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Environmental Pollution Levels of Lead and Zinc in Ishiagu and Uburu Communities of Ebonyi State, Nigeria

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Abstract Water and soil samples from the area were therefore analyzed for their lead and zinc content. Computation of pollution statuses of lead and zinc revealed topsoil lead geoaccumulation indices of −0.143 and −0.069 and zinc geoaccumulation indices of 1.168 and 0.713 for Ishiagu and Uburu respectively. The pollution indices were determined to be 0.499 and 0.3564 for soil in Ishiagu and Uburu respectively and also 5.11 and 2.42 for water in Ishiagu and Uburu communities respectively. Water/soil concentration ratio were found to be 0.0018 and 0.0014 for lead in Ishiagu and Uburu respectively. On the other hand, the water/soil concentration ratio for zinc was computed to be 0.001 and 0.0008 for Ishiagu and Uburu respectively. These results seem to suggest that the pollution of the environment by these heavy metals in the areas were as a result of the water being contaminated by lead and zinc not necessarily their concentrations in the soil.

Keywords Lead · Zinc · Geoaccumulation index · Pollution index · Water/soil concentration ratio

Lead is a heavy metal naturally present in trace amount in soil, water, plants and animals (Strmiskova 1992). It is a known environmental toxicant that has no physiological function in organisms (Neumann et al. 1990). Lead is also known to affect almost all the organs in the body even at low concentration. Lead can gain entrance in the environment through both natural (leaching, weathering and erosion) and anthropogenic (industrial activities including mining, exhaust pipe of automobile etc.) means. Mining of lead which takes place in Ishiagu exposes the environment to lead. The release of these heavy metals posses a significant threat to the environment and public health because of their toxicity, bioaccumulation in the food chain and persistence in nature (Ceribasi and Yetis 2001). The heavy metal zinc is not toxic at low concentration but has some undesirable effect at high concentration. Zinc influences cell division, growth and development (Beach et al. 1980) as well as sexual maturation (Coble et al. 1971). It is also a membrane stabilizer (Chvapil 1973) and essential for the integrity of the immune system (Schlesinger et al. 1993). Moreover, zinc is required by more than 100 enzymes as cofactor, and it seems to help in the proper storage and release insulin, growth and repair of tissues, wound healing, the ability to taste food, mineralization of bone, blood clotting, the function of vitamin A, and the functions of the thyroid hormones (Prasad 1983; Hands 1999). Some indices can be used to determine the level of pollution caused by these metals in the environment. These indices include; the geoaccumulation index which has been employed in assessing contamination of soils (Kwapuliński et al. 1996; Miko et al. 2000) and pollution index, which has been used to assess the pollution levels by putting into consideration the joint effect of all polluting metals in soil (Lee et al. 1998). This study has extrapolated this index to water. The use of the water/soil concentration ratio is another index that can be used to assess the pollution levels of these metals in the environment. With these indices, the pollution levels and potential contaminations of these heavy metals can be determined. This study is therefore aimed at estimating the pollution levels of lead and zinc in Ishiagu and Uburu communities which have

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commercial accumulation of the metals with a view of advising the natives for their safety.

Materials and Methods

Perken–Elmer flame atomic absorption spectrometer (FAAS) (model 2380 England), equipped with burner–nebulizer for air–acetylene having single slot 100 mm, was used for carrying out the AAS analysis. The wavelength and the slit band width of the atomic absorption spectrometer are shown on Table 1.

About 200 g of soil were collected from four different agricultural soils in Ishiagu in Ivo Local Government Area and Uburu in Ohaozara Local Government Area both in Ebonyi State. Top- and sub-soils (topsoil 0–15 cm depth and subsoil 15–30 cm depth) (Adie and Osibanjo 2009) were collected. Both soils were collected from the same locations. The collected soil samples were put in polyethene bag where it was transported to the laboratory and kept in the refrigerator till use.

Lead and zinc in soil samples were prepared according to the method of USEPA (1986). The soil samples were oven dried for 24 h and then ground into powder and sieved. One gram of each sieved soil sample was placed in a small beaker and 10 mL of concentrated HNO_3 was added and allowed to stand for 4 h. It was then placed over a hot plate until the evolution of red nitrogen (IV) oxide (NO_2) fume ceased. The beaker and its content were cooled and 4 mL of 70% of $HClO_4$ was added. The solution was gently heated to evaporate to smaller volume. The digested sample was then made up to 100 mL. This solution is used for lead and zinc analysis.

