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LEAD (Pb) MINING IN EBONYI STATE, NIGERIA: IMPLICATIONS FOR ENVIRONMENTAL AND HUMAN HEALTH RISK

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ABSTRACT: *Recent cases of lead (Pb) poisoning in Nigeria which has claimed the lives of over 500 children has been traced to mining. Forty soil samples were collected from the vicinity of four mining sites (A - D) scattered across the three senatorial zones of the state. These samples were sieved to <125 µm particle size fractions and digested using hotplate. Lead levels in these samples were determined using Flame atomic Absorption Spectrophotometer (FAAS). The results revealed that the mean concentration of Site A was 7177 mg/kg, Site B = 5051 mg/kg, Site C = 3198 mg/kg and Site D = 7881 mg/kg. These values were compared with soil guideline values (SGVs) from six countries and they were all in excess of the SGVs. It is to be noted that when Pb levels exceed SGVs, it signifies a level of risk to man and his environment.*

KEYWORDS: lead (Pb), mining, health risk, children, soil

INTRODUCTION

The Nigeria nation is indeed blessed with abundant mineral resources; fossil fuels and solid minerals. However, over the years the nation has depended greatly on the fossil fuel industry. It is reassuring to note that the government has progressively in recent past years shown great interest in the exploitation of Nigeria's solid minerals as a means of diversifying our economic base, instead of depending solely on the depleting petroleum sector. Lead (Pb) is one of the solid minerals that occur in large quantity in different Nigerian states. It has been estimated (1) that Nigeria has over 10,000,000 tons of lead ore deposits with sulphide galena (PbS) dominating other ores.

Ebonyi State is one of the States in Nigeria that is endowed with solid minerals including lead ores. Unregulated mining in Ebonyi State started with the mining of lead-zinc (Pb-Zn) ore in 1925 (2) and since then Pb mining has progressed tremendously because of its high demand. Lead has a low melting point, is easily moulded and shaped, and can be combined with other metals to form alloys. For these reasons, global processing and consumption of Pb is on the increase, because of increasing demand for energy-efficient vehicles. The largest current use of lead is in storage batteries for cars and other vehicles. This use now exceeds the use of lead in petrol (3). It has been reported (4) that the mining industry is the greatest source of Pb in our environment. The presence of Pb in environmental matrices particularly soil represents significant health risks to children, adult and the ecosystem in general. Lead in the environment raises health concern because it can be toxic, ubiquitous and cannot be degraded to non-toxic forms by any known method and as a result remain in the environment for decades (5).

Some countries have robust programmes for monitoring levels of lead in the environment, as well as strong programmes for primary and secondary prevention of childhood lead poisoning. These countries have imposed bans on certain uses of lead, have set environmental standards and have deployed screening programmes. This is not the case with Nigeria as there is no strict monitoring and regulation of mining and other related activities. This has resulted in recent Pb

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poisoning in Nigeria. It was reported (6-8) that Pb poisoning occurred in Zamfara State (North-West of Nigeria) in 2010. The epidemic which was reported as the worst of such an occurrence in modern history killed 400 children (< 6 years) and made about 3,500 children seriously sick. Recently, it was reported (9) that Pb poisoning occurred in Niger State (Central Nigeria) killing 28 children (< 5 years) and 65 children seriously sick. It is in the light of these ugly occurrences that this study was undertaken to ascertain Pb levels in soils within the mining sites of Ebonyi State.

LITERATURE REVIEW

Human health risk assessment is the characterization of the potential adverse health effects of human exposure to environmental contaminants (10). This process involves the determination of the likelihood that human exposure to toxic chemicals like Pb could result in adverse effects on human health and quantitatively estimate consequences. Risk assessment is useful in the determination of the significance of contamination in a site and the necessary action required. As a result, regulatory decision issues are based on risk assessment studies. Although health implications of environmental contaminants affect everyone but children are more prone to health effects than adult because of their sensitivity and vulnerability to potentially toxic elements (PTEs) (10). This is evident in Nigeria Pb poisoning where adults do the illegal mining but children who are exposed die. It has been noted that due to the importance of children's healthcare, no guidance document on risk assessment that did not recognise children's unique exposures and special vulnerability can be considered adequate to protect human health (11).

