DETERMINATION OF SELECTED HEAVY METALS CONTENT OF SUBSURFACE SOILS IN OWERRI – UMUAHIA HIGHWAYS

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ABSTRACT
This research investigates the concentration levels of selected heavy metals content, Lead (Pb), Cadmium (Cd), Chromium (Cr), and Zinc (Zn) in subsurface soil samples collected from Owerri- Umuahia highways location in Imo State, Nigeria. Soil samples were taken at depths of 0 – 15 cm, and 15 – 30 cm, and analyzed using Atomic Absorption Spectrophotometer (AAS). Results revealed varying concentrations of heavy metals across the different sites, and depths, with some values exceeding permissible limits recommended by regulatory bodies. Data obtained were subjected to analysis of variance (ANOVA), means were separated and standard deviation calculated. The findings suggest potential environmental and health concerns due to anthropogenic activities such as waste disposal, vehicular emissions, and industrial operations. This underscores the need for continuous monitory and remediation strategies to manage soil contamination in urban environments. The outcome with the control, shows that there was an increased concentration of heavy metal along Owerri -Umuahia highway while, a decline of soil heavy metal was observed with depth for each site.

Keywords: *heavy metals, concentration, highways, soils.*

INTRODUCTION

Heavy metal is any metallic substance that has a relatively high density and a low concentration, it is toxic. Some of such heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), titanium (Ti) and lead (Pb), etc (Obineche et al., 2020). Similarly, Cameron et al. (1997) noted that, heavy metals are widely recognized as group of elements with atomic density greater than 6.0 g/cm^3, they tends to bioaccumulate and cannot be degraded nor destroy. In the same vein, Pleisnicar and Zupanic (2005) posit that, heavy metals occur naturally in the ecosystem with large variations in concentration. In modern times, anthropogenic sources of heavy metals pollution have been introduced in the ecosystem. Additionally, heavy metals are found in nature, they are constituent of rock and sediment in natural conditions. Heavy metals enters the environment as a result of both artificial and natural activities or sources, the natural process involves the breakdown of mineral and translocation of the product accession from storms, volcanic eruption (Wadu et al., 1997).

Soil is a vital resource for producing the food and fibre needed to support an increasing world population (Obineche et al.,2022). Furthermore, soil is a dynamic resource that supports plant life. It is made of different-sized minerals particles, organic matter, and numerous species of living organisms. Oriaku and Obineche (2022) noted that, soil has biological, chemical, and physical properties, some of which are dynamic and can change in response to how the soil is managed. Soils are classified as natural bodies on the basis of their profile characteristics. In addition, Obineche et al.(2022) noted that, soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. Changes in the capacity of the soil to function are reflected in soil properties that change in response to management or climate.

Roads are important infrastructure that plays a major role in stimulating social and economic activities of any nation. However, road construction has also resulted in heavy environmental pollution (Baid et al., 2008). Environmental pollution is any discharge of substance into water, soil as well as air that cause acute or chronic which is detrimental to the earth's ecological balance in addition to reducing the quality of life. Pollution by automobile constitutes severe environmental hazards to most urban cities and soil adjacent to highways. Main sources of pollution include corrosion of metal parts, fuel or oil spillage, chemical, waste materials, dust from tyre attrition, gaseous fumes from vehicular exhaust (Manta et al., 2002). Consequently, Pleisnicar and Zupanic (2005) noted that, automobile releases metals into the environment mainly through cars wears such as tyres, brakes, and engines, leaking oil and corrosion. These metals include lead, cadmium, copper, and zinc (Van Bohemen and Van De Laak, 2003). Concentrations of these heavy metals may vary depending on traffic volume, road conditions, physical state of vehicles and season (Abida et al., 2009). They continued to state that heavy metal concentration increases with number of vehicles, traffic flow and traffic density. Fakayode and Owolabi (2003) observed that, high metal concentrations at low vehicular speed which is attributed to increase exhaust fume emissions with lengthier time. Due to increase wear and tear from tyre abrasion and attrition, rough road often intensify metal concentration (Akinula and Adedeji, 2007) metals released by automobiles are transported into the air and subsequently transported into the soil by rainfall or wind (Jankainde et al., 2008). According to Abida et al. (2009) due to their persistence and non-biodegradation, these metals accumulate in soil. Additionally, Chesworth (2008) defines soil as a mixture of organic matter, minerals, gases, liquids and organisms that together support life Soil is a product of several factors; the influence of climate, elevation, orientation, and slope of terrain, organisms; as well the soils parent materials interacting over time. According to Ponge (2015) it continually undergoes development by way of numerous physical, chemical and biological processes, which include weathering with related erosion. In the same vein, Jankainde et al. (2008) posited that, soil metal concentrations are affected by soil properties. They continued to state that, the chemistry of heavy metals depend on factors such as metrological conditions, chemical and mineralogical composition of rocks, soil texture, pH, sorption capacity and organic matter.

