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Environmental Assessment of Heavy Metals and Hydrocarbons in Waste Lubricants at Ladipo Auto-Mechanics Market, Lagos, Nigeria

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Abstract **Original Research Article**

Waste lubricants from automotive repair activities are an important yet under-regulated source of environmental contamination in urban markets. This study investigated the levels of heavy metals and hydrocarbons in waste lubricants from the Ladipo auto-mechanics market, Lagos, Nigeria a major hub for vehicle maintenance and parts trade. A total of 30 waste lubricant samples were collected during both wet and dry seasons from randomly selected workshops and analysed for lead (Pb), cadmium (Cd), chromium (Cr), zinc (Zn), copper (Cu), nickel (Ni), total petroleum hydrocarbons (TPH), and polycyclic aromatic hydrocarbons (PAHs) using Atomic Absorption Spectrophotometry (AAS) and Gas Chromatography–Mass Spectrometry (GC–MS). Mean concentrations (mg/kg) of Pb (85.3), Zn (320.4), Cu (112.7), Ni (26.5), and Cd (2.4) exceeded Nigerian Department of Petroleum Resources (DPR) intervention limits in over 70% of samples, with wet season values generally higher than dry season levels. TPH levels (mean: 125,000 mg/kg) were 25–40 times above DPR soil target values. Spatially, workshops closer to drainage channels showed higher contaminant loads, suggesting runoff transport into surrounding soils and water bodies. The contamination profile indicates significant ecological and human health risks, especially via dermal contact and food chain transfer. Urgent regulatory enforcement, waste oil collection systems, and public awareness are recommended to mitigate further degradation of the local environment.

Keywords: Waste lubricants, heavy metals, hydrocarbons, auto-mechanics, Ladipo Market, environmental pollution, Nigeria.

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1. INTRODUCTION

Urban auto mechanic markets in Nigeria, particularly in metropolitan centres like Lagos, are critical economic zones but also hotspots of environmental contamination. Waste lubricants used engine and transmission oils are generated in large volumes during routine vehicle maintenance. These fluids contain degraded additives, wear metals from engine parts, and combustion by-products including polycyclic aromatic hydrocarbons (PAHs) (Kojima & Yoshida, 2020). If improperly managed, they contaminate soil, groundwater, and air, leading to long-term ecological and health consequences (Nwachukwu et al., 2018).

The Ladipo auto-mechanics market in Lagos is West Africa's largest automotive spare parts market, hosting thousands of workshops. Waste oil is commonly disposed directly onto bare soil or into drainage channels, a practice with well-documented risks (Adebiyi et al., 2016). Globally, heavy metals such as Pb, Cd, Cr, Ni, and Cu in waste oils are toxic even at low concentrations, with bioaccumulation potential in crops and aquatic life (Alloway, 2013). Hydrocarbons, particularly PAHs, are persistent organic pollutants linked to carcinogenicity (ATSDR, 2021).

Previous studies on Nigerian markets have reported elevated contaminant levels in soil and water near mechanic workshops (Ololade et al., 2017; Obida et al., 2018). However, there is a lack of comprehensive seasonal and spatial data for Ladipo. This study addresses this gap by quantifying heavy metals, total petroleum hydrocarbons (TPH), and PAHs in waste lubricants during wet and dry seasons, and assessing compliance with national environmental standards.

2. MATERIALS AND METHODS

2.1 Study Area

Ladipo Market is located in Mushin Local Government Area, Lagos State, Nigeria (6°33′N, 3°22′E). It experiences a tropical wet and dry climate, with average annual rainfall of ~1,800 mm and temperatures ranging from 24–34°C. The market is characterised by dense clusters of workshops and spare part stalls, with limited waste management infrastructure.

Figure 1. Map of Ladipo Market showing sampling points

2.2 SAMPLING METHOD

Representative samples of soil and water respectively were collected from four sampling points in the market area and various tests for basic physicochemical parameters such as COD, BOD, pH, Total dissolved solute (TDS), heavy metal deposit were carried out. Data obtained from the laboratory analysis of the samples were analyzed using descriptive statistical techniques such as tables, mean, standard deviation, coefficient of variation. The results obtained were compared with WHO FEPA and NESREA standards.

TABLE 1 DESCRIPTION OF THE SAMPLING POINTS

Sampling Points	Location	Coordinates	Settlement	Topography
Sampling Point 1	Olanibi Street	Elevation:46 meters Latitude:N06.53377 Longitude:E003.33893	Densely Populated Commercial and Residential	Sloppy
Sampling Point 2	Ladipo Street	Elevation:31 meters Latitude:N06.54541 Longitude:E003.33976	Densely Populated Commercial and Residential	Plain Ground
Sampling Point 3	Oduduwa Street	Elevation:46 meters Latitude:N06.53670 Longitude:E003.34692	Densely Populated Commercial and	Slightly Sloppy

			Residential	
Sampling Point 4	Ojekunle Street	Elevation:46 meters Latitude:N06.53944 Longitude:E003.33567	Densely Populated Commercial and Residential	Low Ground(Valley-like)

