International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Heavy Metal Contamination in Roadside along Some Selected Metropolitan Area in Port Harcourt Nigeria

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ABSTRACT

Heavy metal accumulation in plants grown alongside roadsides is a well-documented issue, particularly in developed countries where industrial activities and vehicular emissions contribute to higher levels of pollutants. A study to investigate the level of heavy metal polluted in soil samples and plants species along 3 roads (Omagwa, Isoikpo and Obiri Ikwerre). This area includes portions of two Local Government Areas: Obio/Akpor and Ikwerre Rivers State of Nigeria was conducted. Four sampling points were taken at each road at distance 5 m, 10 m and 15 m from the road inward. Cadmium (Cd) and lead (Pb) were analyzes for the soil and dominate plants using Atomic Absorption Spectrophotometry. The results showed that Pb concentration were highest at Omagwa (85 mg/kg, 84.5 mg/kg, 56 mg/kg) for 5-15 m, followed by Pb Isoikpo (60 mg/kg, 53 mg/kg, 52 mg/kg) for 5 m- 15 m respectively. While lowest was at Obiri Ikwerre: (3.0 mg/kg, 1.0 mg/kg, and 2.0 mg/kg) 5-15 m. Cd level was highest at the sample points at Isoikpo (17 mg/kg, 16.8 mg/kg, and 15.32 mg/kg) followed by that of Omagwa road and the lowest was found at Obiri Ikwerre (5.2 mg/kg, 3.5 mg/kg 2.46 mg/kg) for 5- 15 m respectively.The Plant (Sida sp) at Omagwa showed higher values of Cd and Pb while the least was found in Calapogonium sp grown in the reference soil. These heavy metal values decreased with increasing distance from the road inward. The average geoaccumulation values, contamination factor and pollution load index calculated indicated that the studied sites are seriously polluted with Pb and Cd. Therefore heavy metal contamination along roads requires a multi-faceted approach that combines monitoring, regulation, public awareness, and remediation efforts. By taking proactive measures, communities can safeguard their health and the environment from the adverse effects of heavy metal pollution.

Keywords: Heavy metal, vehicular emission, systematic sampling technique

Introduction

Increase in heavy metals concentration in the environment due to anthropogenic activities is indeed a key environmental problem with far-reaching implications. Heavy metals are non-biodegradable substances, meaning they cannot be broken down or decomposed by living organisms or natural processes over short periods of time. As a result, they tend to persist in the environment for long periods, accumulating in various environmental compartments such as soil, water, and sediments (Rajaram *et al*., 2020). Heavy metals, including lead, mercury, cadmium, arsenic, and chromium, are naturally occurring elements that are released into the environment through human activities at levels that can pose serious risks to ecosystems and human health. Anthropogenic activities such as industrial processes, mining, agriculture, waste disposal, and combustion of fossil fuels are major contributors to heavy metal pollution. Roadside dust, often overlooked but significantly impactful, is a product of various anthropogenic activities and natural processes. These sources contribute to the accumulation of pollutants in roadside environments, posing risks to soil, plants, and human health.

Vehicle-related sources play a significant role in roadside dust pollution. Road surface wear, degradation of road paints, and emissions from vehicle components such as tires, brakes, and body contribute to the accumulation of particulate matter along roadsides (Arslan and Gizir, 2004). Additionally, vehicular fluid particulate emissions, including those from metal processing industries, further exacerbate heavy metal contamination in roadside environments. Traffic congestion exacerbates these issues by increasing the frequency of vehicle emissions and particulate matter deposition. The exhaust from combustion engines, combined with industrial emissions, releases heavy metals into the air, which eventually settle onto roadside soils and vegetation (Ghrefat and Yusuf, 2006). These activities release heavy metals into the air, water, and soil, where they can persist for long periods and accumulate in the environment. The impacts of heavy metal pollution are widespread and can affect ecosystems, biodiversity, and human health in innumerable ways (Wang, *et al*.,2005). When deposited in roadside dust, heavy metals can be easily dispersed into the surrounding environment through wind and water erosion (Amadi and Chuku, 2023). They can contaminate soil, water bodies, and vegetation, leading to ecosystem disruption and biodiversity loss. Moreover, heavy metals can also bioaccumulate in the food chain, posing risks to human health when consumed through contaminated food or water ((Igwe *et al*., 2002; Rajaram *et al*., 2020). Exposure to heavy metals in roadside dust has been linked to various health problems such as respiratory issues, neurological disorders, developmental abnormalities, and even cancer (Rajaram *et al*., 2020). Heavy metals can accumulate in soil, reducing soil fertility and inhibiting plant growth. Heavy metals can bioaccumulate in the tissues of organisms, meaning that concentrations increase up the food chain. Predators at the top of the food chain, including humans, can accumulate high levels of heavy metals through the consumption of contaminated prey. Although, heavy metals are essential trace elements necessary for proper physiological functioning in the human body, such as zinc, copper, iron, and manganese, their accumulation at high concentrations can indeed pose significant health challenges.

