# Environmental Implications of Heavy Metals in Spent Oil - Contaminated Soil of Kaduna Northern Guinea Savanna Ecozone of Nigeria

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## Abstract

*Pollution of the city/urban soil by contaminants arising from spent oil and other sources is considered a serious problem. Lead (Pb) has long been known as a potential hazard to health, especially in cities where users of spent oil, especially mechanics, indiscriminately dump the oil in the farmlands, which releases high quantities of lead into the soil and environment. Consequently, this study assessed heavy metals in soil samples polluted with spent oil in the Kaduna Northern Guinea Savanna ecozone of Nigeria. Soil samples were collected from six (6) different farmlands (Mando, Rigachuku, Panteka, Sabo-Birnin, Buruku, and Jaji) where spent engine oil was frequently dumped by mechanics near auto mechanic workshops and where mechanic activities had been carried out for a period of 5 – 7 years using a subjective sampling method. Topsoil only was collected from each site; these soil samples were thoroughly mixed and labeled as polluted samples (PS). Topsoil samples were equally collected from six (6) other farms located within the same sites where no auto mechanic workshops had been sited before, nor had any mechanic activities been carried out. These samples were bulked and also labelled as an unpolluted sample (US). Soil heavy metal analysis was carried out using an Atomic Absorption Spectrophotometer (Model Buck 210 VGP) following Association of Official Analytical Chemists (AOAC) procedures. The results show increases in Cd (100%), Pb (71.94%), Sn (65.91%), Cr (63.83%), Hg (58.14%), and Ni (63.93%), while silver (Ag) remains undetected in both PS and US. In conclusion, the soil absorbs and accrues heavy metals above the allowable limits of the WHO/FAO/EEA permissible limit standard, respectively. In view of these negative effects, the general public, especially the mechanics, should be enlightened about the dangers involved in indiscriminate dumping of spent oil on farmlands, from a health and environmental point of view, with convincing reasons, while it needs to be controlled.*

**Keywords:** Heavy Metal, Environmental Contamination, Soil Pollution, Spent Oil Contamination, Ecotoxicology

## Introduction

Heavy metals, in general terms, apply to the group of metals or metalloids with an atomic density greater than 5g/cm$^3$ in their elemental form (Ademoroti, 1996; Sodimu,2016; Sodimu, 2019). They belong to a group of geochemical substances described as trace elements because they collectively comprise less than 1% of the rock in Earth's crust. They cannot be degraded or destroyed. All heavy metals are toxic to living organisms at extreme concentrations (Alloway, 1996; Sodimu,2019). The elements that can be classified as heavy metal comprises of 38 elements, 17 of which are considered to be toxic and relatively accessible. Some of the heavy metals are zinc (Zn), lead (Pb), Nickel (Ni), Chromium (Cr), Aluminium (Al), Arsenic (As), Mercury (Hg), and cadmium (Cd). Heavy metals can be explained in terms of toxic level, excessive toxic level, and below the excessive toxic level (Jorgenson and Johnson 1989). The toxicity of heavy metals depends on the types of metals, their role, and the types of organisms that are exposed to the heavy metals. Heavy metals occur naturally in the environment at different concentrations. At lower concentrations, they are not hazardous, but at higher concentrations, they pose a health risk as they are unconsciously ingested through food, water, and air. Studies have shown that the occurrence of heavy metals in the soil is affected by urbanization. For instance, under natural conditions, lead occurs in the soil at 5 - 20ppm, cadmium at 0.05- 0.5 ppm, and arsenic at 1 – 5ppm. In highly urbanized areas, these concentrations may increase to 100 – 200ppm, 1 -5ppm, and 10 – 20ppm for lead, cadmium, and arsenic, respectively (Langad, 1999; Sodimu,2016)

However, areas with high-intensity anthropogenic activity are likely to have more heavy metals, at preeminent levels, particularly in the soil. This is because the soil particles have the potentials of absorbing and store these metals for a long time (Sodimu,2016). Jorhem & Zundstrom (1999) ascertained that the potential dangers associated with heavy metals correspond to their accumulation in the soil, which may lead to plant mineral toxicity or result in increased uptake of such metals into the food chain. Soil pH, organic matter content, cation exchange capacity, and temperature can affect the uptake of heavy metals by plants. It has also been accepted that sources of heavy metals in soil and water of most urban communities are often activated by the indiscriminate dumping of waste that contain these metals. In Nigeria, one of the sources of soil pollution is the dumping/pouring of spent oil on farmlands by auto mechanics, motorists, and other users of such products. Spent oil/used engine oil is a mixture of hydrocarbon fractions, pure when it's produced, but impurities may be incorporated into the engine oil through viscosity improvers, defoamers, antioxidants, corrosion inhibitors, dispersants, anti-wear/extreme pressure additives, and so on. (Linful, 1970). It is used in transmission fluids, vehicle crankcases, lubricating oil, gearboxes, and differential compartments. However, prolonged use of engine oil renders such oil exhausted or spent and needs to be discarded.

