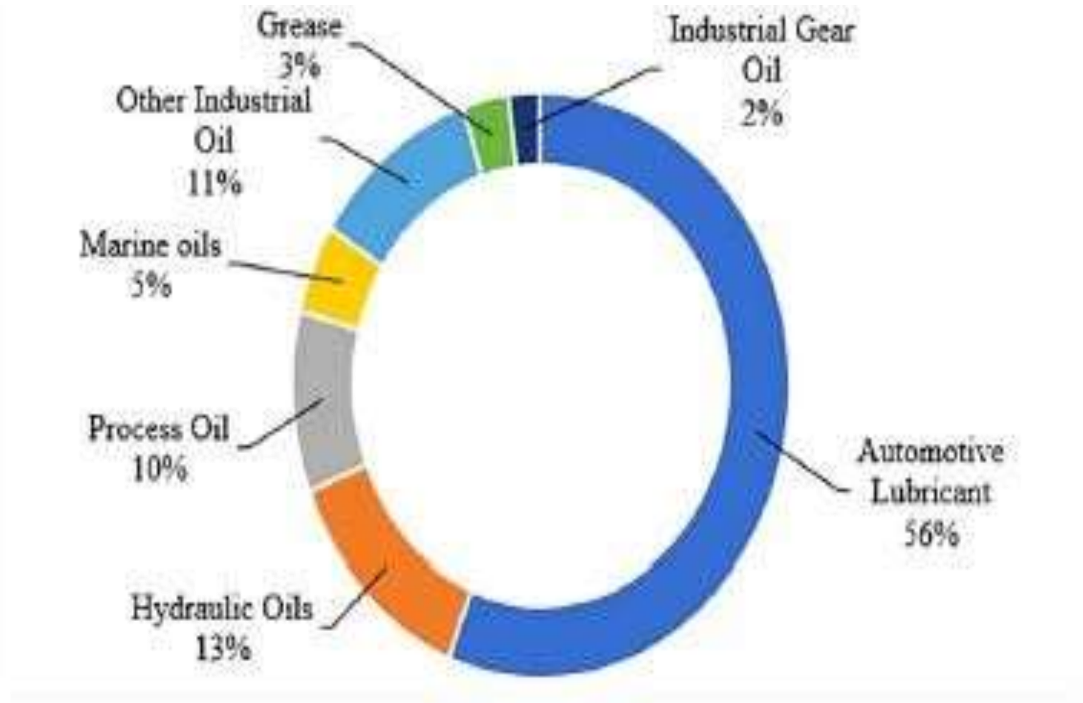

Figure 1.1: Percentage contribution of used lubricant oil (Sazzard et al. 2024)

Nigeria, as Africa's most populous nation and a rapidly industrializing economy, exemplifies this escalating challenge. Its lubricant market is estimated at 574.93 million liters in 2025, with an anticipated increase to 695.80 million liters by 2030, at a CAGR of 3.89% within the 2025-2030 forecast interval. The automotive sector, particularly commercial vehicles and motorcycles, drives significant lubricant consumption due to a large fleet of used vehicles requiring frequent maintenance and the growth in freight transportation and logistics. The country's per capita income, while showing limited upward movement, contributes to a growing consumer base for vehicles, further fueling lubricant demand.

Based on the general observation that 50% of lubricating oil is returned as waste, Nigeria is estimated to generate approximately 287.465 million liters of WLO in 2025 alone

(Mohammed et al., 2013). This figure is alarming, especially when considering earlier estimates from 2004, which projected a total national used oil generating capacity of over 200 million liters per annum, with over 75% from used crankcase engine oil. The sheer volume of WLO generated annually, coupled with a critical absence of organized WLO collection, storage, and recycling procedures, means that a significant portion of this waste finds its way directly into the environment (Bamiro and Osibanjo, 2004). This lack of infrastructure and policy is the root cause of widespread environmental contamination.

In contrast to countries like the USA, Australia, Saudi Arabia, and European Union Member States, where re-refining has become a crucial industry with an estimated 400 oil re-refineries worldwide, Nigeria currently has no commercial WLO re-refining plants (Kupareva et al., 2013a; Giovanna et al., 2003; Nixon and Saphores, 2002). This stark difference highlights a significant gap in Nigeria's waste management strategy. The epileptic operation of domestic refineries further exacerbates the problem, leading to a heavy reliance on the importation of virgin lubricating base oil and additives for local blending plants (Bamiro and Osibanjo, 2004; Sasu, 2023). This overdependence not only creates a substantial economic burden but also means there is a critical lack of an alternative, internal source for lubricating base oil production, hindering the nation's economic independence.