Heavy metal accumulation in plants grown alongside roadsides is a well-documented issue, particularly in developed countries where industrial activities and vehicular emissions contribute to higher levels of pollutants. They are released into the environment through various human activities and subsequently accumulate in soil and plants, posing risks to human health and ecosystems. While research on this topic has been more prevalent in developed countries due to their higher levels of industrialization and stricter environmental monitoring, there is increasing recognition of the issue in developing countries as well. However, limited resources, infrastructure, and prioritization of environmental concerns often hinder the extent of research conducted in these regions (Atayese *et al*., 2009). This study attempts to determine the accumulation of heavy metals in the studied plants and topsoil along some high vehicular roads in Port Harcourt using Obio/Akpor and Ikwerre Local Government Area as a case study.

MATERIALS AND METHODS

Study Area

The study area for soil sampling in Rivers State, Nigeria, was chosen to encompass a broad spectrum of traffic density and ensure geographical diversity. This area includes portions of two Local Government Areas: Obio/Akpor and Ikwerre. The combined population of these areas was estimated to be approximately 401,873 as of 2006, covering an area of approximately 100 square kilometers. A total of 12 soil samples were collected randomly from various distances around the sampling sites within Port Harcourt. The sampling locations were strategically selected to represent different levels of traffic density. Three locations were situated along busy roads: Isiokpo road, Omagwa road, and Airport–Obiri Ikwerre road. Another location chosen as a control was Aluu, a rural settlement characterized by low traffic densities. Aluu is described as sparsely populated, primarily residential, and devoid of industrial activities.

Sample Collection

Soil samples were collected at a depth of 0-10 cm, with sampling intervals of 5, 10, and 15 meters from the roadway. A surface-sterilized auger was used for soil collection, and samples were placed into polythene bags. Additionally, the most dominant plant species present in the area were also collected to assess their ability to accumulate metals. At each distance interval, three soil samples were collected from three distinct points and combined to create composite samples. These composite samples, along with the dominant plant species adopting the method of Markert (1993), the criteria for selection of a species as a biomonitor include: species abundance (Species that are abundant in the sample area are preferable because they are more likely to provide representative data on heavy metal accumulation and expose environmental interference making them effective indicators) and easy identification (species that are easy to identify are advantageous for practical reasons. Researchers and fieldworkers can quickly and accurately identify them during sampling. Easy identification reduces the likelihood of misidentification, ensuring the reliability of the data collected). The collected soil and plant samples were placed in an ice-pack and transported to the laboratory for analysis.

Sample Preparation and Analysis

The soil samples were air dried using a bulb for 1 month to constant weights. The samples were grounded after drying and sieved using a 2mm wire mesh sieve and the coarse particles were discarded. The powdered form was then stored for digestion and subsequent analysis of heavy metals and physiochemical characteristics. Plant samples were washed with distilled water to get rid of all adhering soil and was dried to constant weight. Each dried sample was ground to fine powder using a wearing blender (Model type A 10 Janke and Kunkel GBH). The samples were then stored for digestion and subsequent analysis.

Preparation of Plant Sample:

Two (2g) of 2mm sieved plant sample is taken and placed in a crucible containing the sample which was further incinerated in a furnace at 500°C for 4 hours. The resulting ash is dissolved in 5ml of 20% HCl. Solution and filtered using acid-washed filter paper. The volume of the filtrate is increased to 50ml using distilled water.

Preparation of Soil Sample:

Two (2g) of air-dried soil sample is accurately weighed and transferred into a 250ml conical flask. A measured volume of perchloric acid, nitric acid, and sulfuric acid in a ratio of 1:2:2 is added to the flask. The sample is heated for about 15-20 minutes on a hot plate until white fumes are observed. After cooling, 20ml of distilled water is added, and the mixture is filtered using Whatmann 42 filter paper. The filtrate is diluted to 100ml with distilled water.

