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Comparative assessment of heavy metals in drinking water sources from Enyigba Community in Abakaliki Local Government Area, Ebonyi State, Nigeria

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This study assessed the levels of heavy metals in drinking water sources in Enyigba community in Abakaliki Local Government Area, Nigeria. Four sites were visited for sampling: two surface water (streams) and two underground water (boreholes). Three water samples were collected from each source making it a total of twelve water samples. The levels of Arsenic (As), Cadmium (Cd), Copper (Cu), Zinc (Zn) and Lead (Pb) were determined using an Atomic Absorption Spectrophotometer (AAS). The result showed significantly ($P<0.05$) high level of As, Cd and Pb which also exceeded the World Health Organization (WHO) recommended maximum limits specification for drinking water. The metal index revealed significant ($P<0.05$) elevated level of As, Cd and Pb. There was no significant ($P>0.05$) difference between the stream water and borehole waters in terms of their elemental load. The findings suggest that drinking water from these sources are heavily contaminated by As, Cd and Pb and there is possible risk of contamination of the diverse ecosystem located in the neighbourhood. Therefore, the mining communities and the miners should be properly enlightened on the dangers associated with exposure to heavy metals to prevent them from polluting water bodies.

Key words: Enyigba, borehole, drinking water, stream, heavy metals, pollution.

INTRODUCTION

The inability to access potable water supply in developing countries is a global issue that needs urgent attention. About 884 million people in the world, mostly in developing countries do not have access to drinking water sources that conform to the permissible limit specification of WHO (WHO/UNICEF, 2010). More so, in developing countries of the world, about 780 million people lack access to potable water as result of pollution,

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which has been attributed to contamination with micro-organisms and chemicals. These chemical contaminations involve mainly pollution of water bodies with heavy metals through anthropogenic activities (WHO/UNICEF, 2012).

The principal sources of surface and groundwater pollution by heavy metals are natural processes and anthropogenic activities (Ato et al., 2010; Naveedullah et al., 2014). The rise in concentration of heavy metal in water irrespective of the origin is posing a serious health threats to human and aquatic ecosystems (Humood, 2013; Naveedullah et al., 2014). Arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni) and zinc (Zn) are the most familiar heavy metals of health concern to human (WHO, 2008). When the concentrations of heavy metal in water surpass the environmental acceptable border, the use of such water for agricultural purposes might be detrimental to the aquatic ecosystem and human through the food chain (Wright and Welbourn, 2002). For instance, several kinds of diseases besides organ dysfunction had correlation with raised levels of heavy metal concentrations in drinking water sources above the permissible limit specified by regulatory bodies (Lenntech, 2013).

Additionally, heavy metal contamination of drinking water sources has been linked with deficiencies of some essential nutrients, which culminates in compromised immunological defenses, disabilities associated with malnutrition, intrauterine growth retardation, impaired psychosocial faculties, and increased prevalence of upper gastrointestinal cancers (Arora et al., 2008). Although few of these heavy metals like Cu, Iron (Fe), Ni and Zn are essential nutrients required in trace amount for animals and plants; they are harmful at high levels. However, some heavy metals like Cd, Cr, Pb and cobalt (Co) have no known physiological functions and are deleterious at certain levels (Aktar et al., 2010; Kar et al., 2008).

Despite the substantial contribution of small-scale mining to the economy of Ebonyi State and Nigeria at large since the discovery of Pb-Zn deposit in Enyigba and its environs in the early 1900s, it has impacted negatively on the environment and health of the residents (Nnabo, 2015). This study is therefore aimed at determining and comparing the levels of some heavy metals (Pb, Cd, As, Cu and Zn) in the drinking water sources from Enyigba mining community in Abakaliki Local Government Area. It also seeks to assess the trace metal indices in comparison with the observed concentration of water quality permissible limit specified by WHO (2011).