In environmental and human health risk assessment, ''exposure pathway'' is an important term. It refers to the channel an environmental contaminant (example, Pb) takes from its source to exposed populations. It forms a link between environmental release and the potentially exposed populations. Humans are exposed to environmental Pb indirectly or directly. Indirect exposure occurs, for example, through the food chain where plants grown on contaminated soil take up Pb and pass on to humans while direct exposure occurs where the environmental matrix (soil) carrying Pb enters the human body. This study focuses on direct exposure. When one is directly exposed to soil released from a mining site, it could enter the body through the mouth (oral ingestion), nose (inhalation) or skin (dermal absorption. However, considering soil particle size in a mining site, oral ingestion is the most important exposure pathway. Oral ingestion of soil occurs intentionally or unintentionally. Due to the pervasive nature of soil, it is constantly in contact with the skin, clothes and any other objects not specially protected. It has been noted (12) that every exposed population would possibly ingest a small quantity of soil. This easily happens because soil adhering to our body, especially the fingers, may be unintentionally ingested due to hand-to-mouth activity. It was observed during sampling that many people were unavoidably exposed to soil resulting from mining. These include, the miners (men, women and children), marketers who bring food and other essential materials to the site as well as visitors. It was also observed that none of these people especially the miners wore the necessary protective gear (Figures 1 and 2). It was also observed that in each site, there was a relaxation centre. Some miners also use the site as residential homes. It should be noted that these scenarios are sources through which people are exposed to Pb resulting from mining, hence the need to investigate Pb levels in these sites.

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METHODOLOGY

Study Area

Ebonyi State (South-East Nigeria) comprises of three senatorial zones namely; Ebonyi Central, Ebonyi North and Ebonyi South. Each of these zones have at least two Pb mining sites. Four sites were randomly selected from the three zones. Mkpumaakpatakpa mine and Achara Nuhu mine were selected from Ebonyi North while Ohankwu mine and Ishiagu mine were selected from Ebonyi Central and Ebonyi South respectively (Figure 3).

Figure 1: Miners at work without protective gears

Figure 2: Washing of Pb after mining without protective gears

Sample collection and preparation

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Forty (40) surface soil samples were collected from four mining sites selected for the study. Surface samples were collected because surface material is most relevant for wind-borne transport, human exposure, and direct contact with precipitation and surface runoff. Ten samples were collected from Mkpumaakpatakpa (Agbaja) mining site (Ebonyi North) on

Figure 3: Map of Ebonyi State, Nigeria showing study location.

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February 19, 2015, ten samples were collected from Ohankwu Ikwo mining site (Ebonyi Central) on February 28, 2015, ten samples were collected from Ishiagu Ihetutu mining site (Ebonyi South) on March 8, 2015 and ten samples were collected from Achara Nuhu mining site (Ebonyi North) on March 15, 2015. In each of these sites, 5 samples were collected from the mining premises where miners use as relaxation centre and 5 samples were collected 500m away from the relaxation spot. The samples were placed inside labelled bags and sealed and then transported to the laboratory. The samples were then oven dried at a temperature of 35 °C for two days, and then gently disaggregated before sieving. The soil samples were sieved using a < 125 µm nylon sieve to remove extraneous matter such as small pieces of brick, stones, and other debris. The >125 µm soil samples collected after sieving were weighed (their mass recorded) and stored in sealed plastic containers. All procedures of handling were carried out without contact with metal objects/utensils to avoid potential cross contamination of the samples. Finally, the < 125 µm soil samples were stored in plastic containers prior to digestion.

Sample Digestion and Analysis

Reagent grade chemicals were used in all cases. Sample digestions were carried out using a hot-plate. Method 3050b (13) was adapted in sample digestion. 10 ml 1:1 nitric acid (HNO_3) was added to beakers containing 1g soil sample, covered with watch glass and heated for 15 minutes without boiling. Samples were cooled, 5 ml HNO_3 was added and heated for 30 minutes (brown fumes was given off). More 5 ml HNO_3 was added and no brown fumes was given off. Solution was allowed to evaporate to < 5 ml and allowed to cool. 2 ml water and 3 ml 30% hydrogen Peroxide (H_2O_2) was added and heated for 2 hrs until effervesces ceased. Solution was reduced to 5ml via evaporation. 10 ml hydrochloric acid (HCl) was added and heated for 15 minutes without boiling. After cooling, the digested samples were filtered using a whatman filter paper (grade 41, pore size 20 µm) into 100 ml volumetric flask. The filtrate was diluted to the mark with ultrapure water of resistivity 18.2 MΩ-cm at 25^0C and ready for analysis using Flame atomic Absorption Spectrophotometer (FAAS). Each sample was digested in triplicates.