Also 2 L of water were collected from streams, wells and boreholes in different locations in Ishiagu and Uburu. The water samples were stored in a two litre container at 4°C till used. The water samples were prepared according to the method modified by Eletta (2007). The collected water samples (100 mL) measured with a measuring cylinder were poured into 200 mL beaker and the water acidified with five drops of concentrated HNO_3 to keep the metals in solution. The solutions were then concentrated on a hot plate to 20 mL, cooled and then stored in storage bottles for AAS analysis.

The concentration of lead and zinc were calculated after AAS analysis thus;

Table 1 The wavelength and slit band width of the AAS machine

Element	Wavelength	Slit band width (mm)
Lead (Pb)	283.3	0.7
Zinc (Zn)	213.9	0.7

$$\text{Concentration of trace metal} = \frac{\text{AAS results}}{\text{Concentration factor}} \quad (1)$$

$$\text{Concentration factor} = \frac{\text{Intial sample volume}}{\text{Final volume}} \quad (2)$$

Pollution index is determined according to the method of Lee et al. (1998). Pollution index (PI) assesses pollution level by considering the joint effect of all polluting metals in soil. The PI is obtained by calculating the average ratios of metal concentration to the tolerance levels or the metal concentration above which crop growth are considered unsafe for human health (Ezeh et al. 2008). It was computed using the formula as stated below;

$$\text{Pollution index (PI)} = \frac{1}{n}\left(\frac{M_1}{TL_1} + \frac{M_2}{TL_2} + \cdots \frac{M_n}{TL_n}\right) \quad (3)$$

M_1, M_2,…, M_n are the average concentrations of the polluting metals; TL_1, TL_2,…, TL_n are the tolerable levels for each metal; 'n' is the number of polluting metal considered.

A pollution index of more than 1.0 indicates that the average metal concentrations are above the permissible levels.

The index of geoaccumulation (I_{geo}) measures the bottom sediment contamination (Müller 1969), and was employed in this study to assess the contamination of soils (Miko et al. 2000; Kwapuliński et al. 1996). The content accepted as background in multiplied each time by the constant 1.5 in order to take into account natural fluctuations of a given substance in the environment as well as very small anthropogenic influences (Loska et al. 2003). The value of the geoaccumulation index is described by the following equation;

$$I_{geo} = In\frac{C_n}{1.5 \times B_n} \quad (4)$$

I_{geo} = geoaccumulation index, C_n = concentration of lead/zinc in the soil, B_n = background value.

The index of geoaccumulation consists of seven grades, whereby the highest grade (6) reflects 100-fold enrichment above background values. Listed on Table 2 are the

Table 2 Geoaccumulation index classification (Forstner et al. 1993)

Sediment geoaccumulation index (I_{geo})	I_{geo} classes	Contamination intensity
>5	6	Very strong
>4–5	5	Strong to very strong
>3–4	4	Strong
>2–3	3	Moderate to strong
>1–2	2	Moderate
>0–1	1	Uncontaminated to moderate
<0	0	Practically uncontaminated

geoaccumulation classes and the corresponding contamination intensity for different indices (Forstner et al. 1993).

The water/soil concentration ratio determines or assesses the pollution levels taking into consideration the mean of the heavy metals in both subsoil and topsoil and the mean of the heavy metal concentration in the water bodies. The water/soil concentration index can be calculated thus;

$$\text{Water/soil Conc. ratio (w:s)} = \frac{\text{Mean Conc. of metals in water bodies}}{\text{Mean Conc. of metals in both top and subsoil}} \quad (5)$$

Results and Discussion

The concentrations of lead in the soil were shown in Fig. 1. When compared with permissible limit of WHO, the concentrations of lead in subsoil in Ishiagu (14.03 ± 0.8 μg/g) were found to be lower than that in Uburu (16.3 ± 1.70 μg/g) although both were found to be lower than the WHO permissible limits.

The concentrations of zinc were also determined. Figure 2 shows that the concentration of zinc in topsoil (245 ± 7.02 μg/g) and subsoil (268.33 ± 3.05 μg/g) in Ishiagu were found to be higher than the concentration of zinc in topsoil (154.33 ± 5.68 μg/g) and subsoil (187.00 ± 4.35 μg/g) in Uburu. The difference in mean values of zinc in soil in Ishiagu were found to be significantly different at $p < 0.05$.

