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Analysis of Some Heavy Metals in Drinking Water Sources of Effa Communities of Ugbokolo Town, Benue South, Nigeria

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Abstract

The study was to evaluate the level of heavy metals in the drinking water sources of Effa communities and its pollution load index. Water samples were collected from three surface running waters and a borehole around the area. The analysis for heavy metal was conducted using Inductively Coupled Plasma Mass Spectroscopy. The results of heavy metals concentrations from the waters samples in the area were 0.67 mg/L, 5.75 mg/L, 8.88 mg/L, 0.53 mg/L, 16.87 mg/L, 17.58 mg/L, 9.25 mg/L and 5.11 mg/L for As, Zn, Pb, Cd, Cr, Mn, Fe and Cu respectively. These values were higher than the guideline for drinking water according to World Health Organization. The trend of the average concentrations of the heavy metals follows the order of Mn> Cr > Fe > Pb > Zn > Cu > As > Cd. The pollution indices such as Contamination factor (CF), Geo-accumulation index (Igeo), Pollution load index (PLI) was determined. The results indicated that the water samples of the studied area were moderately polluted with heavy metals. The correlation analysis indicated significant positive correlation of metals in water. The concentration of heavy metal indicated that the study area does pose health risk to the communities. Hence, the attention of relevant Authorities should be drawn to take necessary action in providing safe drinking water for the communities to prevent outbreak of incurable diseases. The study recommends assessments of heavy metals other than those determined and conduct a physiochemical analysis of water sources in the communities.

Key words: heavy metals, water sources, water pollution, Inductively Coupled Plasma Mass Spectroscopy

Introduction

The exposure to heavy metals such as mercury, lead, and arsenic, manganese, cadmium, chromium can negatively affect the structure and function of cells, tissues, and organs even though, some are of health benefits if not in excess. Heavy metals constitute heterogeneous group of elements widely varied in their chemical properties and biological functions. The term "heavy metals" defined as those metals, which have specific weights more than 5g cm^{-3} (Holleman and Wiverd, 1985). Heavy metals are kept under environmental pollutant category due to their toxic effects in plants, human and food. Some heavy metals such as Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg) are cumulative poison (Adua, et al., 2020). The wide spread of heavy metals contamination in the last decades has raised public and scientific interest hence, special attention is given to them throughout the world because of their toxic effects even at very low concentrations (Kumar, 2004; Islam et al., 2007). Rivers, streams, lakes, water from ponds and ground water are used to irrigate crops, households and industrial uses. Water is one of the major media for the transportation of metal contamination as it feeds the plants, animals and man. Human activities such as mining, smelting, irrigating with sewage water, etc have contributed to the pollution of soil and the environments with heavy metals (Joshua and Oyebanjo, 2009). The heavy metals may present a distortion on soil ecology and ground water quality, and ultimately pose health problems to human population (Guidotti, 2005; Li *et al*., 2007; Gregorauskiene, 2008; Dissanayake and Chandrajith, 2009; Adaikpo, 2013). Mining of coal is a common practice around the Effa area it is to this end that the present study seeks to assess the levels of heavy metals and the pollution levels of water sources in the area to ascertain if their concentrations are within internationally acceptable limits.

Material and method

The study was conducted in three Effa communities; Effa itself, Abache where coal is mined and Efewu. Effa is situated in Ugbokolo district of Okpokwu local government area of Benue state, Nigeria which lies between the locations described as 7°11'0''N 7°47'0''E, 7°3'46''N 8°12'36''E (Figure 1).