According to Alegaria (1999) and Kawedo *et al.* (2024), spent oil can be said to be any oil refined from crude oil or synthetic oil that has outlived its usefulness as a result of extensive usage, storage, or spillage and becomes contaminated by physical or chemical impurities. Such oil contains many toxic and environmentally harmful substances, such as cadmium, chromium, lead, benzene, toluene, etc. In most parts of the study area, oil is faced with the problem of discarding the expired oil; some discard the product with caution, while others do so indiscriminately on farm lands and water sources, not minding the negative consequences of such practice to plants and inhabitants of the area (Sodimu, 2016). Numerous investigations have demonstrated that lead emission from motor vehicles produce elevated concentration of the metal in roadside vegetation (Cannon & Bowles, (1963), Quinche *et. al.,* (1969), Daines *et. al.,* (1970), Atayese *et. al.,* (2009) and Sodimu *et. al.,* (2026) and is reasonably established that a variety of motor vehicles introduce several toxic metals into the atmosphere which are deposited on road verges (Williamson, 1973; Moore & Moore, 1996 and Atayese, *et. al.,* 2009). Most heavy metals have been reported to have dangerous long-term effects on human health. Cadmium, nickel, and Mercury have been reported to accumulate at toxic levels in plants, thus posing a hazard to plants, animals, and humans (Dandone *et. al.,* 2000; Sodimu *et. al.,* 2020)

However, organometallic compounds such as tetraethyl lead [$(C_2H_5)_4Pb$], an additive to petrol, are a source of lead in automobile exhaust emissions (Ademoroti, 1986). It has been found that 15 – 30% of lead emissions from automobiles are airborne, which, in the long run, stay on the soil or leaf surfaces. (Quinche *et al.,* 1969; Farre & Legarda, 1999). Human beings and animals inhale the airborne particles, while the rest are deposited on vegetation and soil (Ademoroti, 1996; Islam *et.al.*, 2006). Research has shown that toxic heavy metals such as lead (Pb), Cadmium (Cd), Nickel (Ni), and gases such as sulfur (IV) oxide ($SO_2$), Carbon (II) Oxide (CO) are responsible for certain diseases which have lethal effects on man and animals (Lawther 1965; Giddings 1973; Singh *et. al.*, 2004).

## Materials and Methods

### The Study Area

This investigation was carried out in Nigeria's Northern Guinea Savannah Ecological Zone, specifically in Igabi Local Government. Latitude 10047'55 '' and 10046'41 '' N / longitude $7^{0}31'29''$ and $7^{0}30'26''$E (Figure 1). Apart from the Gbagyi, who were initially non - Muslims or traditionalists before converting to Christianity, the majority of the indigenous population of Igabi is Muslim. Its area is 3,222 km2, and its density is 180.5 km². With a projected estimated population of 581,500 residents, the region receives 1000–1500 mm of rainfall annually (KDBS, 2016)

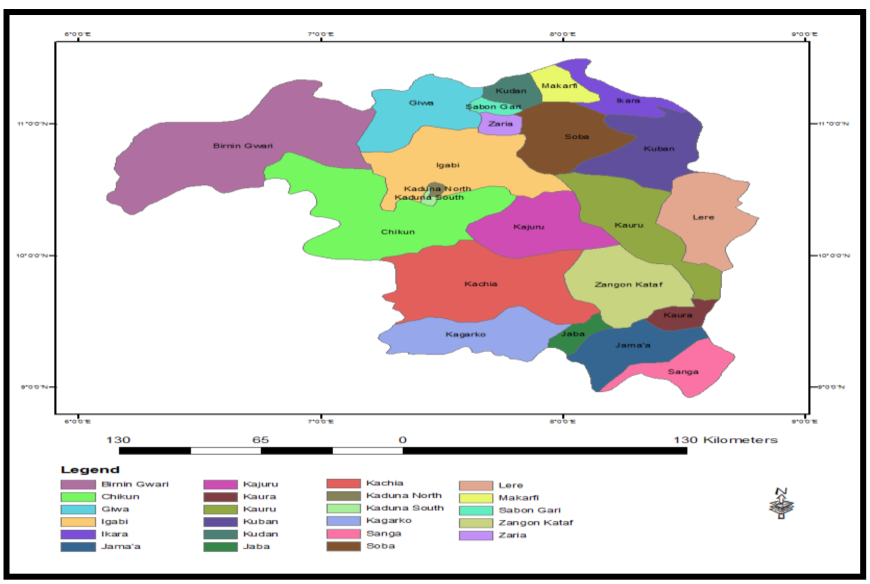


*Figure 1: Position of the study area, Igabi Local Government, on a map of Kaduna State*
*Source: Sodimu et al., 2021*