MATERIALS AND METHODS

Study area

The study was carried out in Enyigba, a mining community, located in Abakaliki Local Government Area of Ebonyi State, South Eastern region of Nigeria. Enyigba shares borders with Ikwo Local Government Area, precisely at Amechara, Ameri and Amegu communities. It lies between latitude $6°27^{1}5.0^{11}$ north of the equator and longitude $8°26^{1}11.0^{11}$ west of the Greenwich meridian as recorded by a conventional global positioning system (Google map-GPS). The topography of Enyigba is undulating plain alternating with running of ridges and hills from east to west. The plains are underlain by shale outcrops, which serve as the host for Pb-Zn mineral ore bodies. The area had about 60 m as its highest elevation and 30 m as its lowest elevation above sea level. The area falls within the tropical rainforest belt of South East, Nigeria and characterized by an average rainfall of 1750 to 2000 mm per annum. The highlands are characterized by drought resistance grasses, along stream and rivers. The area is majorly drained by Ebonyi River. All the drainage systems flow eastward to join the cross river somewhere outside the area (Nnabo, 2015) (Figure 1).

Water sample collection

Water sampling was carried out in the month of May. Water samples for analysis were collected from surface waters (streams) and underground sources (Borehole water). These sources are representative of the drinking water sources of the inhabitants of the community. Four sites were visited for sampling; two surface sources: Nwangele Orugwu streams (stream 1) and Inyina stream (stream 2) and two underground sources: Enyigba Primary School borehole (borehole1) and Ishiagu Enyigba town hall (borehole 2). In each site, three water samples were collected, making it a total of twelve water samples.

Digestion of water samples for analysis of As, Pb, Zn, Cu and Cd

Turbid water samples from the streams were digested before the proper analysis using the method as described by American Public Health Association (APHA, 1998).

Procedure

The water samples were thoroughly mixed by shaking. Three different water samples from each of the surface water sources (Nwagele Orugwu stream and Inyina stream) were digested as follows: 50 ml of the sample was transferred into a glass beaker and 1.0 ml of concentrated nitric acid was added. The beaker with the contents was placed on a hot plate and evaporated down to about 20 ml. On cooling, the sample was filtered through Whatman No. filter paper 42 to remove some insoluble materials that could clog the atomizer. The volume was adjusted to 50 ml using metal free distilled water.

Quality assurance and quality control

Strict quality assurance and quality control procedures were employed in order to ensure authenticity, correctness and precision of the results. All the reagents and chemicals used were purchased from Sigma-Aldrich (Sigma-Aldrich Co. LLC, USA) and were of analytical grade.

Glass wares used during laboratory analysis were thoroughly washed with several changes of 9% HNO_3 and properly rinsed several times using de-ionized water. Dilutions were carried out using de-ionized water.

A blank solution and standards were analyzed along with the replicate samples to ensure precision and accuracy of the determinations.