Environmental Consequences of Indiscriminate Disposal

The indiscriminate disposal of WLO in Nigeria leads to severe environmental contamination through multiple pathways, posing significant threats to both ecosystems and human health. WLO is not merely a spent product; it is a complex and hazardous mixture that accumulates a range of toxic and carcinogenic substances during its operational life (Speight and Exall, 2014).

- **Composition and Hazardous Nature of Waste Lubricating Oil**

Waste lubricating oil consists of a blend of base oil, water, sludge, worn metals, and compounds from oxidation reactions in the lubricating oil (Emam and Shoaib, 2013; Kashif et al., 2018; Saleem and Karim, 2020). During its lifecycle, lubricating oil picks up heavy metals like lead (Pb), cadmium (Cd), chromium (Cr), arsenic (As), zinc (Zn), copper (Cu), and sulfur (S). These metals originate from engine wear, fuel impurities, and additives. Beyond metallic contaminants, WLO can also contain harmful organic compounds like polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), benzene, and chlorinated solvents. These substances are inherently toxic, genotoxic, fetotoxic, and carcinogenic, making WLO a significant environmental and health hazard.

- **Pathways of Environmental Contamination**

The absence of organized WLO collection and recycling procedures in Nigeria means that a significant portion of this waste is disposed of indiscriminately, leading to widespread contamination (Bamiro and Osibanjo, 2004):

a. **Water Contamination:** When WLO is dumped indiscriminately, it infiltrates storm water drains, sewers, waterways, coastal waters, and landfills (Motshumi et al., 2013). From these points, it migrates into ground and surface water through percolation and leaching. The polluting potential is alarming: a single volume of WLO can contain at least

250,000 volumes of water, making it a significant mutagenic agent in aquatic environments. Contamination of groundwater is a particular concern, as it can render water sources unusable for drinking and other purposes. The formation of tiny films or sheens on water surfaces reduces oxygen penetration, leading to the suffocation and death of aquatic biota.

Figure 1.2: Indiscriminate waste lubricating oil disposal in a typical developing economy setting

b. **Soil Degradation:** Indiscriminate spraying of WLO on land, a common practice by autorepair artisans, leads to severe soil contamination. This can cause inactivity of microorganisms, poor aeration, and alter soil temperature, making it lethal to many plant species. Heavy metals in WLO can be retained in soils in various forms, and while some metals are micronutrients at low concentrations, high concentrations cause metabolic disorders and growth inhibition in plants. Studies in Nigeria have reported growth retardation in plants like tomato and pepper, and defective germination of spinach seeds in WLO-polluted soil (Anoliefo and Vwioko, 1995; Odjegba and Idowu, 2002).

c. **Air Pollution:** The uncontrolled combustion of WLO, often occurring without proper pretreatment to remove metallic contaminants, results in a substantial discharge of metals and unintentionally produced Persistent Organic Pollutants (POPs) like dioxins and furans into the atmosphere (Pinheiro et al., 2021.). This contributes significantly to air quality degradation, posing respiratory and other health risks.

• Impacts on Living Organisms and Human Health

The toxic and carcinogenic nature of WLO components directly impacts both living organisms in aquatic ecosystems and human health. Exposure can occur through ingestion of contaminated food or water, dermal contact, and inhalation of fumes.

a. **Human Health Impacts:** Chronic and acute exposure to WLO can cause severe health problems. It is carcinogenic, genotoxic, and fetotoxic. Exposure can impact immunological and reproductive systems, and damage vital organs such as kidneys, liver, heart, lungs, and the nervous system. Specific studies in Nigeria and related contexts have linked oil spills and exposure to hydrocarbons (including PAHs and benzo(a)pyrene) to increased prevalence of certain cancers, acute renal failure, hepatotoxicity, hemotoxicity, and infertility. Occupational exposure among automobile mechanics in Nigeria, who frequently handle WLO, is a significant concern. Many mechanics are unaware of the hazards of skin contact or inhalation. Direct contact can trigger allergic skin reactions or eye irritation, and long-term repeated contact increases the risk of skin cancer, haematological disorders, and increased blood pressure. Respiratory problems, coughing, and difficulty breathing have also been linked to air pollution near industrial sites in Nigeria.

b. **Ecological Impacts:** Beyond direct toxicity, WLO contamination can impair reproduction in fauna, damage intestinal tracts, and reduce fur insulation. The reduction of oxygen levels in water bodies due to oil films leads to the suffocation and death of aquatic life. The widespread contamination underscores the severe ripple effect stemming from the lack of effective WLO management.