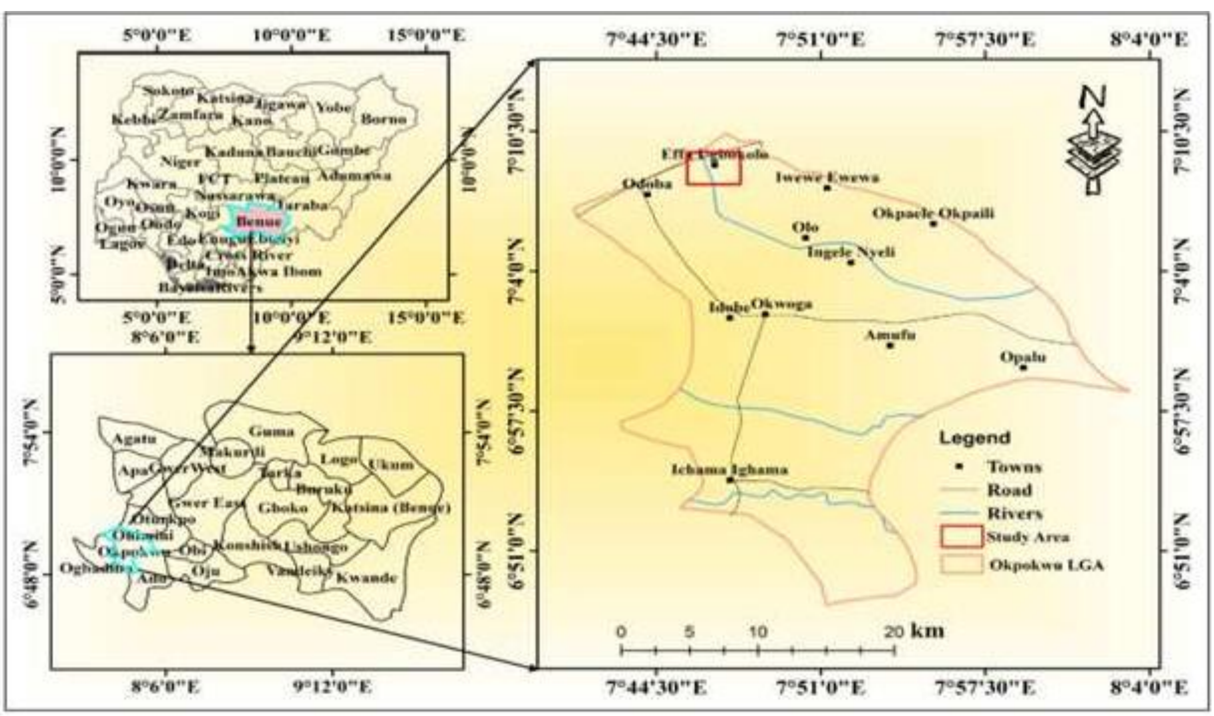

Figure 1: Geographical map of the study area.

Sample Collection

Samples were collected from the study area in the month of November 2023. The locations of sample collection are shown in the Table 1.

Table 1: Location for collection of Water samples at the study area

Sample No	Sample Code	Latitude (ºN)	Longitude (ºE)
1	RO-1	0361565	0794743
2	RM-1	0361483	0795613
3	BH-1	0361980	0794580
4	OLUM-1	0360114	0795320

Water samples were collected directly from Okolo stream coded as RO-1 (Figure 2), Mabe stream as RM-1, Borehole as BH-1 and Olumabe stream as OLUM-1 into amber coloured plastic bottles rinsed with distilled water, properly sealed and marked. A Global Positioning System (GPS) was used to mark each sampling points (Table 1). The samples were later transported to the Department of soil science Federal University of Agriculture, Makurdi now known as Joseph Sarwuna Tarka University, Makurdi laboratory for preparation and subsequent analysis.

Figure 2:Fig.3.4 Coal mine site, coal and soil samples

A section of RO-1

Each water sample collected was preserved with 4ml concentrated nitric acid to prevent the precipitation and absorption of metals and stored in freezer at 4^{o}C. The concentrations of the elements of interest from the collected water samples were determined using ICP-MS technique

Assessment of site contamination with heavy metals

To quantify the contamination of an area, it is necessary to compare heavy metal concentrations in matrix with guideline limit upon which informed decision about the area quality could be made. In this study, area contamination was assessed using the criteria of Contamination factor (CF) (Hakanson, 1980), Index of geo-accumulation (Igeo) (Tijani and Onodera, 2009), and Pollution load index (PLI) (Tomilson *et al*., 1980). Each of these assessment criteria was calculated using Equations 1 to 3.