### Sampling Procedure

Soil samples were collected from six (6) different farmlands (Mando, Rigachuku, Panteka, Sabo-Birnin, Buruku, and Jaji) where spent engine oil was frequently dumped by mechanics near auto mechanic workshops and where mechanic activities had been carried out for a period of 5 – 7 years using a subjective sampling method. However, only the topsoil was collected from each site because this portion contains vital nutrients required for plant growth (Sodimu, 2016). These soil samples were thoroughly mixed and labeled as polluted samples (PS). Topsoil samples were again collected from six (6) other farms located within the same sites where no auto mechanic workshops had been sited before, nor had any mechanic activities been carried out. These samples were mixed thoroughly and labelled as an unpolluted sample (US). kept in labeled, clean plastic bottles until needed

### Soil Heavy Metal Analysis Using an Atomic Absorption Spectrophotometer

Soil heavy metal analysis procedures were adopted from AOAC (1985). A sample of 0.5g of polluted soil (PS) and Unpolluted soil (US) was transferred to a 25ml conical flask separately; 5ml of concentrated $H_2SO_4$ was added, followed by 25ml of concentrated $HNO_3$, and 5ml of concentrated HCl. The contents of the tube were heated to 200 °C for 1 hour in a fume hood and then cooled to room temperature. After cooling, 20ml of distilled water was added, and the mixture was filtered using Whatman filter paper number 1. Finally, the mixture was transferred to a 50ml volumetric flask, filled to the mark, and allowed to settle for at least 15 hours. The supernatant was analyzed for heavy metals by using an Atomic Absorption Spectrophotometer (Model Buck 210 VGP).

### Statistics Analysis

Data obtained was analyzed using SAS version 9.0 and subjected to Duncan Multiple Range Test (DMRT) at 5% level of probability (P=0.05) (Sodimu,2016)

## Results and Discussion

### Results

The results of heavy metal contents in unpolluted (UP) soil samples are presented in Tables 1 and 2.

Table 1 shows the results of heavy metal contents in polluted soil samples, with Lead (Pb) and Nickel (Ni) having the highest values of 50.58 ± 0.02mg/l and 25.85 ± 0.01 mg/L, respectively. Chromium (Cr) had 0.34 ± 0.02mg/L; closely followed by Mercury (Hg) with 0.18 ± 0.02mg/L while Tin (Sn) had the least, 0.15 ± 0.01mg/L. However, Silver (Ag) and Cadmium (Cd) were Not Detected (ND) at all.

***Table 1: Heavy Metals in Unpolluted (UP) Soil Sample`***

| S/N | Heavy Metal | Mg/L ± SD |
|---|---|---|
| 1. | Silver (Ag) | ND |
| 2. | Chromium (Cr) | 0.34 ± 0.02 |
| 3. | Cadmium (Cd) | ND |
| 4. | Lead (Pb) | 50.58 ± 0.02 |
| 5. | Mercury (Hg) | 0.18 ± 0.02 |
| 6. | Tin (Sn) | 0.15 ± 0.01 |
| 7. | Nickel (Ni) | 25.85 ± 0.01 |

**All values are means of duplicate determinations ± SD (ND in Ag and Cd means not detected)*

Table 2 below shows that the polluted soil (PS) sample contains high amounts of Pb (129.65 ± 0.02mg/L) and Ni (45.81 ±0.01mg/L). When those values were compared to those of the unpolluted sample, there were increases of 71.94% and 63.93%. Furthermore, the table also revealed that the polluted soil sample showed an increase in Sn (65.91%), Cd (100.00%), Cr (63.83%), and Hg (58.14%)