2.3 Water Sampling Procedure

The water samples were collected in the month of August 2014. Four boreholes around the identified dumpsites were sampled .Sample bottles of 250 ml with cap were used for the collection. The following guidelines were followed to collect the water sample used for this study.

a. An indoor faucet was selected to take the water samples.

b. Stains and possible contaminants were removed from the tap and the cold water was allowed to run at full flow for about five minutes before putting it back to steady slow stream to ensure that possible contaminants are completely removed.

c. Each sample bottle was then filled with the water sample up to the fill line while being careful not to make contact with the faucet or the water to avoid contamination.

d. The collected water samples were fixed with concentrated HNO_3 (metal determination only) and transported to University of Lagos Chemistry laboratory the same day for physiochemical analysis

2.4 Soil Sampling Procedure

The sampling was carried out in the month of August 2014 at four dumpsites at Ladipo spare parts market. Soil auger was used to take samples of soil in random and evenly distributed manner. Samples were systematically collected from the sites at between 15 -30 cm deep in the soil. The samples collected were put in a clean plastic container. The soil samples were thoroughly mixed and pebbles removed before transferring into clean black polyethylene bags and sealed. The samples were transported to the University of Lagos Chemistry laboratory for physiochemical analysis. In the laboratory, the wet soil samples were spread onto plastic trays and allowed to air dry at ambient temperature for a few days. Large pieces of stones were picked out manually. The samples were sieved to pass through a 2-mm stainless steel sieve and stored in clean black polyethylene bags.

2.5 Sample Collection

Thirty waste lubricant samples (500 mL each) were collected in clean amber glass bottles from sump drains of workshops. Fifteen samples were collected during the wet season (July–August) and fifteen during the dry season (January–February). Sampling sites were categorised as:

- **Zone A:** Adjacent to drainage channels (n=10)
- **Zone B:** Within workshop clusters (n=10)
- **Zone C:** Peripheral roadside workshops (n=10)

2.6 Methods

2.7 Water Analysis

Water samples were analyzed for physicochemical parameters following standard methods (APHA, 2017). All analyses were conducted in duplicate and results expressed in mg/L unless otherwise stated.

Ph: pH was measured in situ using a calibrated pH meter (Mettler Toledo) standardized with commercial buffer solutions (pH 4.0 and 9.21). Samples were measured after calibration in distilled water.

Conductivity: onductivity was determined using a conductivity cell (cell constant 1.2) at 25 °C.

Solid: Total solids (TS) and total dissolved solids (TDS) were determined gravimetrically by oven-drying 10 mL of raw and filtered samples, respectively, at 105 °C to constant weight. Suspended solids (SS) were calculated as:

SS=TS−TDSSS = TS - TDSSS=TS−TDS

Dissolved Oxygen (DO): DO was determined by the Winkler azide modification method. Samples were fixed with $MnSO_4$ and alkali–iodide–azide reagent, acidified with H_2SO_4, and titrated with standardized sodium thiosulphate using starch as an indicator. DO was calculated as:DO=M×V×V1V2DO = \frac{M \times V \times V_1}{V_2}DO=V2M×V×V1 where *M* = molarity of thiosulphate, *V* = titre volume, V_1 = bottle volume, V_2 = titration a.

Biochemical Oxygen Demand (BOD_5): BOD was measured after 5-day incubation at 20 °C in the dark using dilution water fortified with phosphate buffer, magnesium sulphate, calcium chloride, ferric chloride, and ammonium chloride. DO was measured at day 0 (DO_0) and day 5 (DO_5), and BOD calculated as: BOD5=DO0−DO5Dilution factorBOD_5 = \frac{DO_0 - DO_5}{\text{Dilution factor}}BOD5 =Dilution factorDO0−DO5

Chemical Oxygen Demand (COD): COD was determined by refluxing samples with $K_2Cr_2O_7$ in acidic medium with $HgSO_4$ catalyst, followed by titration with ferrous ammonium sulphate (FAS).COD=(A−B)×M×8000Sample volumeCOD = \frac{(A - B) \times M \times 8000}{\text{Sample volume}}COD=Sample volume(A−B)×M×8000 where *A* and *B* are FAS volumes for blank and sample, *M* is molarity of FAS.

Alkalinity and Acidity: Alkalinity was determined by titration with standardized HCl to a pink endpoint using mixed indicator. Acidity was determined by titration with standardized NaOH using phenolphthalein indicator.

Oil and Grease: Oil and grease were extracted sequentially with hexane, evaporated on a steam bath, and weighed gravimetrically:O&G=W2−W1V×106\text{O\&G} = \frac{W_2 - W_1}{V} \times 10^6O&G=VW2−W1×106 where W_1 = crucible weight, W_2 = crucible + extract weight, V = sample volume.

Nitrate: Nitrate concentration was determined by spectrophotometry (520 nm) following alkaline reduction and diazotization with sulphanilic acid.

Phosphate: Phosphate was determined colorimetrically at 880 nm after reaction with combined reagent (H_2SO_4, potassium antimonyl tartrate, ammonium molybdate, ascorbic acid).