Analysis of Heavy Metals:

The extracts from both soil and plant samples are taken for subsequent analysis of cadmium (Cd) and lead (Pb) using an Atomic Absorption Spectrophotometer (PG Instrument AA 500 Spectrophotometer). The concentrations of cadmium and lead in the samples are determined following the methods described by Ebong *et al.,* (2008).

Data Analysis

Data generated were analyzed using the Statistical Package SAS 9.0. The data were expressed in terms of descriptive statistics while the figures were presented with mean values.

Furthermore,

Contamination factor (CF)

The level of contamination of the soil dust by metal is expressed in terms of a contamination factor (CF) calculated as: $CF = Cm\ sample/\ Cm\ Background$ ------------------------------- (1)

Where, the contamination factor CF < 1 refers to low contamination; 1≤ CF < 3 means moderate contamination; 3 ≤ CF ≤6 indicates considerable contamination and CF > 6 indicates very high contamination.

Pollution Load Index (PLI)

Each side was evaluated for the extent of metal pollution by employing the method based on

the pollution load index (PLI) developed by Thomilson *et al.,(*1980) as follows:

PLI = (∏ $CFini$=1)1/n -- (2)

PLI is a useful tool for assessing site quality based on the concentration of pollutants in the environment. The formula for PLI involves the contamination factor (CF), which is calculated using equation 2. The PLI itself is then derived from the geometric mean of the contamination factors for the studied pollutants.

The interpretation of PLI values is straightforward:

- PLI < 1 suggests perfection or very low pollution levels.

- PLI = 1 indicates baseline levels of pollutants.

- PLI > 1 indicates a deterioration in site quality due to higher pollutant concentrations.

While different authors have proposed various methods for calculating PLI, your study has opted for the geometric mean of the contamination factors. This approach helps mitigate the impact of outliers in the data, which could potentially skew the results (Abrahim 2008).

Geo-accumulation Index(Igeo)

To quantify the degree of metal contamination in the roadside dust the geo-accumulation

index (Igeo) (Doung and Lee, 2011) was calculated based on the

$Igeo$ = log2 Cn/1.5Bn --- (3)

Where Cn = metal concentration in the roadside dust and Bn = concentration in unpolluted

soil. Due to the non-availability of the studied heavy metals in background soil dust Igeo was calculated using the global average shale data (Doung and Lee, 2011). The 1.5 is a factor used because of the possible variations of the background data due to lithological variations.

RESULTS

Mean concentration of heavy metals in the various sampled sites. The mean concentrations of soil Pb and Cd along the studied sites are shown in Fig 1and 2. The mean concentrations of soil lead (Pb) and cadmium (Cd) at various sampled sites can be summarized as follows:

Soil Lead (Pb) Concentrations:

- Isoikpo road: - 5m: 60 mg/kg - 10m: 53 mg/kg - 15m: 52 mg/kg

- Omagwa road - 5m: 85 mg/kg- 10m: 84.5 mg/kg - 15m: 56 mg/kg

- Obiri Ikwerre: - 5m: 3.0 mg/kg - 10m: 1.0 mg/kg - 15m: 2.0 mg/kg

Soil Cadmium (Cd) Concentrations:

- Isoikpo road: - 5m: 17 mg/kg - 10m: 16.8 mg/kg - 15m: 15.32 mg/kg

- Omagwa road: - 5m: 16.4 mg/kg - 10m: 15.9 mg/kg - 15m: 14.6 mg/kg

- Obiri Ikwerre: - 5m: 5.2 mg/kg - 10m: 3.5 mg/kg - 15m: 2.46 mg/kg

Generally, there is a decrease in both Pb and Cd concentrations with increasing distance from the pollution source. The highest concentrations of both Pb and Cd are observed closest to the pollution source (5m), with concentrations decreasing at greater distances (10m and 15m). Among the sampled sites, Isoikpo road exhibits the highest initial concentrations of both Pb and Cd. Obiri Ikwerre shows the lowest concentrations of Pb and Cd among the sampled sites, particularly at distances of 10m and 15m. Overall, there are variations in heavy metal concentrations with distance, indicating the influence of distance on contamination levels in the soil samples.