The direct link between Nigeria's lack of organized WLO management and the subsequent widespread environmental contamination by toxic and carcinogenic compounds highlights an urgent need for intervention. This multi-stage causal chain, from inadequate policy to severe ecological and health consequences, makes the development of sustainable re-refining solutions a critical priority.

Economic Burden of Over-reliance on Imports and Limited Domestic Capacity

Nigeria's current approach to lubricant supply, characterized by a heavy reliance on imports and a nascent domestic re-refining sector, imposes significant economic burdens and vulnerabilities.

- **Overdependence on Imports and Capital Flight**

Nigeria's domestic refining capacity is severely hampered by epileptic operations, leading to a heavy reliance on the importation of virgin lubricating base oil and additives for local blending plants (Bamiro and Osibanjo, 2004). This overdependence on imports constitutes a significant economic burden, resulting in substantial capital flight from the country. The absence of a robust domestic re-refining industry means there is a critical lack of an alternative, internal source for lubricating base oil production, exacerbating the nation's import reliance and hindering its economic independence.

- **Impact on Local Industry and Job Security**

The influx of imported lubricants, particularly cheap, recycled, and adulterated products, poses a severe threat to Nigeria's local lubricant manufacturing industry. While local manufacturers currently produce only about 40% of Nigeria's total lubricant demand, the remaining 60% is met by imports. The Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA) has issued import permits to bridge this supply shortfall, but local producers, under the Lubricants Producers Association of Nigeria (LUPAN), argue that this policy enables unfair competition.

LUPAN claims that this policy is "killing" indigenous manufacturers, leading to significant financial losses (billions of Naira) and factory shutdowns. This directly jeopardizes job security, with warnings of jobs at stake. The unchecked influx of substandard finished products cripples domestic growth, despite Nigeria having more than enough installed capacity to meet national demand and even export. This situation creates a paradox where policies intended to address supply gaps inadvertently undermine local production and job creation, acting against the spirit of industrialization.

- **Limited Technical Expertise and Infrastructure**

Furthermore, Nigeria faces a notable knowledge gap and limited technical expertise in the re-refining of waste lubricating oil. This deficiency impedes the development of indigenous solutions and contributes to the ongoing economic challenges associated with lubricant supply. The lack of organized WLO collection and recycling procedures also reflects broader issues in waste management infrastructure and funding across Nigeria. Problems confronting efficient waste management include poor infrastructure, insufficient funding, dysfunctional legal and policy frameworks, and attitudinal behavior. These systemic issues collectively hinder the establishment and effective operation of a domestic WLO re-refining industry.

Transformative Socio-Economic Benefits of Waste Lubricating Oil Re-refining

The implementation of WLO re-refining technologies offers a transformative pathway for Nigeria, addressing both its environmental challenges and economic vulnerabilities. This approach aligns perfectly with the principles of a circular economy, which aims to design out waste and pollution, keep products and materials in use, and regenerate natural systems.

- **Job Creation and GDP Enhancement**

Establishing a domestic re-refining industry would create numerous job opportunities across the entire value chain. This includes direct employment in WLO collection, transportation, processing, plant operation, maintenance, and the distribution of re-refined products. Indirect jobs would also be generated in supporting industries, such as equipment manufacturing, chemical supply, and logistics. The study explicitly states that the re-refining process "will lead to job creation and improve the GDP of the nation".

Globally, the shift towards a circular economy, including waste management, is projected to generate significant economic value and new jobs. While specific figures for WLO re-refining in Nigeria are not yet quantified, the establishment of such an industry would undoubtedly contribute substantially to national Gross Domestic Product (GDP) by fostering a new industrial sector and promoting a circular economy approach to lubricant utilization.