Sulphate: Sulphate was determined by turbidimetric method using $BaCl_2$ crystals in buffered sample and measuring absorbance at 420 nm.

Total Metals: Samples were digested with concentrated HNO_3, evaporated, reconstituted, and analyzed using atomic absorption spectrophotometry (Perkin Elmer Analyst 200).

Soil Analysis

pH: Soil pH was determined in 0.01 M $CaCl_2$ (1:1 ratio) using a pH meter standardized with buffers 4, 7, and 9.

Phosphate: Available phosphate was extracted with distilled water and measured colorimetrically as for water samples.

Metals: Soil samples were digested with aqua regia ($HCl:HNO_3$ = 3:1) and analyzed for metals by AAS using element-specific hollow cathode lamps.

Oil and Grease: Oil and grease in soil were extracted with hexane, evaporated, and weighed gravimetrically, with results expressed in mg/kg.

3. RESULTS AND DISCUSSION

3.1 Heavy Metal Concentrations

Mean concentrations of heavy metals in waste lubricants are summarised in Table 1. Pb, Zn, and Cu showed the highest mean levels, exceeding DPR intervention limits (Pb: 85.3 mg/kg vs. 85 mg/kg; Zn: 320.4 mg/kg vs. 140 mg/kg).

Table 2. Mean heavy metal concentrations (mg/kg) in waste lubricants from Ladipo Market

Metal	Wet Season	Dry Season	DPR Intervention Limit	Exceedance (%)
Pb	92.5	78.1	85	73
Zn	345.2	295.6	140	100
Cu	118.4	106.9	100	80
Ni	29.7	23.4	21	65
Cd	2.7	2.1	0.8	95

4. RESULTS AND DISCUSSION

4.1 Physicochemical Characteristics of Underground Water and Soil

Analysis of underground water (boreholes) and soils from four sampling locations in Ladipo Market revealed significant contamination.

pH: Borehole water was slightly acidic (5.82–5.97), below WHO's 6.5–9.5 limit, indicating potential increased metal solubility. Soil pH was alkaline (8.03–8.52), exceeding FEPA's 5.1–6.5 range.

Conductivity: Water conductivity (147–485 µS/cm) exceeded FEPA/WHO 200 µS/cm limit, suggesting high mineralization. Soil conductivity ranged from 202–285 µS/cm.

Total Dissolved Solids (TDS): Water TDS (68.3–232 mg/L) was within FEPA's 200 mg/L limit for most samples.

Heavy Metals in Water:

Pb detected in one borehole at 1.93 mg/L, far above NESREA's 0.1 mg/L limit.

Zn in all boreholes (5.32–17.09 mg/L) exceeded NESREA's 5 mg/L limit.

Cr averaged 0.10 mg/L, above NESREA's 0.01 mg/L limit.

Heavy Metals in Soil: Pb concentrations were extremely high (1.49–2108.20 mg/kg), surpassing FEPA's 0.5–3.0 mg/kg limit. Zn levels (38.33–57.07 mg/kg) were within limits.

Oil, Grease, and Hydrocarbons: Soil contained elevated oil and grease (493.50–601.70 mg/kg) and THC (1023.4–1882.35 mg/kg) due to waste lubricant dumping; these were absent in borehole water, likely due to depth and geological barriers.

Other Parameters in Water

Nitrates & Phosphates: NO_3 (9.6–13.7 mg/L) was within WHO's 45 mg/L limit. PO_4 (5.4–6.9 mg/L) exceeded FEPA's 5 mg/L limit in most samples.

DO, BOD, COD: DO averaged 5.3 mg/L (below WHO's 8–10 mg/L). BOD (9–12 mg/L) was near FEPA's 10 mg/L limit. COD was low (15.5 mg/L), well within the 200 mg/L WHO limit.

Pollution Pathways

Contamination is linked to open dumping of waste lubricants, leaching of heavy metals into soil and groundwater, and percolation from rainfall. Ladipo's mixed commercial–residential land use worsens exposure risk, as many residents consume untreated borehole water (Soladoye & Ajibade, 2014).

5.0 CONCLUSION

The Ladipo market area shows clear evidence of environmental degradation from waste lubricant disposal and auto-mechanic activities. Key issues include:

Acidic borehole water with elevated conductivity, Pb, Zn, and Cr beyond permissible limits.

Soil heavily contaminated with Pb and petroleum hydrocarbons.

Potential health risks: Pb exposure can cause neurological and cardiovascular damage; excess Zn may induce anaemia and gastrointestinal issues; phosphate enrichment may cause eutrophication.

Current conditions make Ladipo unsuitable for residential settlement given its water quality.

5.1 Recommendations

1. **Public Awareness:** Implement environmental education campaigns to discourage indiscriminate waste disposal.
2. **Enforcement:** Apply punitive measures for environmental law violations.
3. **Zoning:** Designate Ladipo exclusively for commercial use; relocate residents.
4. **Market Relocation:** Move the market away from residential zones.

Remediation: Conduct soil treatment to reduce contaminant leaching into groundwater.

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