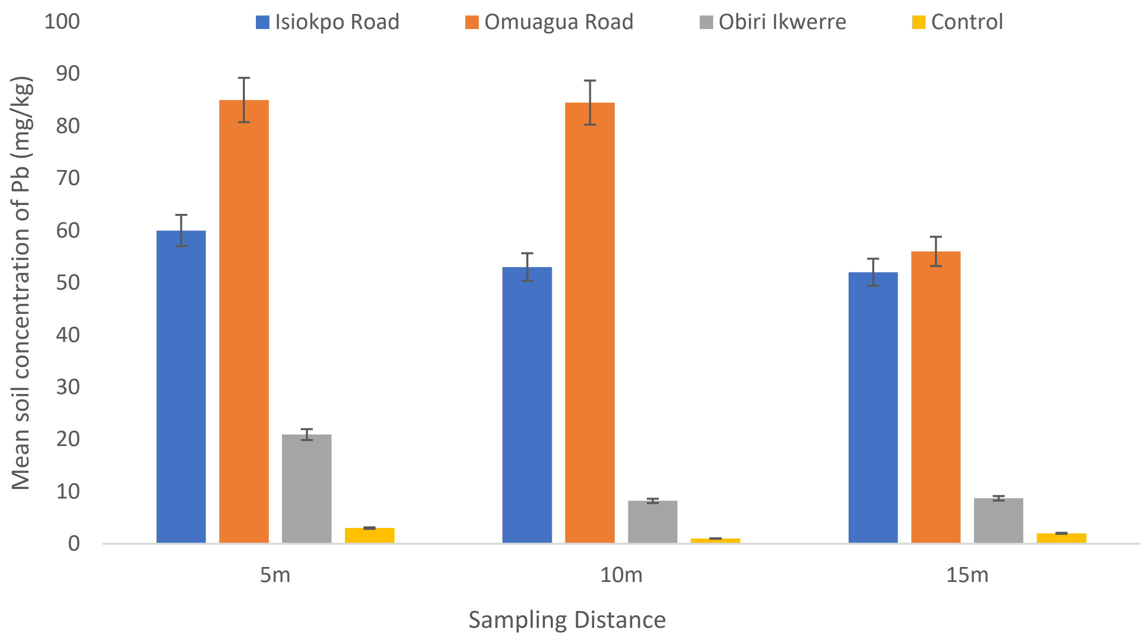

Fig 1. concntration of Pb from the various sampling location and distance

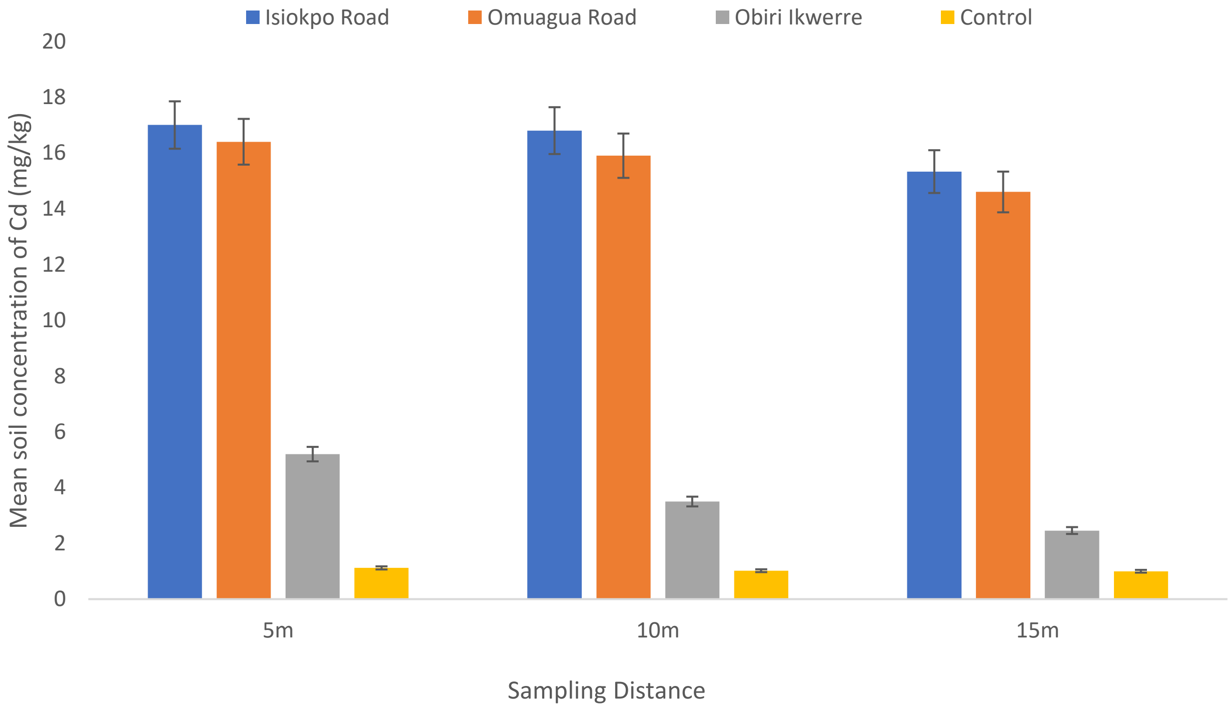

Fig 2. concntration of Cd from the various sampling location and distance

The results from the heavy metal analysis of dominant plant species at different sampling areas reveal interesting patterns of metal accumulation. Isoikpo Road, characterized by Kyllinga sp. as the dominant plant species, exhibited the highest increase in Cd and Pb accumulation. This suggests elevated pollution levels in this area, as indicated by the significant accumulation of both metals in Kyllinga sp. Conversely, the control site with dense car traffic showed a comparatively lower decrease in Cd and Pb accumulation in its dominant plant species, indicating some level of contamination even in areas with high vehicular activity. Among the studied plant species, Sida sp. demonstrated the highest accumulation of Cd and Pb, suggesting its strong affinity for heavy metal uptake from the soil. This highlights the potential of certain plant species to act as efficient bio-accumulators of heavy metals. The observed differences in metal accumulation across various locations indicate variations in pollution levels and the response of plants to heavy metal contamination. The statistical significance of these differences, indicated by a significance level of p=0.05, reinforces the conclusion that the variations in plant metal accumulation are not random but are indeed influenced by the specific environmental conditions at each location Figure 3.