Contamination factor (CF)

The contamination factor gives an indication of the degree of contamination of soil. This is defined as the ratio of concentration of metal in a sample to the concentration of metal in the background. The level of contamination factor of sample by metal is expressed by Equation 1. C_{sample} is the given metal in sample; $C_{Background}$ is the background value of metal. In this study, the $C_{Background}$ value is equals to the control values. According to Hakanson (1980) contamination factor can be classified as shown in Table 2.

$$CF = C_{sample} / C_{Background} \qquad (1)$$

Table 2: Contamination factor classification according to (Hakanson, 1980)

Contamination factor	Level of Contamination
CF < 1	Low
$1 \leq CF < 3$	Moderate
$3 \leq CF < 6$	Considerate
$CF \geq 6$	Very high

Index of Geo-accumulation (Igeo)

The index of geo-accumulation is used to assess the degree of metal contamination in terrestrial, aquatic as well as marine environment in comparison to background contents (Tijani and Onodera, 2009). The index of geo-accumulation is given as:

$$Igeo = \log_2 C_{metal} / 1.5\, C_{metal\ (control)} \qquad (2)$$

Where C_{metal} is the measured concentration of element and $C_{metal\ (control)}$ is the geochemical background value (Control). The constant 1.5 is possible natural fluctuations in background value due to lithologic effect. Table 3 gives the contamination criteria based on index of geo-accumulation.

Table 3: Classification of geo-accumulation index (Tijani and Onodera, 2009; Huu *et al.*, 2010)

Index of geo-accumulatio	Degree Contamination
Igeo < 0	Unpolluted
$0 \leq Igeo < 1$	Unpolluted to Moderately polluted
$1 \leq Igeo < 2$	Moderately polluted
$2 \leq Igeo < 3$	Moderately to strongly polluted
$3 \leq Igeo < 4$	Strongly polluted
$4 \leq Igeo < 5$	Strong to very strongly polluted
Igeo > 5	Very strongly polluted

Pollution load index (PLI)

Pollution load index is used in evaluating the pollution level for an environment. The PLI for this current work was evaluated using the method proposed by Tomlinson *et al.*, (1980) given in Equation 3.

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ \ldots\ \times CF_n)^{1/n} \qquad (3)$$

Where, CF is the contamination factor and n is the number of metals investigated. If PLI value is > 1 it means polluted while PLI value < 1 indicates no pollution.

Results and Discussion

Table 4: the concentrations of some heavy metals in mg/L in water of the

Sample ID	As	Zn	Pb	Cd	Cr	Mn	Fe	Cu
RO-1	0.69	5.90	8.96	0.55	16.90	17.66	9.60	5.20
BH-1	0.65	5.54	8.75	0.51	16.85	17.50	8.70	4.95
RM-1	0.66	5.80	8.92	0.53	16.87	17.58	9.45	5.18
Min	0.65	5.54	8.75	0.53	16.85	17.50	8.70	4.95
Max	0.69	5.90	8.96	0.55	16.90	17.66	9.60	5.20
Mean	0.67	5.75	8.88	0.53	16.87	17.58	9.25	5.11
STDEV	0.02	0.19	0.11	0.02	0.03	0.08	0.48	0.14
OLUM-1	0.63	5.30	7.98	0.49	15.88	16.70	8.63	4.80

The concentrations of the metals in mg/L were 0.65 – 0.69mg/L for As, 5.54 – 5.90mg/L for Zn, 8.75 -8.96mg/L for Pb, 0.53 – 0.55mg/L for Cd, 16.85 – 16.90mg/L for Cr, 17.50 – 17.66mg/L for Mn, 8.70 – 9.60mg/L for Fe and 4.95 – 5.20mg/L for Cu with their average concentrations of 0.67mg/L, 5.75mg/L, 8.88mg/L, 0.53mg/L, 16.87mg/L, 17.58mg/L, 9.25mg/L and 5.11mg/L respectively.