- **Resource Conservation and Energy Efficiency**

Re-refining offers substantial environmental and economic advantages in terms of resource utilization. It remarkably requires only one-third of the energy needed to produce virgin base oil from crude oil (Speight & Exall, 2014). This energy efficiency translates into reduced operational costs and a smaller carbon footprint compared to producing new base oil or even turning waste oil into fuel. This efficiency directly contributes to the conservation of finite crude oil resources, which is crucial given that crude oil is a non-renewable resource whose extraction and consumption have significant environmental impacts. By extending the life cycle of resources and promoting material reuse, re-refining reduces the demand for new raw materials and helps extend the life of existing oil reserves, promoting long-term sustainability

- **Alternative Domestic Source and Enhanced Energy Security**

The development of re-refining capabilities provides a viable alternative source of lubricating base oil, significantly reducing Nigeria's dependence on imports. This is particularly vital for a nation that currently relies heavily on imported lubricants, leading to substantial capital flight. Studies suggest that Nigeria has the potential to produce at least 40% of its required lubricating base oil through WLO re-refining, unlocking considerable economic benefits and saving foreign exchange. Reducing reliance on imports enhances energy security and mitigates exposure to price volatility and geopolitical risks associated with global oil production. This internal production capacity would strengthen the national economy and foster greater self-sufficiency in a critical industrial input.

Alignment with Sustainable Development Goals (SDGs)

The strategic implementation of WLO re-refining technologies in Nigeria aligns directly and significantly with several United Nations Sustainable Development Goals (SDGs), elevating this industrial process to a strategic pillar for national sustainable development. This positioning demonstrates that investing in re-refining contributes to a holistic, internationally recognized framework for development, addressing environmental, economic, and social dimensions of sustainability.

- **SDG 8: Decent Work and Economic Growth:** The establishment of a domestic re-refining industry directly promotes sustained, inclusive, and sustainable economic growth and productive employment. By creating numerous job opportunities across the entire value chain, from WLO collection and transportation to processing, plant operation, maintenance, and the distribution of re-refined products, it contributes to full and productive employment and decent work for all. The enhancement of national GDP through the fostering of a new industrial sector further reinforces this alignment.
- **SDG 9: Industry, Innovation, and Infrastructure:** The development and adoption of re-refining technologies represent a significant advancement towards building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation within Nigeria. This initiative encourages companies to adopt sustainable practices and sustainability reporting, supporting the nation's scientific and technological capacity and promoting research and innovation.
- **SDG 10: Reduced Inequalities:** The economic benefits and job creation, particularly in a developing context like Nigeria, can contribute to reducing inequalities by providing opportunities for a broader segment of the population, including those in informal sectors involved in waste collection. By fostering a more equitable distribution of economic opportunities, re-refining can

help uplift communities and reduce socio-economic disparities.

In essence, the re-refining of waste lubricating oil in Nigeria offers a multifaceted solution that addresses critical environmental challenges while simultaneously fostering economic growth, creating employment opportunities, and promoting resource efficiency. These outcomes are central to achieving comprehensive sustainable development within the nation, demonstrating a commitment to a regenerative and restorative economic model.

CONCLUSION

The escalating generation of WLO, especially in rapidly industrializing developing economies like Nigeria, poses significant environmental threats through indiscriminate disposal of toxic and carcinogenic contaminants, alongside substantial economic burdens due to import dependence and limited domestic technical expertise.

The strategic implementation of re-refining technologies offers transformative socio-economic benefits for Nigeria. These include the creation of numerous job opportunities across the entire value chain, significant enhancement of the national GDP, critical conservation of finite crude oil resources, and substantial improvements in energy efficiency. Furthermore, re-refining provides a viable alternative domestic source for lubricating base oil, thereby reducing the nation's costly over-reliance on imports and strengthening its energy security. Crucially, these outcomes directly align with key United Nations Sustainable Development Goals, including SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), SDG 10 (Reduced Inequalities).

While Nigeria possesses foundational environmental legislation, the absence of a specific national policy for WLO management and persistent challenges in regulatory enforcement have hindered the development of a robust re-refining industry. The indiscriminate disposal of WLO continues to cause widespread environmental pollution and poses severe risks to human health and ecosystems. However, the immense volume of WLO generated, coupled with the nation's significant import dependence, presents a compelling opportunity for the establishment and scaling up of re-refining operations.

To fully realize the transformative potential of WLO re-refining, a multi-pronged approach is essential. This includes the development and rigorous enforcement of a comprehensive national WLO management policy, incentivizing private sector investment in modern re-refining technologies, fostering public-private partnerships, and implementing widespread public awareness campaigns to promote responsible WLO collection and disposal. By embracing WLO re-refining, Nigeria can not only mitigate critical environmental challenges but also unlock substantial economic growth, create sustainable employment, and make significant strides towards achieving its national development objectives and international sustainability commitments. This transition from a linear "take-make-dispose" model to a regenerative circular economy is not merely an environmental choice but an economic imperative for a resilient and sustainable future.

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