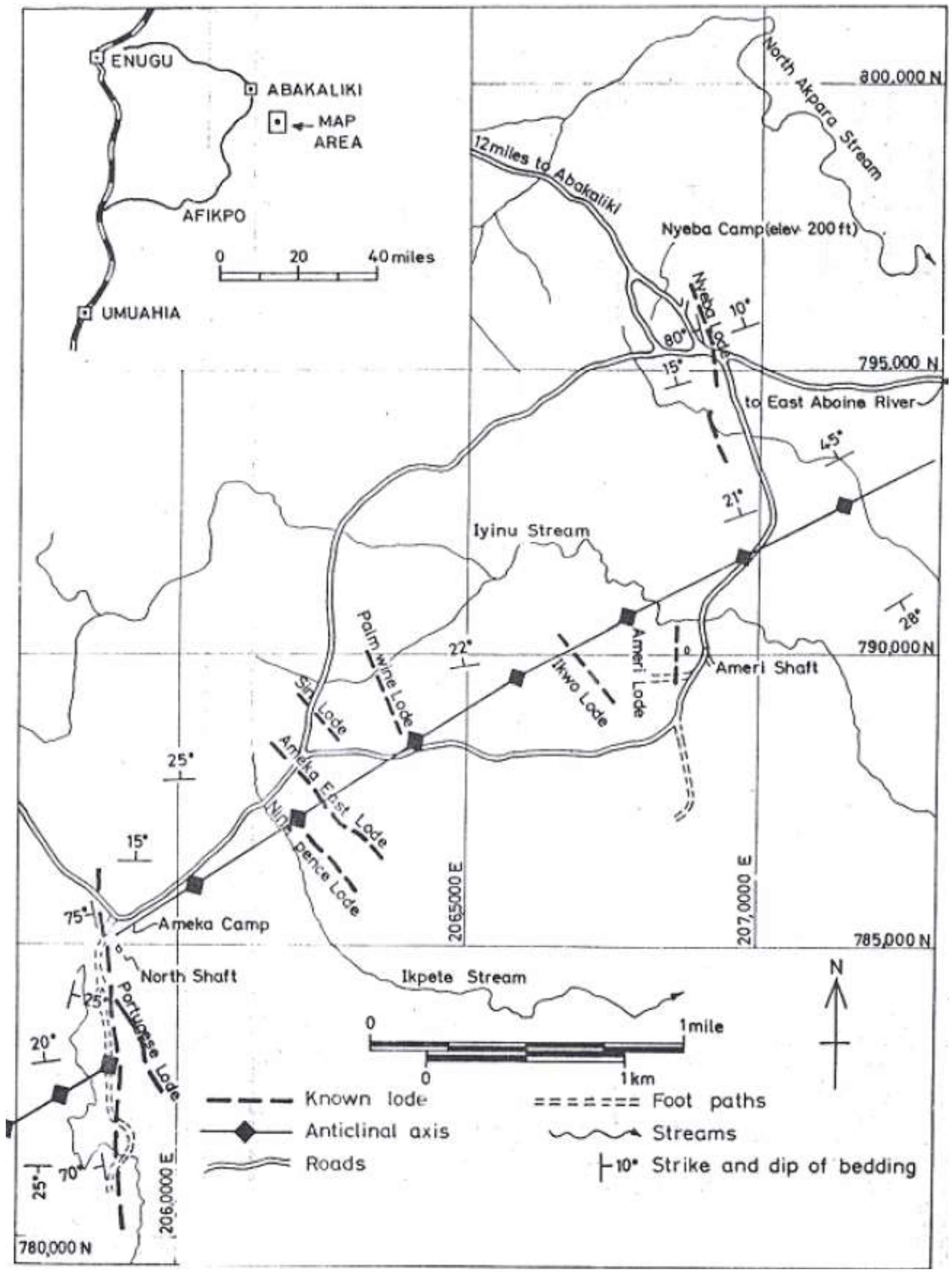

Figure 1. Geographical map of lead-zinc deposits of Enyigba district, near Abakaliki, lower Benue Trough. The area is underlain by Abakaliki shales.
Source: Modified by Orajaka (1965).

Metal index (MI)

MI was calculated using the method described by Akpoveta et al. (2011) as follows:

$$MI = Mc / MAC \quad (1)$$

where Mc represents the concentration of metal in the test sample, MAC is the maximum allowable concentration of metal in drinking water as specified by WHO (2011). Values < 1 indicates significant degree of contamination and values >1 shows no contamination. Metal indices provide information on the relative contamination contributed by individual metal in a water sample.

Statistical analysis

Results were expressed as mean ± standard deviation of three replicates. Data obtained were analyzed using SPSS (version 15 Inc., USA). The values of $P<0.05$ were considered statistically significant.

RESULTS

The result in Table 1 showed that the mean arsenic (As) and lead (Pb) concentrations in water samples from both streams and boreholes exceeded the WHO (2011) permissible maximum limit of 0.010 mg/L for drinking water. The results of the mean concentrations of Cd from water samples collected from stream 2 and borehole 2 were within the WHO (2011) permissible limit while the level recorded from stream 1 and borehole 1 was above the WHO (2011) permissible maximum limit of 0.003 mg/L for drinking water. The results of the mean concentration levels of Cu and Zn in water samples from both streams and boreholes were within the WHO (2011) permissible limit of 2.0 mg/L for drinking water.

The result in Table 2 revealed significantly ($P>0.05$) high metal indices for As, Cd and Pb in both streams and boreholes which were above the WHO permissible limit while the metal indices for Cu and Zn were within WHO permissible limit.