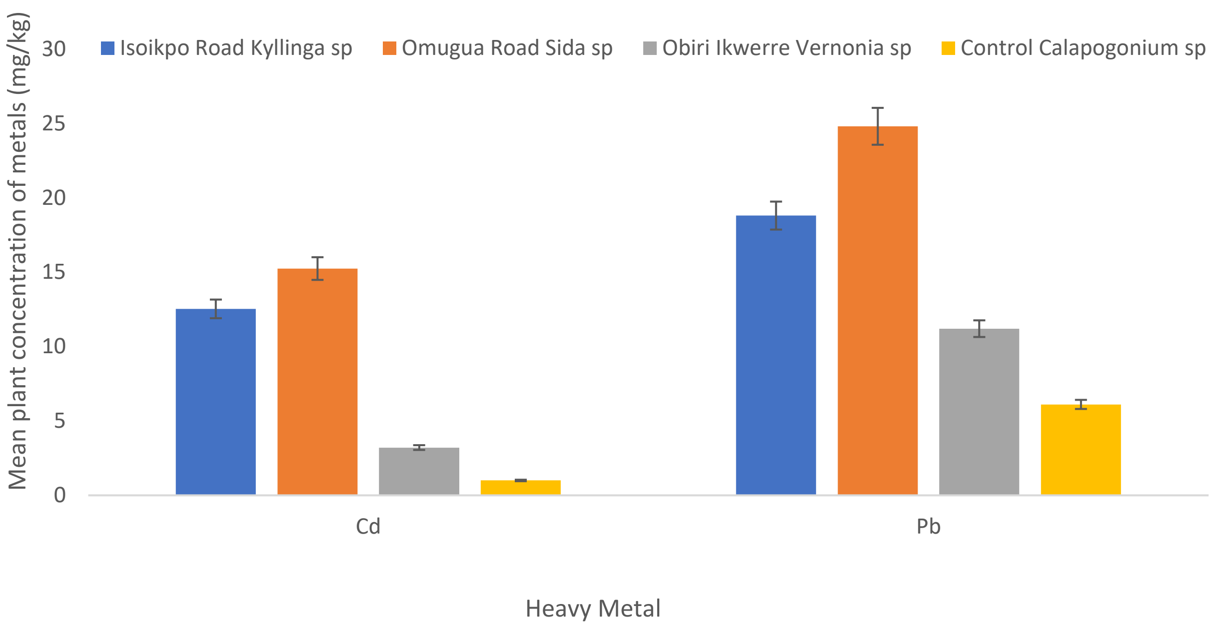

Fig 3. Heacvy metals concentration in the dorminant plants

The contamination factor (CF) calculated for the studied sites (Table 1) indicated the studied sites are highly polluted with Pb and Cd. Contamination Factor for Lead (Pb): 5 meters: Omagwa: CF = 9.4, Isoikpo: CF = 6.6, and Obiri Ikwerre: CF = 2.3 while at 10 meters Omagwa had the highest Pb contamination closely followed by Isoikpo while Obiri Ikwerre showed the least Pb contamination. Similar trend for Pb Cf level was recorded at 15 meters.

The Contamination Factor for Cadmium (Cd) at 5 meters was recorded as :Isoikpo: CF = 15.2, Omagwa: CF = 14.6 and Obiri Ikwerre: CF = 4.6. At 10 meters, Isoikpo had highest Cd contamination while Obiri Ikwerre studied area showed the least Cd contamination and similar trend for Cd Cf level was recorded at 15 meters. The contamination factor (CF) values indicate high levels of pollution with both Pb and Cd at all studied sites. For Pb contamination, Omagwa consistently showed the highest contamination levels across all distances, while Obiri Ikwerre consistently showed the least contamination. Similarly, for Cd contamination, Isoikpo consistently showed the highest contamination levels across all distances, while Obiri Ikwerre consistently showed the least contamination. The trends in contamination factor for both Pb and Cd suggest that pollution levels decrease with increasing distance from the pollution sources. Overall, the contamination factor analysis confirms the presence of significant pollution with both Pb and Cd at the studied sites, with variations observed across different distances and locations.

Table 1. **Results of Pb & Cd contamination factor**

	Pb Contamination Factor			**Cd Contamination Factor**		
Studied sites	**5m**	**10m**	**15m**	**5m**	**10m**	**15m**
