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Research Article

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Spatial Distribution of Lead in Soil in Uyo Metropolis, Akwa Ibom State, Nigeria

***Michael Eyibio Okon, *†Selegha Abrakasa**

*Department of Geology, University of Port Harcourt, Port Harcourt, Nigeria
†Centre for Petroleum geosciences, University of Port Harcourt, Port Harcourt, Nigeria

Abstract An investigation was conducted to model the distribution of lead in surface soil in Uyo metropolis. The study entails determination of background concentration, contamination (if any), delineate contamination pathways and recommend measures toward contamination mitigation and remediation of contaminated areas. Concentrations of lead (in ppm) were determined using discrete tile soil samples from different points within the metropolis. Methodology applied were the standard sampling method (grid sampling) using the GPS. Analyses were carried out using the Atomic Absorption Spectrophotometry (AAS), an American Public Health Association – APHA (3111C) method. Corroborating the Uyo Urban map and the modeled contour map indicates that concentration of lead within the area of study ranges from <0.001 ppm to 8.9 ppm. The study further indicates that concentrations of lead are high along both sides of the road (Abak Road) (5.5ppm-7.5ppm); and higher within the Automobile village and the back of the State Secretariat complex (7.5ppm and above). Within the residential areas and bushes, concentrations are far lower (3.5ppm and below). The presence of lead within this area is not due to mineralization or mining activity, but due majorly to indiscriminate disposal of used automobile oil, others sources are vehicular emission along the road. Reduction in the use of leaded fuels, construction of proper waste disposal facilities and treatment of drinking water sources are some of the steps to mitigating the effects of lead on humans within the area.

Keywords Lead, Uyo, Spatial distribution, soil

Introduction

One of the ways man has mismanaged the earth's environment is the indiscriminate dumping of domestic, industrial and agricultural waste. As materials and substances area not static, but constantly cycling and recycling, this waste has more than a thousand routes. Some of these routes directly and indirectly link with biological systems of plants, animals and humans. Such links have negative significance as many of these substances are known to be non-biodegradable and carcinogenic. Heavy metals including lead fall within these non-biodegradable and carcinogenic substances in nature. But, these are the very substances which are indiscriminately and ignorantly dumped all around our environment especially in the cities.

Heavy metal pollution of the environment had since been identified as a public health hazard [1]. The major source of lead in roadside soil, dust fall and vegetable, has been attributed to the use of leaded petrol-driven vehicles. Other sources are batteries and electric gadgets. Lead is also used in the manufacture of products like plastics, paints and other evaporates. Lead content of gasoline sold in African countries is now among the highest in the world; with typical concentrations found in the range 0.5 – 1.0g/l [2]. The average lead content of regular gasoline in Nigeria is about 0.14g/l. These are far higher than the WHO permissible concentration of 0.05mg/l [1].

Automobile mechanic shops are found virtually everywhere in Uyo metropolis, with high occurrences around 'mechanic village' along Abak Road, Uyo. Such places generate and dispose large amounts of waste and used substances like petrol, diesel, engine oil, paint residue, varnishes, etc., into the environment during repair and washing of automobile parts. Also, major highways in Uyo carry thousands of vehicles per day, but during the rush hours traffic speed typically decreases to less than 10km/hr for most roads which are clogged with cars, trucks and tricycles. The poorly maintained vehicles emit blue or black plumes of lead odour and un-burnt hydrocarbons resulting in a large fraction of the lead in gasoline being released to the soil by the roadside and into the atmosphere carried by dust [3-4]. These emissions are dispersed to the roadsides by some physical and chemical factors including rain, wind and soil erosion. Human activities in the likes of street cleaning also aid in the dispersion of lead in the soils of Uyo. With leaching, these substances find their way into ground water and streams. Lead washes through the soil and is absorbed by plants and vegetables into their biological systems. Further percolation moves the lead into ground water systems and streams where humans directly source drinkable water [5-6]. The short-term and long-term effects of these metals in humans and other biological systems could be deathly.

Uyo municipal city hosts the automobile village, popularly known as 'mechanic village.' Often, used oil, fuels, batteries and paints from vehicles and other machinery, are disposed indiscriminately on the surface, contaminating surface soil and surface water flow network. This study seeks to investigate the degree of contamination of surface soil within the 'mechanic village' in Uyo metropolis relative to other areas, and evaluate contamination margin within the impacted mechanic village soil; relative to control samples from other parts of Uyo metropolis. The study shall also determine the background concentration of lead contained in the soil of Uyo municipality; delineate or deduce contamination pathways from the model; recommend steps to mitigating the processes of contamination; and also suggest possible remediation measures.