DISCUSSION

The present study observed significantly higher concentrations of As and Pb in both streams and boreholes when compared with the WHO permissible limits for drinking water, with high metal indices for the two metals. However, while level of Cd was within the WHO permissible limit in Inyina stream and Ishiagu Enyigba town hall borehole, the level of the metals was above the WHO permissible limit for Nwangele Orugwu stream and Enyigba Primary School borehole. Meanwhile, levels of Zn and Cu observed in both streams and boreholes were within the WHO permissible limits with low metal indices.

The significantly elevated As concentrations in both streams and boreholes which exceeded the WHO (2011) permissible maximum limit of 0.010 mg/L for drinking water in the current study in agreement with previous findings (Nnabo, 2015). The significantly raised metal index for As was an indication of high contamination. The high concentration of As may be as a result of mining activities or runoff from agricultural areas, where material containing As such as fertilizer and pesticides was used (Cobbina et al., 2015). It has been reported that mined rocks and ore containing arsenic piled up in proximity to surface water bodies may be leached into drinking water sources (Ravengai et al., 2005). The implication of this finding is that the residents may be at risk of As poisoning through consumption of such polluted water. The effect of As on human health is well known. For instance, elevated level of As in blood/plasma (e.g. through consumption of water and food) is associated with pigmentation changes, skin lesions and hard patches on the palms and soles of the feet (hyperkeratosis), which serves as precursors for skin cancer. Besides skin cancer, As exposure also causes cancer of the bladder and lungs. Hence, the International Agency for Research on Cancer (IARC) has classified As and its compounds as carcinogenic to humans, and has also stated that As in drinking-water is carcinogenic to humans (Flanagan et al., 2012).

The results of the mean concentrations of Cd from water samples collected from Inyina stream and Ishiagu Enyigba town hall borehole were within the WHO (2011) permissible limit while the level recorded from Nwangele Orugwu stream and Enyigba Primary School borehole were above the WHO (2011) permissible maximum limit of 0.003 mg/L for drinking water. The metal index for Cd was high which indicates significant contamination. The present findings are in consonance with the result of previous study conducted in the area which reported that concentration of Cd from Enyigba stream was 6 and 0.5 mg/L in Enyigba Primary School borehole which were above the stipulated limit by regulatory bodies (Nnabo, 2015). The high concentration of Cd in water sources in the area could possibly be due to their waste disposal method, natural processes, anthropogenic activities, human activities and their agricultural methods (WHO, 1998a, b; Patrick et al., 2002; Ejikeme, 2003). Yakasai et al. (2004) revealed that the concentration of Cd and other heavy metals in ground water is dependent on the closeness of the water source to the roads with high traffic density, industrial activities like metal melting and coal refining and oil fired power stations, electroplating plants, rate of development of the area, the topography of the land, climatic conditions and solid waste disposals. Environmental exposure to Cd has detrimental health hazard as it is toxic and has cumulative effect (Ferrer et al., 2000; Klaassen, 2001). Kidney being the major storage organ for Cd is the critical organ that first display signs of toxicity (Nordberg, 2001).

The significantly ($p<0.05$) high concentration of Pb obtained in this study which exceeded the WHO permissible limit is in tandem with the previous study conducted in the area which reported that concentration of Pb from Enyigba stream was 0.7 and 0.1 mg/L in Enyigba Primary School which were above the stipulated limit by regulatory bodies (Nnabo, 2015). The high metal index for Pb observed in the present study shows significant Pb contamination of water sources. Pb as a result of its insoluble nature, decreased rapidly with distances away from the mineralization zones (Bolucek, 2007). High concentration of Pb in streams could be due to disintegration/breakdown and leaching of lead from waste rocks dumps (Cobbina et al., 2015). This has important public health implications as Pb poison can affect both the foetus and neonates because it excretes through the placenta and breast milk. Miscarriage, still birth, and premature birth are among the complications reported in mothers due to Pb poisoning. Developing brains (fetal, neonatal and infant brains) are highly prone

Table 1. Mean concentration of heavy metals in drinking water sources in Enyigba.