Flame atomic Absorption Spectrophotometer (FAAS) protocol.

Samples to be analysed by FAAS were prepared in triplicates. Reagent blanks were included to check contamination. Six calibration standards over the range 0-10 µgmL^{-1} (mgL^{-1}) were prepared from 1000 µgmL^{-1} Pb stock solution; this was used to calibrate the instrument and also to plot the calibration graph and the regression coefficient (R^2) obtained was 0.999 (linear graph). Based on the excellent R^2 value, the samples were analysed.

RESULTS AND DISCUSSION

The results showed that in Site A (Mkpumaakpatakpa mine) concentration of Pb ranged from 2436 mg/kg to 17321 mg/kg. In site B (Achara Nuhu mine) the concentration of Pb varied from 1743 mg/kg to 8643 mg/kg, in site C (Ohankwu mine) it ranged from 1173 mg/kg to 8096 mg/kg while in site D (Ishiagu Ihetutu mine) Pb concentration varied from 3053 mg/kg to 18753 mg/kg.

A box plot (Figure 4) showing median, mean, box boundary (25th and 75th percentile) and whiskers (10th and 95th percentile) as well as statistical analysis (Table 1) showing minimum,

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maximum, median, mean and standard deviation (SD) have been used to show Pb distributions across the four mining sites.

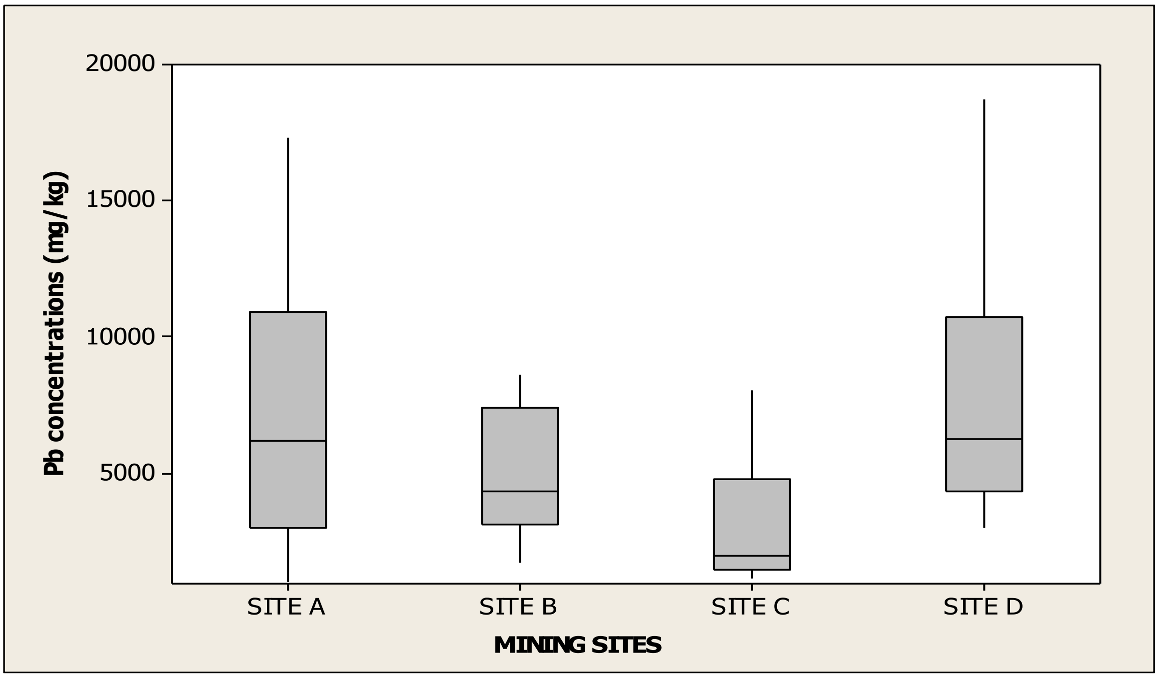

Figure 4: **Box plot for the concentration of Pb across the mining sites.**

(**SITE A**: Mkpumaakpatakpa (Agbaja), Izzi LGA; **SITE B**: Achara Nuhu, Abakaliki LGA