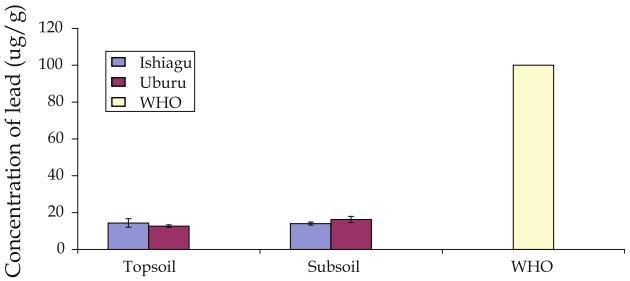

Fig. 1 The mean concentration of lead in topsoil and subsoil in Ishiagu and Uburu communities

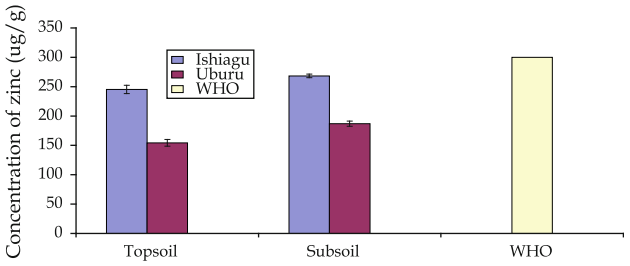

Fig. 2 Barchart showing the mean concentration of zinc in topsoil and subsoil of both Ishiagu and Uburu communities

The mean concentrations of lead were also determined in stream, well and borehole water bodies. Figure 3 shows that the concentration of lead in boreholes in both communities were higher than those of well water and stream water. Apart from the concentration of lead in Uburu stream water (0.006 ± 0.002 μg/dl), all other have concentrations significantly higher than the permissible limit of lead in water.

Figure 4 shows significantly high concentration of zinc above the permissible limit for zinc in drinking water. The concentrations of zinc ranges from 0.172 ± 0.001 to 0.383 ± 0.001 μg/dL in well water in Ishiagu and 0.126 ± 0.003 to 0.156 ± 0.007 μg/dL in Uburu.

The result below in Table 3 shows that Ishiagu has higher pollution indices for both soil and water than Uburu. It also showed that pollution index (combined effect of lead and zinc) is higher in water than in soil.

The geoaccumulation indices of lead and zinc were calculated and the result showed that the level of contamination caused by zinc is within the range described as "uncontaminated to moderate contamination" while lead was calculated to show "practically uncontaminated" as seen in Table 4.

The water/soil concentration ratio was found to be higher in Ishiagu than in Uburu for both lead and zinc as seen in Table 5.

Pollution levels of lead and zinc were investigated in the lead mining environment of Ishiagu in Ivo local government and non-lead mining community of Uburu in Ohaozara local government area of Ebonyi state by measuring the concentrations of the metals in soil and water in the areas and also by calculating their geoaccumulation, pollution indices and the water/soil ratios of the heavy metals.

The observation of minimal lead concentration in the stream water when compared to well water and borehole water could be as a result of the deposition of the lead down the earth crust resulting to its dissolution into the ground water showing that the concentrations of lead in the water bodies have the order borehole water > well water > stream water (Fig. 2). The flowing of the stream water could have contributed to the diminished lead concentration in the stream water. The observation of lower concentration of lead in steam than in borehole or well water is consistent with similar observation by Orisakwe et al. 2006) who also reported a concentration lower than the maximum contamination level (MCL) for lead. When compared with maximum permissible limit of lead, it was observed that the concentration of lead in borehole water in both communities were higher than the permissible limits. It was also observed that the concentration of lead in water in Ishiagu where mining presently going on were higher in the water bodies when compared to that of Uburu where mining has been suspended for more than 20 years.