Isoikpo	6.6	17.6	8.6	15.2	16.4	15.3
Omagwa	9.4	28.1	9.3	14.6	15.5	14.6
Obiri Ikwerre	2.3	2.7	1.5	4.6	3.43	2.46

The calculated pollution load index (PLI) for the studied sites (Table 2). The pollution load index at 5m, 10m and 15m for both Pb and Cd PLI > 1 which indicates a deterioration in site quality due to higher pollutant concentrations. The maximum concentrations of the studied metals at 5-15 meters were found as Omagwa and Isoikpo for Pb and Cd respectively.

Table 2. Results of Pb and Cd Pollution Load Index

	Pb Pollution Load Index			Cd Pollution Load Index		
Studied sites	**5m**	**10m**	**15m**	**5m**	**10m**	**15m**
Isoikpo	20	53	26	5.0	5.4	5.1
Omagwa	28.3	84.5	28	4.8	5.2	4.9
Obiri Ikwerre	6.9	8.2	4.4	1.5	1.1	0.8

The result in table 3 showed the Geo-accumulation Index for the studied heavy metal and its respective locations.

The Geo-accumulation value > 5 was found for Omagwa sampled unit for Pb at 5-15 meters and 15m for Isoikpo study site (strongly to extremely contaminated), with Isoikpo and Omagwa showing Igeo class 6 (extremely contaminated). Igeo value between 3 was found for Isoikpo at 5 meters (moderately to strongly contaminate), while Igeo class of 0-1 which was found at Obiri Ikwerre at 5-15 meters (uncontaminated to moderately contaminate). Igeo value >3 was found for Isoikpo at 10-15 meters and Omagwa at 10m (moderately to strongly contaminate) for Cd Igeo result. Omagwa and Obiri Ikwerre at 5 and 15 meters showed Igeo class of 0-1 (uncontaminated to moderately contaminate)

Table 3. Results of Pb & Cd Geo-accumulation Index (lgeo)

	Pb Geo-accumulation Index			Cd Geo-accumulation Index		
Studied sites	**5m**	**10m**	**15m**	**5m**	**10m**	**15m**
Isoikpo	3.9	10.6	5.2	2.6	3.3	3.2
Omagwa	5.1	16.9	5.6	2.5	3.11	2.9
Obiri Ikwerre	1.3	1.6	0.8	0.8	0.7	0.5