SITE C: Ohankwu, Ikwo LGA; **SITE D**: Ishiagu Ihetutu, Ivo LGA)

Table 1: Statistical summary of Pb levels in the mining sites

Mining Sites	Minimum	Maximum	Median	Mean	Standard deviation (SD)
SITE A	1093	17321	6211	7177	5246
SITE B	1743	8643	4403	5051	2329
SITE C	1173	8096	2030	3198	2349
SITE D	3053	18753	6318	7881	4868

The highest concentration of lead (18753 mg/kg) was found in soil samples collected from Site D (Ishiagu Ihetutu mine) while the lowest Pb concentration (1093 mg/kg) was obtained from soil sample collected from Site A (Mkpumaakpatakpa mine). Ivestigations revealed that Ishiagu Ihetutu mine is the oldest mine while Mkpumaakpatakpa mine is the newest, so it is expected that Pb must have accumulated more in the older mine. It has been reported (14-15) that Pb is immobile in soil and accumulate over time which may result in elevated concentration. Obviously, such scenarios could be a potential threat to human health and the environment. It was also observed that Pb concentrations were more in the samples collected within the mining premises than samples collected 500m away from the sites. This was applicable in all the sites. This implies that even though everyone within the neighbourhood is at risk, however, visitors to the site, site hawkers and miners (particularly residential ones) are at a higher risk because accumulation level in the body depends on exposure time.

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One way to assess the environmental health impact is to compare these PTEs levels with soil guideline values (SGVs). Soil guideline values are scientifically based generic quality standards adopted in many countries to assess human health risks from soil contamination due to the presence of contaminants. With respect to the element of interest, the SGVs are in the form of concentration thresholds in soil of which exceedance may signify a potential risk to humans. As at the time of this study, Nigeria has no SGVs. South Africa is the only country in Africa continent with SGVs. Thu, it became necessary to compare results from this study with South African SGVs as well as SGVs from other countries of the world. Table 2 shows SGVs from six countries. It can be seen from Table1 that the mean concentrations of Pb from Site A to Site D are: 7177 mg/kg, 5051 mg/kg, 3198 mg/kg and 7881 mg/kg. When these results are compared with the SGVs (Table 2), it is observed that even the lowest Pb mean concentration (3198 mg/kg) from Site C exceeded the highest SGVs recorded in

Table 2: **Global Soil Guideline Values (industrial soil-use) for Pb**

S/N	Countries	Soil Guideline Values (SGVs) (Industrial) (mg/kg)
1	South Africa[16]	1,900
2	England[17]	750
3	Germany[18]	2,000
4	Australia[19]	500
5	Netherlands[20]	530
6	Canada[21]	600

Germany (2,000 mg/kg). It is to be noted that Pb concentrations in these sites exceeding SGVs from six countries signifies a potential risk to humans.

Implications of the study

High concentration of Pb from these sites implies that there is possibility of Pb entering the human body directly via the exposure pathways (oral, inhalation and dermal) particularly in these scenarios where miners and other people that are regular in the sites do not put on the expected protective gears. Besides, considering the weather conditions (tropical) in Ebonyi State, Pb could easily enter the water bodies as well as the food chain. This could cause water and food pollution thereby leading to Pb poisoning which has been the case in Nigeria. The effects of lead are the same whether it enters the body through breathing or swallowing. The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults to lead at work has resulted in decreased performance in functions of the nervous system (22-23). Lead exposure may also cause weakness in fingers, wrists, or ankles. Lead exposure can also cause slight increases in blood pressure, particularly in middle-aged and older people. Lead exposure may also cause anaemia. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause a miscarriage. High-level exposure in men can damage the organs responsible for sperm production.

CONCLUSION

The study has shown that Pb mining is a significant source of Pb to the environment and it is obvious that once Pb is the environment it could enter the human body through any of the

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exposure pathways, it is therefore, advisable that miners, site visitors and those that use mining sites for commercial purposes should put on adequate protective gear to reduce exposure. In the light of these findings, it is strongly recommended that the Nigerian Government should formulate and implement strict laws that will govern mining in Nigerian states so as to protect the lives of its citizens.

Future Research

This work investigated only the total Pb content in these samples. There is plan to use the Unified Bioaccessibility Method (UBM) to assess the bioaccessble Pb fractions from these samples.

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