2. Study Location / Geologic Setting

Uyo municipality lies within the South-South region of Nigeria, also known as the Niger Delta, along the Gulf of Guinea in West Africa. It is the administrative capital of AkwaIbom State of Nigeria (Fig. 1).

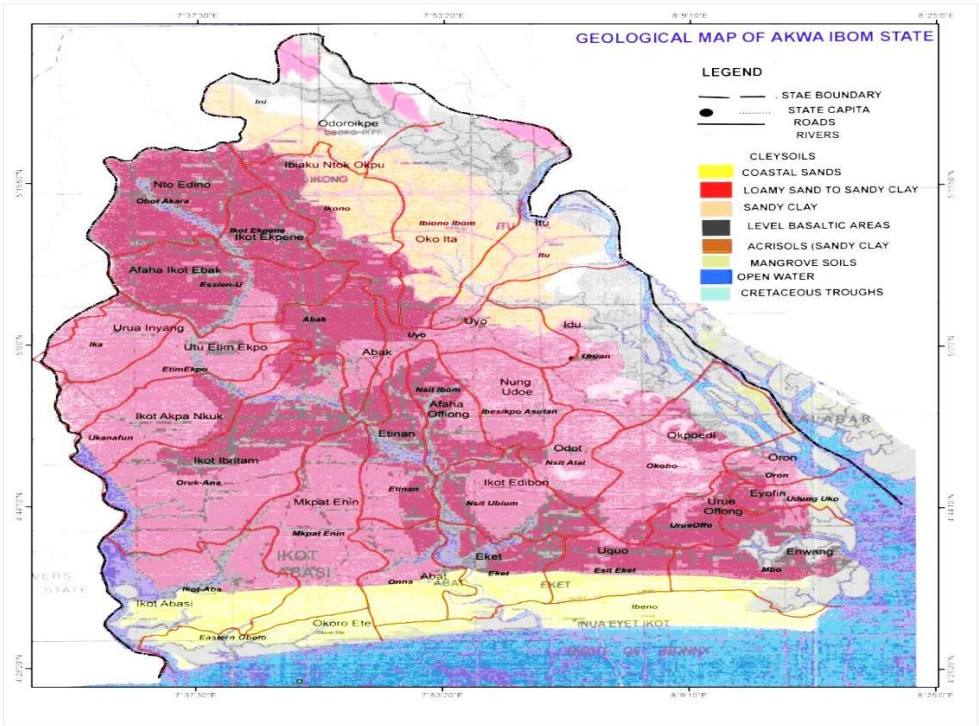

Figure 1: Geological Map of Akwa Ibom State showing the Capital City of Uyo

The terrain is virtually flat to gently undulating, sloping generally in the direction of the southern part of the state. Elevation is from about 40 to 120 m. The mean annual rainfall is about 250mm while the mean

temperature is 27 °C with high relative humidity (annual mean 83%) throughout the year [7]. Within the study area, particular attention is paid to areas around Abak Road extending from the State Secretariat Plaza to the Federal Secretariat (07°53'35 "E - 07°54'25 "E and 5°1'10 "N - 5°1'45 "N)(Fig.4). This area is virtually flat, ranging in elevation between 39m and 69m (see Table 1). Within this area, the Automobile Village (or Mechanic Village) is located.

The geological succession in Akwa Ibom State consists of mostly shales, sandstones, sands and clays representing the transgression and regression which characterized the development of the Southern Sedimentary Basin [8-10]. The deltaic and continental Bende-Ameke group represents the regressive phase which is still continuing. In Akwa Ibom State, groundwater is ubiquitous. Uyo metropolis lies on the extensive alluvial sand deposits of the Benin Formation. It is basically coastal plain sand with minor deposits of alluvium or clay at some locations. Some descriptions are sandy-clay, clay-sand, or loamy-sand.