***Table 2: Heavy Metals in Polluted Soil (PS) Sample in Mg/L***

| S/N | Heavy Metals | Mg/L ± SD | WHO/FAO/EEA (Mg/L) | Percentage (%) Increased |
|---|---|---|---|---|
| 1. | Silver (Ag) | ND | Not Available | 0.00 |
| 2. | Chromium (Cr) | 0.60 ±0.01 | 0.5 | 63.83 |
| 3. | Cadmium (Cd) | 0.19 ± 0.01 | 0.05 | 100.00 |
| 4. | Lead (Pb) | 129.65 ± 0.02 | 50 | 71.94 |
| 5. | Mercury (Hg) | 0.25 ±0.02 | 0.1 | 58.14 |
| 6. | Tin (Sn) | 0.29 ± 0.01 | 0.01 | 65.91 |
| 7. | Nickel (Ni) | 45.81 ± 0.01 | 30 | 63.93 |

**All values are means of duplicate determinations ± SD, FAO/WHO/EEA: Food and Agriculture Organization/World Health Organization/European Environment Agency. Permissible limits of Heavy Metals in the soil (ND in Ag means not detected). The percentage increase showed the increase of heavy metals in polluted soil samples when compared with unpolluted samples.*

## Discussion

Results in Table 1 showed that the unpolluted soil sample contained some amount of Lead, Nickel, and other assessed heavy metals, which was an indication that the soil sample in the study area was not totally free of heavy metals. This observation confirms the assertion of Sodimu (2016) that relatively large quantities and numerous kinds of trace elements were inherent in the urban environment because of intense anthropogenic activities such as industrialization, soil grading, building, construction, demolition, and waste management operations. However, lead is mainly a component of engine oil, other lubricants, and fuel (Dong-Sheng & Peart, 2006; Sodimu *et al.,* 2017), which is therefore higher (50.58 ± 0.02mg/L) than all other heavy metals. However, a rise in heavy metal concentrations above background and recommended values has been associated with the deposition of heavy metals in the soil from a variety of anthropogenic causes (Maine *et al.,* 2004; Bako *et al.,* 2008; Tanimu *et al.,* 2013; Bako *et al.,* 2014; Okorie *et al.,* 2024; and Sodimu *et. al.,* 2025). It has been shown that petroleum products are concentrated with high metal content. Other sources may be from exhausts of automobiles, waste, power plants, Corrosion of metal objects (galvanized metal roofs and wire frames: Zn and Cd), pesticides, manures, impurities in fertilizers, etc., which are easily absorbed by the soil layers (Langard,1999)

Results in Table 2 showed that the soil sample that was constantly contaminated with spent oil contained heavy metals that were hazardous to health. Most of these heavy metals had high amounts of Lead (Pb) up to 6.0 ppm – 7.0 ppm, which has been reported to cause serious environmental contamination. (FAO and WHO,1984) Some of these heavy metals may be present in both flora and fauna tissues as contaminants of the environment (Hopkin,1996; Sodimu, 2016; Sodimu *et. al.,*2021; Sodimu, 2025). These heavy metals can be taken up by vegetables, which, when consumed by man, pose a serious health risk as they aid and abet tissue damage (Linful, 1970; Sodimu, 2025). However, in humans, lead (Pb) is known to cause various diseases, which include retardation in mental development, damage to the central nervous system, and inhibition of hemoglobin synthesis (Rohn *et al*., 1982; Ogwuegbu & Muhanga, 2005). Duruibe *et al.* (2007) noted that the nature of these effects may be acute, chronic, neurotoxic, carcinogenic, mutagenic, or teratogenic. Thus, Lead (Pb), Nickel (Ni), and chromium (Cr), as well as mercury (Hg) and other toxic metals, pose a serious threat to humans with serious consequences on the brain cells (Laskowski,1996). Thus, haphazard dumping of spent oil in farmland should be discouraged apart from human health, as it causes deterioration and depletes soil organisms in the ecosystem. They are tetragenic, mutagenic, and their ingestion seriously affects vital nutrients in the body (Bodansky,1988). Table 2 further shows that all the levels of heavy metals are beyond the acceptable permissive limits of (FAO/WHO 1984; FAO/WHO/EEA, 2023).

## Conclusion and Recommendation

### Conclusion

The results attained from this study have revealed that the degree of soil pollution due to indiscriminate dumping of spent oil is excessive. Those who are involved in these activities may have had little or no knowledge of the retrogressive effects of such unwholesome practices that dumping of spent oil, which adds to already alarming levels of heavy metal contents of the soil. This depletes soil organisms, brings about low crop yield, and poses toxicity to consumers of such crops, as manifested in various diseases linked to heavy metal toxicity.

### Recommendation

In view of these negative effects, the general public, especially the mechanics, should be enlightened about the dangers involved in indiscriminate dumping of spent oil on farmlands, from a health and environmental point of view, and with convincing reasons, while it needs to be controlled.

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