In Owerri, details available regarding metal status of soils adjustment to most highways is scares and rare, to this concern this article critically determines some heavy metals content of subsurface soils in Owerri-Aba highways, their effects on soil adjacent to them.

MATERIALS AND METHOD

The study area is Owerri, Imo State Nigeria. It is located between latitudes 5' 48" E and 7' 03" N, and longitudes 5' 3"E, and 9' 27" N. it has six major entrances and exit routes which are Okigwe, Orlu, Umuahia, Aba, Onitsha and Port Harcourt roads (Statistics and Planning Owerri Municipal, 2006). It was characterized by a main annual precipitation ranging from 2000 – 2500 mm, a mean temperature ranging from 26^0C – 28^0C and humidity ranging from 70% - 80% (Obineche et al., 2023).

Climate and Temperature

The major seasons experienced in the city are the dry and rainy seasons. The dry period starts from October and ends on March, while the rainy seasons starts from April to September. The area is characterized by a high surface temperature which varies from day to day and season to season. The mean temperature annually is 30^0C, while the annual temperature is 37^0C in Owerri Municipal. The annual relative humidity is 87% and the mean relative humidity is 73% respectively (Obineche et al., 2023).

Geology and Geomorphology

Soils of the study area are derived from coastal plain sand (Benin formation) Orajaka (1975). The following stratigraphic units underlie the area, though the greater proportion of the land surface is flat and gentle undulating topography with good drainage system (Onu et al., 2012). The climate is a humid tropical forest ecosystem; it is cold during the raining season.