Mn was found to be higher in the water samples in the area with the average concentration of 17.58mg/L. very close to Mn was Cr with the average concentration of 16.87mg/L and Cd had the least average concentration of 0.53mg/L.

Table 5: concentration in (mg/L) of some heavy metals in water and reference values (Control Value) and World Health Organization (WHO) guideline for drinking water value. (WHO, 2017)

Metal	RO-1	BH-1	RM-1	OLUM-1	WHO
As	0.69	0.65	0.66	0.63	0.01
Zn	5.90	5.54	5.80	5.30	3.00
Pb	8.96	8.75	8.92	7.98	0.01
Cd	0.55	0.51	0.53	0.49	0.003
Cr	16.90	16.85	16.87	15.88	0.05
Mn	17.66	17.50	17.58	16.70	0.20
Fe	9.60	8.70	9.45	8.68	0.30
Cu	5.20	4.95	5.18	4.80	1.30

Table 5 showed that the heavy metals concentration from the study area were significantly higher than the guideline for drinking water according to World Health Organization (WHO), 2017, which agreed with the work of Yebpella et al., (2011). The trend of the heavy metals in tis study follows the order of Mn> Cr > Fe > Pb > Zn > Cu > As > Cd. RO-1 and RM-1 have higher metal concentrations than BH-1 while OLUM-1 was the control for the study. From Figure 3, it is shown that the levels of metals from the water sources are in the order of Okolo Stream > Mabe Stream > Efewu Borehole.

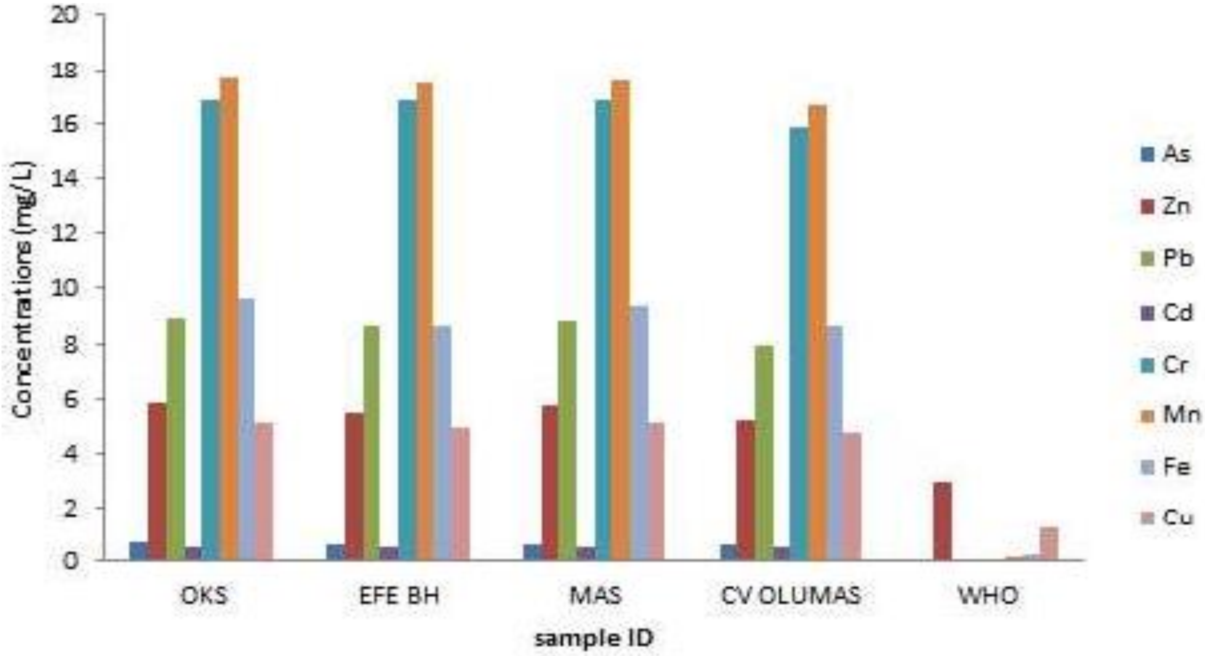

Figure 3: Comparison of heavy metals distribution with reference values.