Discussion

The extensive use of automobiles in developed countries is a major source of heavy metal pollution along roadsides. Vehicles emit pollutants such as lead, cadmium, and zinc through exhaust fumes and wear-and-tear of brakes and tires. These metals can deposit onto roadside soil and plants, where they accumulate over time (Atayese *et al*., 2009). Results showed that heavy metals concentrations in the soil decreased with increase in distance from the road at Omagwa, Isiopko and Obiri Ikwerre. The decrease in roadside heavy metal concentrations with distance from roads might be attributed to several mechanisms such atmospheric dispersion, sedimentation, and vegetation uptake. As heavy metal particles are emitted from vehicles, they disperse and undergo gravitational settling, leading to a decrease in concentration with increasing distance from the source. Furthermore, deposition onto soil and vegetation surfaces contributes to the attenuation of heavy metal concentrations along roadsides. Vegetation plays a vital role in intercepting and accumulating heavy metals, thereby reducing their availability in the surrounding environment. This findings corroborated with Habashi (1992) who reported undesirable concentration of heavy metals in air, water and vegetation alongside. This result also agrees with Yahaya et al (2010) who reported that the heavy metals found in fossil fuel are emitted during combustion process is further transported in air and contaminated soil through accumulation and magnification mechanisms of plants. Results showed that Omagwa road and Isoikpo road at 5- 15 meters had the highest concentration of Pb and Cd respectively. Both lead and cadmium are commonly found in vehicle emissions, particularly those using leaded gasoline. Omagwa road and Isoikpo road might experience heavy traffic flow, especially with vehicles that have inefficient emission control systems, leading to higher levels of these heavy metals in the air. Corroborating this the report that highest value of heavy metals where obtained in the higher traffic sites (Bhattacharya et al., 2011). The highest level of Pb recorded at Omagwa could be attributed to the Pb emitted into the atmosphere from the automobile exhaust while that of Cd level is understandable since tyre wears released Cd into the nearest ecosystem.

Results showed higher concentration of heavy metal in plants species along the roadsides. The dominant plants (Sida sp) grown at Omagwa had highest accumulation of Pb and Cd while the least was found in the reference site in Calapogonium sp. This suggests that there might be variations in the ability of different plant species to accumulate heavy metals, possibly due to differences in their physiology or their ability to absorb these metals from the soil. This corroborated with Amadi et al (2018), reported the uptake of metals from the soil is a function of the metal concentration and availability in the soil. The rate of absorption/uptake is also influenced by the bioavailability of the metals which is in turn determined by both external (soil associated) and internal (plant-associated). The high level of Pb and Cd accumulation in the Sid asp along the roadside is an indication of Pb and Cd of the roadside plants in which if consumed by human might have deleterious effect and even death due to bio-magnifications. When humans consume plants contaminated with high levels of lead and cadmium, there's a risk of health problems due to bio-magnification, where the concentration of these metals increases as they move up the food chain. Chronic exposure to lead and cadmium can lead to various health issues, including organ damage, neurological disorders, and even death in severe cases.

Conclusion

The findings from the 4 road study site highlight the critical need for proactive measures to address heavy metal contamination, particularly in plants along roads with heavy traffic. Cultivating economic plants in such areas poses significant risks to human and animal health due to the accumulation of heavy metals. Implementing effective biomonitoring of the environment is crucial for raising awareness about the dangers of heavy metal pollution. By regularly assessing contamination levels, stakeholders can better understand the extent of the problem and take appropriate actions to mitigate risks. Mitigation strategies should encompass both regulatory and remedial approaches. Monitoring and regulating emissions that contribute to soil contamination are essential steps in preventing further environmental degradation. Additionally, efforts to reduce human exposure to contaminated plants should be prioritized, possibly through public education campaigns and dietary guidelines. Remediation techniques, such as soil restoration, can play a pivotal role in reducing heavy metal levels in affected areas. These methods aim to restore soil health and ecosystem balance, thereby minimizing the long-term impacts of contamination on both environmental and human health. Perhaps heavy metal contamination along roads requires a multi-faceted approach that combines monitoring, regulation, public awareness, and remediation efforts. By taking proactive measures, communities can safeguard their health and the environment from the adverse effects of heavy metal pollution.

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