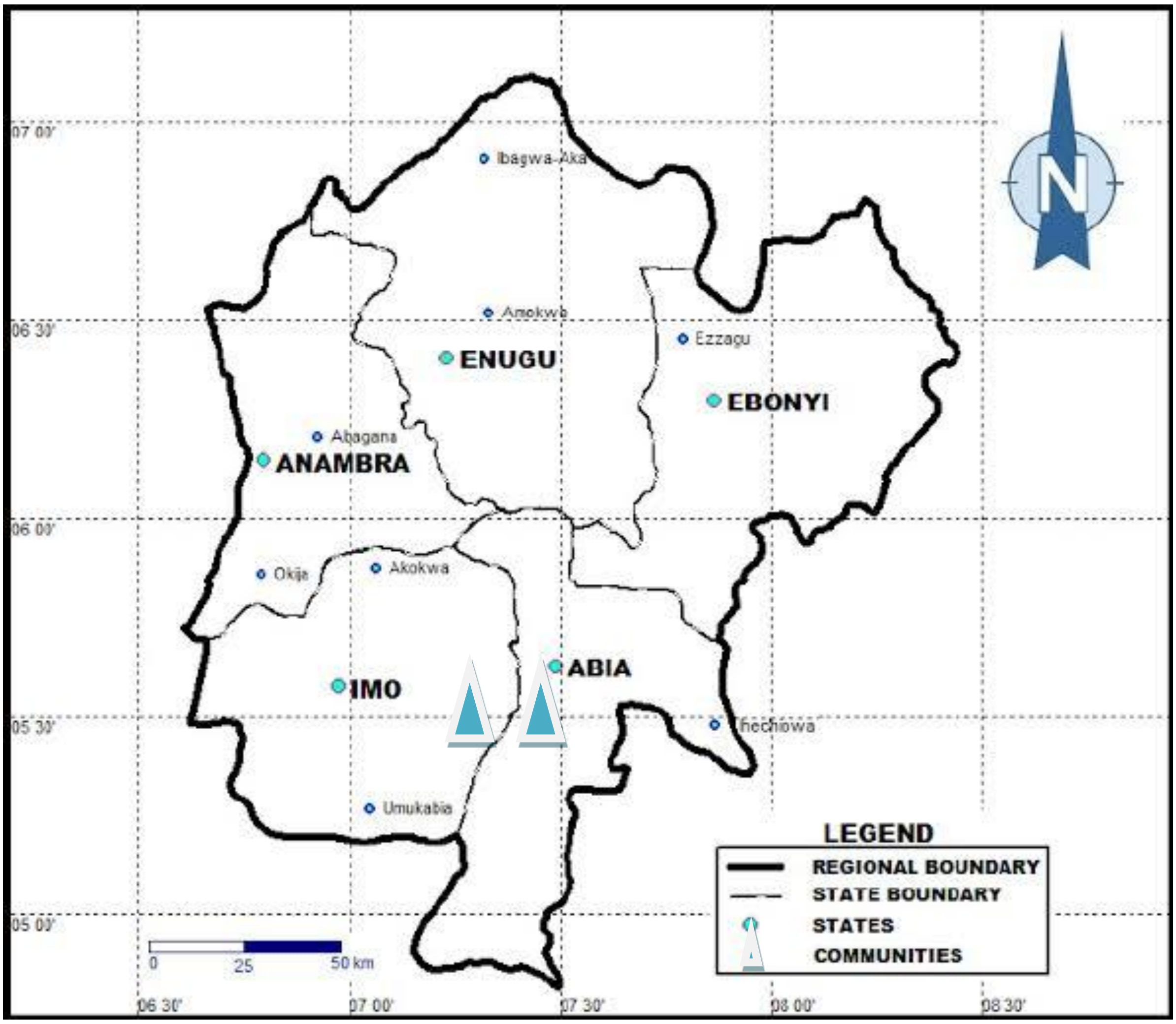

Figure 1: Map of Imo State Showing the study area (Source: Google map)

Fieldwork

A reconnaissance visit was made to the study area, and materials such as location map, topographic map, geology maps, and Munsell colour chart were used hand-held global positioning system receiver (Gamin Ltd Kansas) was used to georeference sampling site. The soil is mainly ultisols, derived from weathering of one major geologic material, coastal plain sand. Inceptisols and Entisols are scantly distributed in the agro-ecology. The lateritic soil type predominates and soil derived from the coastal plain sand (Oformata, 1975).

Field Operations

The first phase of the operation consists of planning, organization of the field work and collection of materials for the study. A review of the existing published literature as to obtain data on map, location, climate, geology and vegetation. Soil samples were collected from 0 – 15 cm and 15 – 30 cm from a distance of 0 – 50 m and 50- 100 m from the road. A total of four samples were collected at the experimental site. The highway under study was Owerri- Umuahia road, and a non high way (control) Egbeada Village road in Mbaitoli Local Government Area. The soil samples obtained at the site were analyzed in the laboratory using standard methods while, atomic absorption spectrophotometer (AAS) were used to determine the heavy metal content of the soil samples.

Laboratory Analysis

The soil samples were analyzed for certain selected properties that are necessary for proper scientific classification of the soils. These include physical properties such as particle size distribution, moisture content, bulk density, and porosity. Chemical properties such as soil pH, organic carbon, total nitrogen, available phosphorus, total exchangeable bases (Ca^{2+}, Mg^{2+},K^{2+}, Na^{2+}), exchangeable acidity (Al^{3+}, H^{+}), cation exchangeable capacity (CEC) and heavy metal concentration (Pb, Zn, Cd, and As). The modified hydrometer method was utilized in the determination of the particle size distribution as posited by Gee and Or (2002). Silt clay ratio was obtained by calculation, soil moisture content was determined gravimetrically by weighing an oven drying soil sample collected from the field at 105^{o}C until a constant weight was obtained (Obi, 1990), Bulk density was determined using the core samples as noted by (Grossman and Reinsch, 2002). Soil pH was determined by the use of distilled water on Beckman Zeromtic pH meter using a glass electrode at a 1:2:5 soil water ratio (Thomas, 1996), exchangeable acidity and organic carbon (OC) was determined by an unbuffered saturated solution such as in KCL at the pH of the soil (Mclean, 1982). Total exchangeable bases was determined from the soil in 1 m ammonium acetate solution (Thomas, 1996), heavy metal concentration (Pb, Zn, Cd, As) was determined using Perkin Elmer method 2280/ 2380 Atomic Absorption Spectrophotometer.