Table 6: Correlation analysis for concentration (mg/L) of heavy metals in water of the study area

HM	As	Zn	Pb	Cd	Cr	Mn	Fe	Cu
As	1							
Zn	0.9764	1						
Pb	0.9717	1.4296	1					
Cd	0.9428	0.9684	0.9410	1				
Cr	0.9245	0.9179	0.8788	0.9806	1			
Mn	3.7712	0.9684	0.9410	1.000	0.9806	1		
Fe	0.9794	0.9930	0.9987	0.9339	0.8767	0.9339	1	
Cu	0.9671	0.9798	0.9935	0.8998	0.8329	0.8998	0.9963	1

The results of statistical analysis revealed positive correlation between all the metals in the water samples. The listed r values indicated the high degree of positive correlation amongst the different metals and significant at á = 0.05. The significant linear relation between various pairs of metals reflect their simultaneous release and originating from identical sources.

Contamination factors (CF)

The values of contamination factors for the three water sources are presented in Table 7. The results showed contamination factors to be more than unity across the water sources with Pb having the highest calculated contaminated factor values in the entire location. The results indicated moderate contamination of the water.

Table 7: Contamination Factor (CF) values of heavy metals in water of the study area

Metal	RO-1	BH-1	RM-1
As	1.0952	1.0317	1.0476
Zn	1.1132	1.0453	1.0944
Pb	1.1228	1.0965	1.1178
Cd	1.1224	1.0408	1.0816
Cr	1.0642	1.0611	1.0623
Mn	1.0575	1.0479	1.0523
Fe	1.1060	1.0023	1.0887
Cu	1.0833	1.0313	1.0792

Geo-accumulation index (Igeo)

The geo-accumulation index has been used extensively in the assessment and evaluation of environmental pollution by heavy metals (Ogbeibu *et al*., 2014; Saikia, *et al*., 2014; Huu *et al*., 2010). The results were obtained using equation 2. The negative values in As, Pb, Cd, Cr, Cu, Fe, Mn and Zn indexes of geo-accumulation shown in Table 8 is a result of moderate levels of contamination (Table 7).

Table 8: Geo-accumulation index (Igeo) values of heavy metals in water of the study area

Metal	RO-1	BH-1	RM-1
As	-0.4537	-0.5399	-0.518
Zn	-0.4302	-0.5211	-0.4549
Pb	-0.4179	-0.4521	-0.4243
Cd	-0.4183	-0.5272	-0.4718
Cr	-0.4952	-0.4994	-0.4977
Mn	-0.5043	-0.5175	-0.5109
Fe	-0.4396	-0.5816	-0.4623
Cu	-0.4695	-0.5406	-0.4750

Table 9: Pollution Load Index (PLI) values of heavy metals in water of the study area

Sample location	RO-1	BH-1	RM-1
PL1	1.0953	1.0443	1.0778

The pollution load index for RO-1(Okolo stream) is slightly higher than those calculated for RM-1(Mabe stream) and in the borehole (BH-1) as shown in Table 9 above. Clearly, it is shown that the PLI values calculated are indicative polluted water sources at the study locations.

Conclusion

The water samples of Effa Ugbokolo communities have been analyzed for heavy metals and the following heavy metals determined As, Zn, Pb, Cd, Cr, Mn, Fe and Cu. The contamination factor, index of geo-accumulation and pollution load index were evaluated. The results indicated that the water sources are polluted with heavy metals with may present a health risk to members of the community who consume the waters. Further studies are recommended to investigate other heavy metals than the ones already determine. Also, physiochemical assessments of the water in the area should be conducted. Regulatory agencies should ensure the miner in the area be made to provide potable drinking water for the communities.

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