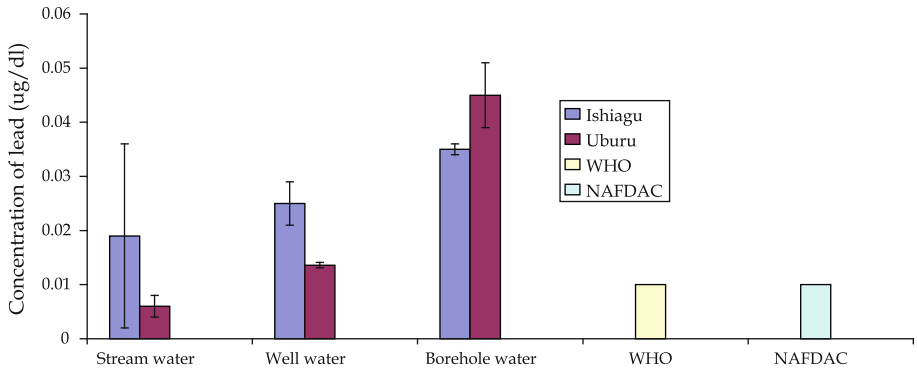

Fig. 3 Lead concentrations in different water bodies in both Ishiagu and Uburu

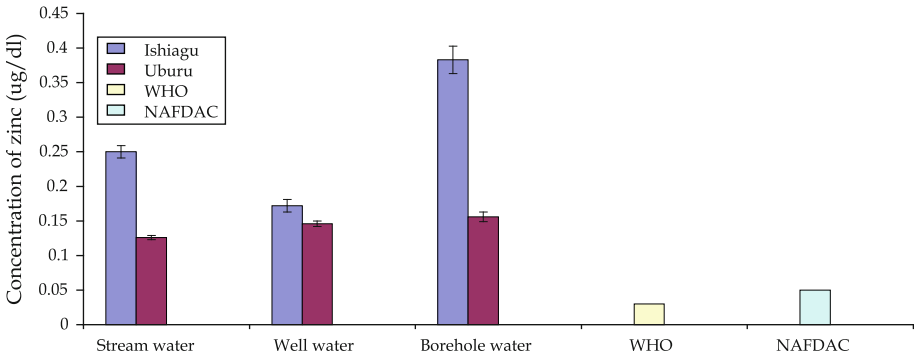

Fig. 4 Barchart showing the concentrations of zinc in water bodies in both Ishiagu and Uburu

Table 3 The result of the calculated pollution indices of lead and zinc in Ishiagu and Uburu

Town	Pollution index (soil) (PI_{soil})	Interpretation [(PI > 1 = polluted) (PI < 1 = not polluted)]
Ishiagu	0.50	Not polluted
Uburu	0.36	Not polluted
Town	Pollution index (water) (PI_{water})	Interpretation [(PI > 1 = polluted) (PI < 1 = not polluted)]
Ishiagu	5.11	Polluted
Uburu	2.42	Polluted

Table 5 The calculated water/soil ratio in Ishiagu and Uburu communities

Metals	Ishiagu	Uburu	WHO calculated values
Lead	0.0018	0.0014	0.0001
Zinc	0.001	0.0008	0.0001

The calculated geoaccumulation indices for lead and zinc in both communities, is an indicator of the levels of pollution caused by these metals (Miller and Koeppe 1971). The results suggest no form of lead or zinc contamination exists in the soil of both communities. The I_{geo} for lead in both communities gave zero (0) and one (1) for zinc showing that the environment has higher contamination of zinc than lead. This observation is confirmed by the calculated pollution indices of the metals in both communities which revealed that even though the pollution indices were higher in Ishiagu than Uburu, both communities have relatively pollution indices below the permissible

Table 4 The calculated geoaccumulation indices of lead and zinc in the soil from Ishiagu and Uburu (Forstner et al. 1993)

Metal	Location	Concentration (μg/g)	I_{geo} index	I_{geo} class	Extent of pollution
Lead	Topsoil (Ishiagu)	13	−0.143	0	Practically uncontaminated
	Subsoil (Ishiagu)	14	−0.069	0	Practically uncontaminated
	Topsoil (Uburu)	14	−0.069	0	Practically uncontaminated
	Subsoil (Uburu)	16	0	0	Practically uncontaminated
Zinc	Topsoil (Ishiagu)	246	1.168	1	Uncontaminated to moderate
	Subsoil (Ishiagu)	156	0.713	1	Uncontaminated to moderate
	Topsoil (Uburu)	156	0.713	1	Uncontaminated to moderate
	Subsoil (Uburu)	189	0.904	1	Uncontaminated to moderate

threshold, suggesting non-contamination of the soil. The pollution index ranged from practically uncontaminated to moderately contaminated. But when the pollution index was computed for water, it gave 5.11 for Ishiagu and 2.42 for Uburu. These values show significant pollution level in the test area. On determining the water/soil concentration ratio of lead and zinc, the results still show that Ishiagu has higher level of contamination of lead than Uburu. But the values were all above the permissible limit even though the level of lead and zinc were found to be below permissible limits in soil. These results could suggest that contamination could be caused by the level of the metals in water. Plants also absorb this water, thereby increasing the level of the metal in the plants and endangering the food chain. The pollution of the metal in vegetable and some food stuffs is our ongoing study.

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