Data and Statistical Analysis
Data obtained were subjected to analysis of variance (ANOVA), while treatments means were separated and standard deviation calculated, in addition simple linear correlation were used to study the relationships between heavy metal content and some selected soil properties (Onuh and Igwemma, 2001).

RESULTS AND DISCUSSION
The results of the soil physical properties are shown in Tables 1 and 2. The mean sand fraction of Owerri – Umuahia values ranged from 82.60 to 84.25% for 50 m and 100 m from the highway respectively. The mean silt value ranged from 10.00 to 12.00% for 50 m and 100 m away from the highway. While, the mean clay values ranged from 3.75 to 7.40% for 50 and 100 m away from highway respectively. The mean sand fraction values of Egbeada (control), ranges from 83.80 to 72.75%, whereas, the mean silt values ranges from 11.20% to 11.50% for 50 m and 100 m, respectively.
Furthermore, Table 2 shows the result of Owerri – Umuahia road at 100m away from the highway. The means values for moisture content, bulk density and porosity was obtained as, 8.5%, 1.44gmc^{-3}, and 46% respectively.

Table 1: Soil physical properties of 0-50 m away from the road

Location	Soil Depth (cm)	Moisture Content (%)	Bulk Density (gmc^{-3})	Sand (%)	Silt (%)	Clay (%)	Textural Class	Porosity (%)
Owerri-Umuahia	0 - 15	12.50	1.62	83.50	12.50	4.00	S	38.90
	15 - 30	14.50	1.65	85.50	11.50	3.50	S	37.80
	Mean	13.50	1.64	84.25	12.00	3.75	S	38.35
	Std. Dev.	1.41	0.02	1.41	0.71	0.35		0.78
Egbeada(control)	0 - 15	19.50	1.20	79.60	6.00	14.40	SL	54.80
	15 - 30	20.00	1.23	88.00	4.00	8.00	S	53.60
	Mean	19.75	1.22	83.80	5.00	11.20	SL	54.20
	Std.Dev.	0.35	0.02	5.94	1.41	4.53		0.85

Table 2: Soil Physical properties of 50 – 100m away from the main road

Location	Soil Depth (cm)	Moisture Content (%)	Bulk Density (gmc^{-3})	Sand (%)	Silt (%)	Clay (%)	Textural Class	Porosity (%)
Owerri-Umuahia	0 - 15	10.00	1.42	80.00	10.00	10.00	SL	46.00
	15 – 30	7.00	1.46	85.20	10.00	4.80	S	45.00
	Mean	8.50	1.44	82.60	10.00	7.40	SL	46.00
	Std. Dev.	2.12	0.03	3.68	0.00	3.67		0.71
Egbeada(control)	0 – 15	16.50	1.21	70.50	16.50	13.00	SCL	54.00
	15 – 30	14.20	1.24	75.00	15.00	10.00	SL	53.00
	Mean	15.35	1.23	72.75	15.75	11.50	SL	54.00
	Std. Dev.	1.63	0.02	3.18	1.06	2.12		0.71