Heavy metal (mg/L)	Stream 1	Stream 2	Borehole 1	Borehole 2	WHO (2011)
As	0.091±0.055[a]	0.187±0.047[a]	0.075±0.041[a]	0.485±0.510[a]	0.010
Cd	0.094±0.124[b]	0.002±0.0204[b]	0.012±0.021[b]	0.003±0.005[b]	0.003
Cu	0.075±0.046[c]	0.067±0.057[c]	0.009±0.008[c]	0.023±0.025[c]	2.000
Zn	2.015±2.011[d]	1.555±0.457[d]	0.078±0.073[d]	0.175±0.133[d]	3.000
Pb	0.574±0.345[e]	0.272±0.157[e]	0.077±0.133[e]	0.043±0.075[e]	0.010

Values are mean ± standard deviation of three values. The values with the same superscript along the row were not significantly different (P>0.05).

Table 2. Metal Index of the heavy metals in the drinking water sources.

Heavy metal	Stream 1	Stream 2	Borehole 1	Borehole 2	Standard (WHO, 2011)
As	9.10±5.50	18.70±4.70	7.50±4.10	48.50±51.00	0.01
Cd	31.30±41.30	0.67±6.70	4.00±7.00	1.00±1.70	0.003
Pb	57.40±34.50	27.20±15.70	7.70±13.30	4.30±7.50	0.01
Cu	0.04±0.02	0.03±0.03	0.01±0.01	0.01±0.01	2.00
Zn	0.70±0.67	0.52±0.15	0.03±0.02	0.06±0.04	3.00

The values show mean ± standard deviation of three replicates of water sample. Values > 1.0 indicates significant contamination while values < 1.0 indicates no contamination (Akpoveta et al., 2011).

to Pb poisoning (Vasudevan et al., 2011).

The result of the mean concentration levels of Zinc in water samples from both streams and bore-hole were within the WHO (2011) permissible limit of 3.0 mg/L for drinking water. The value of the metal indices is low which shows no contamination by Zn. The previous study conducted in the area reported that concentration of Zn from Enyigba stream was 10.1 and 6.6 mg/L in Enyigba Primary School which were above the stipulated limit by regulatory bodies (Nnabo, 2015) and this is at variance with the current study. An elevated dose of Zn over an extended period of time is accompanied with Cu deficiency. There is a competitive absorption between Cu and Zn within the enterocytes. The clinical manifestation of Cu deficiency includes hypocupremia, impaired iron mobilization, anemia, leucopenia, neutropenia, decreased superoxide dismutase, ceruloplasmin as well as cytochrome-c oxidase, but elevated plasma cholesterol and abnormal cardiac failure (Laura et al., 2010).

The results of the mean concentration levels of Cu in water samples from both streams and bore-holes were within the WHO (2011) permissible limit of 2.0 mg/L for drinking water. The value of the metal indices for copper is low which indicates no contamination. The present study is in agreement with the previous study conducted in the area which reported that concentration of Cu from Enyigba stream was 0.08 mg/l which was within the stipulated limit by regulatory bodies (Nnabo, 2015). Cu toxicity induces Zn deficiency that can result to anxiety state through over-production of catecholamines (epinephrine, norepinephrine, dopamine and serotonin) (Eck and Wilson, 1989).

Moreso, The present findings from different streams and boreholes indicate that irrespective of the water source, be it stream or borehole, the levels of As and Pb were elevated. This shows that this area is highly polluted by these metals. Consequently, proper monitoring of these water sources is required. Hence, water from these sources need to be treated to remove these heavy metals probably by using available remediation technologies such as ion exchange, bioremediation, membrane filtration, heterogeneous photocatalyst, etc.

Conclusion

The study showed that drinking water from these sources is heavily contaminated with As, Cd, and Pb which exceeded the WHO recommended maximum limits specifications for drinking water. There is urgent need for proper regulation of mining activities and monitoring of heavy metal levels in drinking water sources. The mining communities and the miners should also be enlightened on the possible health risk associated with exposure to heavy metals to prevent them from polluting water bodies. Besides, drinking water from these sources should be properly treated before consumption to remove these heavy metals.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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