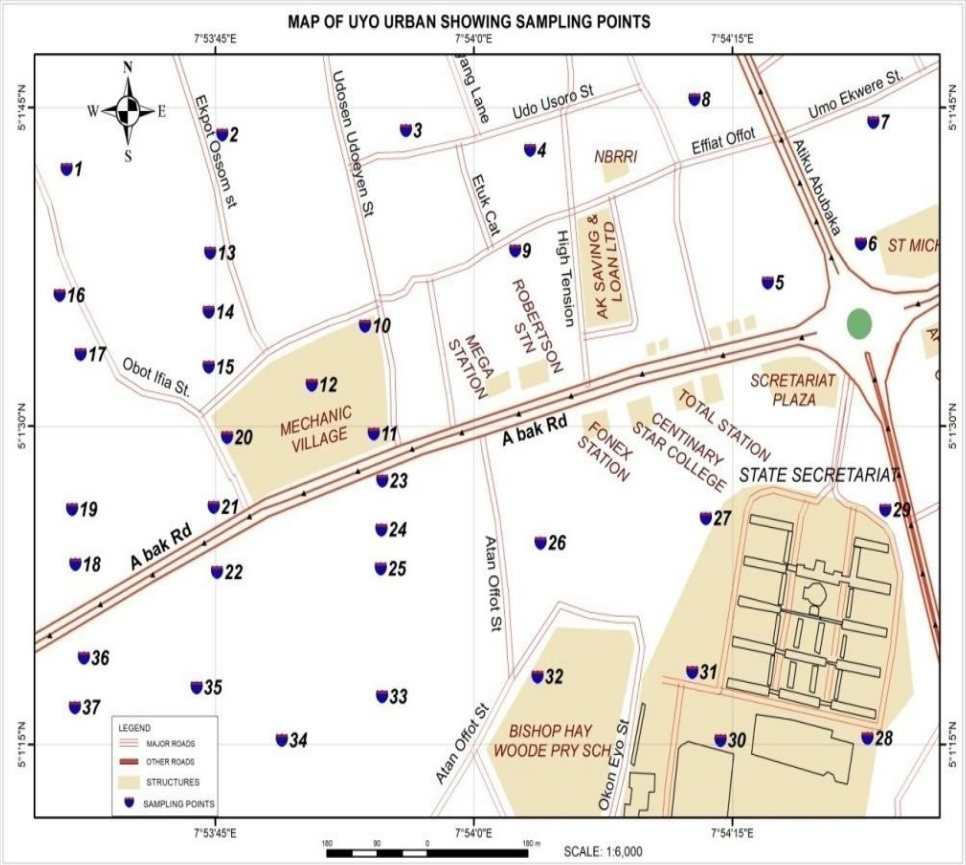

Figure 2: Map of Uyo showing sample points

Sampling and Analytical Methods

Grid method of sampling was used (Fig. 2). This was necessary to obtain an even spread of sample points over the area. Tools and equipment used during sampling and data acquisition included:

Base map (map of Uyo municipality showing study area), GPS (Garmin GPS map 78s), hand trowel, labeled sample bags, field notebook/pencil, and digital camera.

N/B: The GPS used has a ±3m level of accuracy.

Tile samples (about 200g each) were also obtained at each point, 6 inches below the ground surface using the hand trowel. Each sample was carefully wrapped in a cellophane bag labeled and kept for that purpose. A total of 37 data (samples and coordinates) were taken from the study area. The entire samples were carried in a large sack to the laboratory for analysis.

Laboratory method used was the Atomic Absorption Spectro-photometry (AAS) AA500 PG; an American Public Health Association - APHA (3111 C) method. Result of the analysis is presented in Table 1.

Table 1: Laboratory Analysis Results

S/NO	Sample ID	Methods	Pb (mg/kg)
1.	Sample1	APHA 3111C	<0.001
2.	Sample 2	APHA 3111C	<0.001
3.	Sample 3	APHA 3111C	6.900
4.	Sample 4	APHA 3111C	3.850
5.	Sample 5	APHA 3111C	7.150
6.	Sample 6	APHA 3111C	6.300
7.	Sample 7	APHA 3111C	<0.001
8.	Sample 8	APHA 3111C	<0.001
9.	Sample 9	APHA 3111C	<0.001
10.	Sample 10	APHA 3111C	8.600
11.	Sample 11	APHA 3111C	4.650
12.	Sample 12	APHA 3111C	8.050
13.	Sample 13	APHA 3111C	2.850
14.	Sample 14	APHA 3111C	3.600
15.	Sample 15	APHA 3111C	5.200
16.	Sample 16	APHA 3111C	5.450
17.	Sample 17	APHA 3111C	4.850
18.	Sample 18	APHA 3111C	<0.001
19.	Sample 19	APHA 3111C	<0.001
20.	Sample 20	APHA 3111C	5.450
21.	Sample 21	APHA 3111C	7.150
22.	Sample 22	APHA 3111C	4.850
23.	Sample 23	APHA 3111C	7.150
24.	Sample 24	APHA 3111C	6.300
25.	Sample 25	APHA 3111C	<0.001
26.	Sample 26	APHA 3111C	<0.001
27.	Sample 27	APHA 3111C	3.850
28.	Sample 28	APHA 3111C	8.900
29.	Sample 29	APHA 3111C	4.850
30.	Sample 30	APHA 3111C	5.050
31.	Sample 31	APHA 3111C	<0.001
32.	Sample 32	APHA 3111C	3.150
33.	Sample 33	APHA 3111C	5.450
34.	Sample 34	APHA 3111C	6.300
35.	Sample 35	APHA 3111C	5.750
36.	Sample 36	APHA 3111C	6.300
37.	Sample 37	APHA 3111C	5.850