Soil Chemical Properties
The results of the chemical properties of Owerri – Umuahia highway is shown in Tables 3 and 4, respectively. The mean pH values in H_2O are 4.25 and 4.56 for 50 m and 100 m away from the highway. While, the organic matter and organic carbon contents ranges from 1.16% to 1.69%, and 0.55% to 0.95% for 50 m and 100 m, respectively. The available P has a mean value from 2.45 to 3.24 (mgkg^{-1}) for 0 – 50 m, and 50 m – 100 m away from highway. Subsequently, ECEC values ranges from 3.45 to 4.09, and the base saturation values ranges from 37.68 to 44.24,

respectively. Egbeada (control) has the mean value of pH in H_2O ranged from 5.00 to 5.64. At the same time as, 1.56 to 1.91% and 0.91 to 1.11% was recorded for organic matter and organic carbon for 0 – 50 m and 50 to 100 m, respectively. Available P, and ECEC has mean values of 5.96 to 6.10 (mgkg^{-1}), and 4.83 to 5.41, while base saturation has its mean value of 48.45 to 77.26. In Table 4, Egbeada has the highest value of organic matter while, in table 3 Owerri – Umuahia has the highest value of organic matter. Egbeada has the highest pH value in tables 3 and 4, while Owerri - Umuahia has the least value of pH, indicating high soil acidity along Owerri - Umuahia highway. The value of total nitrogen is significantly different in all the sites.

Table 3: Soil Chemical Properties from 0 – 50 m

Location	Soil Depth (cm)	pH H_2O	pH KCL	OC (%)	OM (%)	TN (%)	AV.P Mgkg^{-1}	BS (%)	Ca^{2+}	Mg^{2+}	K^+	Na^+	Al^{3+}	H^+	ECEC
Owerri - Umuahia	0 – 15	4.40	3.50	1.25	2.33	0.06	2.42	40.13	0.54	0.60	0.04	0.73	1.52	1.32	4.76
	15 – 30	4.10	3.48	1.03	1.78	0.07	2.10	37.08	0.50	0.50	0.02	1.63	1.50	1.30	4.45
	Mean	4.25	3.49	1.19	2.11	0.07	2.26	38.61	0.52	0.55	0.03	1.68	1.52	1.31	4.61
Egbeada	0 – 15	5.20	4.80	0.95	1.64	0.19	6.70	77.45	1.72	1.85	0.29	0.58	0.72	0.59	5.73
	15 – 30	4.80	4.30	0.86	1.48	0.13	5.50	77.69	1.52	1.62	0.26	0.50	0.60	0.55	5.02
	Mean	5.60	4.55	0.91	1.56	0.16	6.10	77.26	1.62	1.74	0.28	0.54	0.66	0.57	5.41
	Std. Dev.	0.48	0.65	0.17	0.37	0.06	2.27	22.53	0.64	0.69	0.14	0.52	0.49	0.43	0.55

OC=organic carbon, OM = organic matter, ECEC= effective cation exchange capacity, TN= total nitrogen, AV.P= available phosphorous, Ca^{2+} =calcium, Mg^{2+} = magnesium, Na^+ = sodium, Al^{3+} = aluminum, H^+ = hydrogen, BS= base saturation, K^+ = potassium, Std. Dev= Standard Deviation

Table 4: Soil Chemical Properties from 50 – 100 m

Location	Soil Depth (cm)	pH H_2O	pH KCL	OC (%)	OM (%)	TN (%)	AV.P $Mgkg^{-1}$	BS (%)	Ca^{2+}	Mg^{2+}	K^+	Na^+	Al^{3+}	H^+	ECEC
Owerri - Umuahia	0 – 15	4.82	4.41	0.72	1.24	0.20	3.85	40.95	0.32	0.72	0.07	0.52	1.23	1.12	3.98
	15 – 30	4.30	4.15	0.62	1.07	0.15	2.20	38.10	0.21	0.60	0.02	0.42	1.02	1.01	3.28
	Mean	4.50	4.28	0.67	1.16	0.18	3.03	39.73	0.27	0.66	0.05	0.47	1.30	1.07	3.65
Egbeada	0 – 15	5.86	5.20	1.20	2.07	0.32	5.72	51.33	0.82	0.92	0.32	0.65	1.47	1.20	5.28
	15 – 30	5.42	5.02	1.01	1.74	0.21	6.20	46.12	0.72	0.52	0.22	0.50	1.22	1.07	4.25
	Mean	5.64	5.11	1.11	1.91	0.27	5.96	48.45	0.77	0.72	0.27	0.58	1.35	1.14	4.83
	Std. Dev.	0.68	0.50	0.27	0.46	0.07	1.83	5.84	0.30	0.17	0.14	0.10	0.18	0.08	0.83