The GPS data and the laboratory result (Table 1) were imputed into computer software called Minitab Version 16. This software plots the laboratory results on the location map in form of contours, using the given coordinates. A concentration contour map was produced as shown in Figure 3.

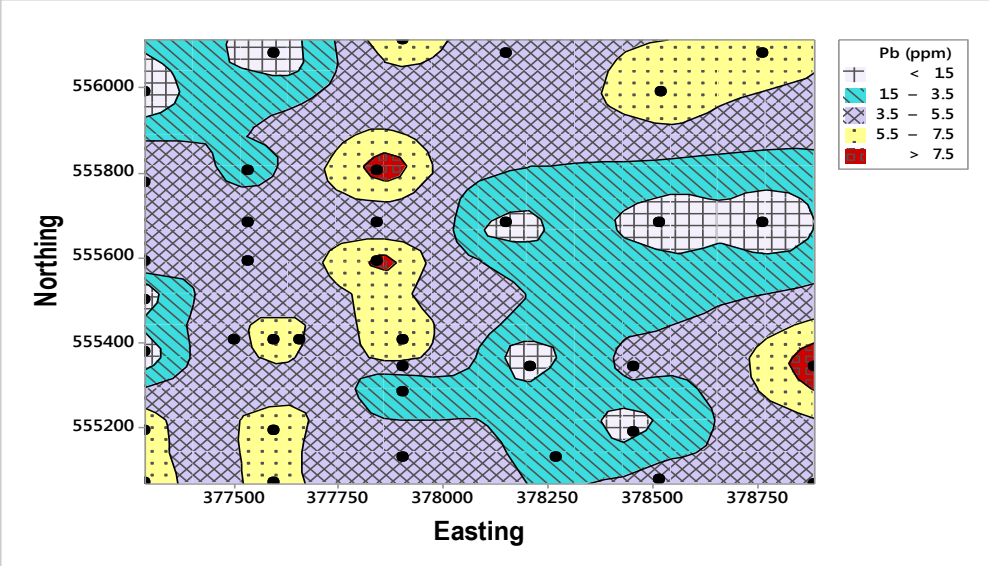

Figure 3: A concentration contour map showing the distribution of lead in Uyo Capital City

Results and Discussion

Results of the study are presented in Table 1 and Figure 3. Corroborating the map of Uyo Urban (Figure 1) and the concentration contour map (Figure 3), the areas around the automobile village recorded values higher than 7.5ppm. Such high values are also seen in the southeastern part of the map, behind the state secretariat complex. These areas show highest (peak) values as far as the study area is concerned. It is also observed that a range of values (7.5ppm-5.5ppm) occur in areas on both sides of the major road (Abak Road); and values tend to reduce away from the road into residential areas and bushes. Generally, lower values (3.5ppm-1.5ppm) and <1.5ppm), were recorded in those areas far away from the road and the automobile village.

Statistically,

Average = 4.15

Mean $(\bar{x}) = 4.157$ (1)

Standard Deviation $(\mho) = 2.84$ (2)

Threshold concentration$(\mu) = \bar{x} + \mho$

$\mu = 4.157 + 2.845$

$\mu = 7.005$ (3)

Anomaly $(\varpi) = X^I > \mu$

NOTE:

Background concentration of lead in the area is 4.157ppm.

Anomaly Concentrations is between 4.157ppm and 7.005ppm.

Contamination is 7.005ppm and above.

Background⇒ anomaly⇒ Threshold ⇒ contamination

0.00 - 4.157 - 7.005 and above.

In the mechanic village, this high levels of lead (>7.5ppm) is not due to mineralization or mining activity of any sort, but due mainly to indiscriminate dumping of lead-contained waste. Such waste includes petrol, diesel, engine oil, batteries, paints, caulking materials, vanishes, residue from oxy-acetylene welding among other forms of waste.