OC=organic carbon, OM = organic matter, ECEC= effective cation exchange capacity, TN= total nitrogen, AV.P= available phosphorous, Ca^{2+} =calcium, Mg^{2+} = magnesium, Na^+ = sodium, Al^{3+} = aluminum, H^+ = hydrogen, BS= base saturation, K^+ = potassium, Std. Dev= Standard Deviation

Soil Heavy Metals Content

The results of soil heavy metal contents as obtained experiment for Owerri – Umuahia highway has the mean value of Lead (Pb) ranged from 0.44 to 1.36 ($mgkg^{-1}$) for 0 – 50 m and 50 – 100 m away from highway. Arsenic (As), Copper (Cu), and Mercury (Hg) mean values ranges from 0.38 to 1.63 ($mgkg^{-1}$), 0.30 to 1.04 ($mgkg^{-1}$), Zinc (Zn) 1.13 to 2.18 ($mgkg^{-1}$), and 0.34 to 0.73 ($mgkg^{-1}$), respectively. In the same vein, Egbeada non highway for 0 – 50 m, and 50 – 100 m has the mean value of Lead (Pb) ranged from 0.04 to 0.12 ($mgkg^{-1}$) for 0 – 50 m and 50 – 100 m away from highway. Arsenic (As), Copper (Cu), and Mercury (Hg) mean values ranges from 0.04 to 0.46 ($mgkg^{-1}$), 0.28 to 1.67 ($mgkg^{-1}$), Zinc (Zn) 0.85 to 2.11($mgkg^{-1}$), and 0.07 to 0.20 ($mgkg^{-1}$), respectively. Comparing the outcome with the control, it shows that there was an increased concentration of heavy metal along Owerri -Umuahia highway while, a decline of soil heavy metal was observed with depth for each site. The heavy metal contents decreases with depth, this is in agreement with Mbila et al. (2001) that the concentration of heavy metals studied exceeded the permissible limits given by the World Health Organization (2006) in the highway except for the Egbeada (control).

Relationship between Heavy Metal Content and Some Selected Soil Properties

Heavy metals (Pb, As, Zn, Cu, Hg) studied correlated positively with moisture content, bulk density, effective cation exchange capacity, and exchangeable acidity, this implies that increase in heavy metal contents increase the moisture content, bulk density, ECEC vice versa. Some correlated negatively with heavy metal content such properties like organic carbon, available phosphorous, total nitrogen, sand content, and clay respectively. This means that an increase in heavy metal contents decreased the soil properties.

Table 5: Relationship between heavy metal contents and selected soil properties

	Pb	As	Zn	Cu	Hg
Sand	-0.32	-0.52	-0.42	-0.15	-0.16
Clay	-0.72	-0.62	-0.16	-0.25	-0.17
Moisture content	0.62	0.60	0.52	0.72	0.32
Bulk density	0.51	0.42	0.78	0.17	0.05
Organic carbon	-0.72	-0.70	-0.52	-0.16	-0.67
Available phosphorous	-0.50	-0.65	-0.42	-0.72	0.55
Total nitrogen	-0.32	-0.44	0.92	-0.77	-0.45
ECEC	0.65	0.55	0.72	0.25	0.15

CONCLUSION

This study emphasizes on the density of the presence of elevated levels of some heavy metals such as Pb, Cd, Cr, and Zn in subsurface soils across the selected locations in Owerri- Umuahia, which highlights a growing environmental concern. The higher concentrations at certain depths suggest that these contaminants may be migrating into deeper soil layers as observed in the study, potentially impacting groundwater quality. Anthropogenic activities are the primary contributors to the observed contamination. Therefore, there is a critical need for environmental awareness, sticker waste management practices, and periodic monitoring to mitigate the long- term effects of heavy metal pollution on public health and ecosystem. There should be periodic assessment of soil and water quality along major highways and industrial areas in with such harmful outcome to track changes in heavy metal concentration and prevent potential environmental degradation in the country.

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