Equivalent high values observed in the southeastern parts of the area (i.e., areas behind the state secretariat complex), is due to the main generating plant, repairs / maintenance; and fuel storage section of the secretariat. These high values may be due to dumping of fuels and oil residues in this area.

Areas both sides of the main road (Abak Road) showed increased concentration of lead (5.5-7.5ppm). Dispersion (anomaly) patterns here are linear. This is mainly due to deposits of lead from exhaust fumes from

automobile tail pipes generated by the heavy vehicular traffic along the road. Other parts of the area record lower concentrations as far as lead is concerned.

Apart from entering the biological system through water, inhalation and skin contact, there is every possibility that this element could be picked up by growing plants. Though the area is mainly residential, pockets of gardens and vegetables exist. This may not only result in retarded growth and poor yield, but may also be an avenue of exposure by humans and animals through ingestion.

Studies on plant growth have shown that high heavy metal concentrations in soil inhibit cytoplasmic enzymes and cause damage to the cell structure due to oxidative stress. It also causes the replacement of essential nutrients at the cation exchange site of plant cells, thereby leading to a decline in plant growth [11].

The WHO and other relevant organizations have attempted to fix certain permissible / action limits for lead in air, water, paint, soil and human body, etc., based on factors such as frequency of exposure, duration of exposure and density of affected population [1]. The limits are as follows:

Air = 0.15μg/m^3 [12].

Soil (play areas) = 400 ppm by weight.

Soil (non-play areas) = 1200 ppm.

Water = 15 ppb (tap water), or 5 ppb (bottled water)

Food = 0.5 μg/dL(ATSDR, 2018).

But, as new and ever-emerging information; and more sensitive parameters are developed, levels / limits previously thought to be safe, have been demonstrated to cause adverse health outcomes. The fact remains that lead, by all standards, is toxic to the human body in particular and the living ecosystem in general, no matter how minute the quantity may be, or how slow the effect may tend to be. The maximum contaminant level goal (MCLG) is zero. This is the level determined to be safe according to toxicological and biomedical considerations [12].

Conclusions

Lead is a toxic metal whose widespread use has caused extensive environmental contamination and health problems in many parts of the world. It is a cumulative toxicant that affects multiple body systems, including the neurologic, hematologic, gastrointestinal, cardiovascular, and renal systems. Children are particularly vulnerable to the neurotoxic effects of lead, and even relatively low levels of exposure can cause serious and in some cases irreversible neurological damage. Recent reductions in the use of lead in petrol, paint, plumbing and solder have resulted in a substantial reduction in population-level mean blood lead concentrations. However, significant sources of exposure still remain. Further efforts are required to continue to reduce the use and releases of lead and to reduce environmental and occupational exposures. Interventions include eliminating non-essential uses of lead such as lead in paint, ensuring the safe recycling of lead-containing waste, educating the public about the importance of safe disposal of lead-acid batteries and computers, and monitoring of blood lead levels in children, women of child-bearing age and workers.

Recommendations

The following strategies are recommended toward contamination mitigation and remediation of contaminated site:

(i) Avoid incessant disposal of used oils into the environment. Used and waste oils should be collected and taken to designated plants for recycling.

(ii) Government legislation and enforcement against incessant disposal of waste oils into the environment is essential. Accessible containers should be provided by Govt. at relevant points where used oils could be turned in free or at a fee. This could abate incessant disposal of oils into the environment within Uyo metropolis.

(iii) Adequate public enlightenment and sensitization on the effects of lead on humans and the environment.

(iv) Adequate treatment of drinking water.

(v) Fruits and vegetables picked from contaminated area should not be consumed.

(vi) Phytoremediation – Planting of ornamental plants that have high ability to degrade oil and oil residues in the area. Where possible, microorganisms / human friendly bacteria could be cultured and introduced into the environment to degrade oil residues.

(vii) Report all health issues to the hospital and screen all cases for lead.

The general public attributes most major illnesses to 'witchcraft', and the minor ones are tagged 'malaria.' This research urges every individual to investigate clinically the root cause of every illness. It also serves as an eye opener into the damaging effects of heavy metals such as lead in the human body, and sounds a warning against such.

Acronyms

GPS - Global Positioning Satellite System
ppm - parts per million
ppb - parts per billion
µg/l - micrograms per litre
µg/dL - micrograms per deciliter
MCLG - maximum contaminant level goal.

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