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Health Risk Assessment of some Heavy Metals in Drinking Water Due to Mining Activities in Gombe Area, Northeastern Nigeria

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Abstract: *Water is one of the essentials that support all forms of life and studies had been carried out to ascertain the quality of drinking water, mainly by determination of heavy metals present. Several researchers have shown that heavy enter our body through the water we drink, air we breathe and food we eat and this is a potential threat to human health. Heavy metal pollution is a global challenge that requires joint efforts of governments, scientists, and communities and there is need for continuous monitoring of water quality. Therefore, in this study the levels of heavy metals (Cd, Cr, Fe, As and Pb) were measured in water samples taken from Gombe, Pindiga and Yamalti-Deba using Atomic Absorption Spectrophotometer methods (AAS). The results showed that all the heavy metals were detected in all the water samples of Gombe, Pindiga and Yamalti-Deba and the order of concentration is Pb > Cr > Fe > Cd > As. The concentration of Pb ranges from 0.216±0.008 mg/L in Shangwam Estate to 1.191±0.010 mg/L in Madagaska Dam. Chromium Cr concentration is highest, 0.973±0.008 mg/L and 0.959±0.016 mg/L in Madagaska Dam and Tumu respectively and minimum value detected was 0.173±0.009 mg/L in Shangwam Estate and 0.038±0.000 mg/L in Riyal. Iron was detected in all the study area and has the maximum values of 1.238±0.012 mg/L and 1.216±0.024 mg/L in Madagaska Dam and Tumu respectively. The concentration of Fe is minimum, of value 0.034±0.010 mg/L, in Shangwam Estate and 0.037±0.000 mg/L in Riyal. The concentration of Cd is ranging from 0.035±0.003 mg/L in Shangwam Estate to 0.230±0.002 mg/L in Madagaska Dam. The minimum value of As concentration detected from the samples is 0.000±0.000 mg/L in Shangwam Estate and the maximum value was 0.024±0.000 mg/L in Dadin Kowa Dam. The results of this study showed that, the heavy metal concentration of Pb, Cr, Fe, Cd and As measured in all the water samples are greater than WHO, USEPA and NSDW permissible limits, therefore, it is suggested that the quality of the drinking water in the mining area of Gombe is contaminated with heavy metals (Fe, Pb, Cr, Cd and As). The uptake of these heavy metals through water can lead to their accumulation in the tissues of organisms and can have harmful and even lethal effects on the human body at higher concentration. This study provides information that will contribute to awareness of the potential impacts of heavy metals pollution in drinking water around the mining area.*

Key words: *drinking water, quality, heavy metals, concentration, health risk, Gombe*

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I. Introduction

Water is one of the essentials that support all forms of plant and animal life [1]. Studies had been carried out to ascertain the quality of drinking water, mainly by determination of heavy metals present [2]. Heavy metals enter our bodies through the water we drink, air we breathe and food we eat, therefore their contamination of water, air or food is a potential threat to human health [3]. Heavy metals are elements with an atomic mass greater than 20, have metallic properties and density greater than 5 g/cm^3 [4,5], therefore are at least five times denser than water (1 g/cm^3). As such, they cannot be metabolized by the body and are stable and bio-accumulative.

The toxicity of heavy metals such as cadmium (*Cd*), lead (*Pb*), iron (*Fe*), arsenic (*As*), chromium (*Cr*) can have harmful and even lethal effects on the human body at higher concentration [1,6-10]. Severe effects include reduced growth and development, cancer, organ damage (liver and kidney), nervous system damage, and in extreme cases, death. They are also known to interfere with synthesis and metabolism of the hormones [11]. The young are more prone to the toxic effects of heavy metals, as the rapidly developing body systems in the fetus, infants and young children are far more sensitive [3]. The health effect of heavy metals in drinking water quality has received considerable attention in recent years considering their strong toxicity even at low concentrations [12]. The exposure to cadmium (*Cd*) and lead (*Pb*) is especially dangerous during prenatal development and infancy. Cadmium (*Cd*) causes skeletal disorders, liver damage, cardiovascular diseases, dysfunctions of the sexual glands, and disrupts a mineral balance in the body [13,14]. Chronic exposure of *Cd* can have harmful effects such as lung cancer, prostatic proliferative lesions, bone fractures, kidney dysfunction, and hypertension. The bioaccumulation of *Pb* in the human body interferes with proper functioning of the mitochondria thereby impairing respiration as well as causing constipation, swelling of the brain, paralysis and could eventually lead to death [5,15,16]. Lead (*Pb*) also causes cardiovascular diseases, kidney and liver dysfunctions and disorders of the immune and the reproductive systems [17]. High concentration of chromium (*Cr*) can be responsible for non-carcinogenic health hazards such as neurological involvement, headache with liver disease. Human exposure to *Cd* above safe concentration limits is a recognized risk for the health [18]. High concentration iron (*Fe*) in body tissues can lead to tissue damage [19]. Several studies have suggested that inorganic arsenic (*As*) affects DNA repair mechanisms and acts as a comutagen in bacterial test systems by inhibiting the repair of damage to DNA caused by another agent [20]. Arsenic (As) poisoning with is dominated by changes in the skin and mucous membranes and by neurological, vascular and haematological lesions. Its Involvement of the gastrointestinal tract, increased salivation, irregular dyspepsia, abdominal cramps and loss of weight may also occur [21].

The population health risk due to heavy metal exposure has been becoming serious and worldwide environmental issue that has attracted considerable public attention particularly in the developing countries [22]. Therefore, heavy metal pollution is a global challenge that requires joint efforts of governments, scientists, and communities [4] and there is need for continuous monitoring of water quality. Several researchers have subsequently shown that the accumulation of heavy metals and other chemical residues in the soils, water and air include mining, cement plant, fossil fuel, coal combustion chemical plants, smelting, waste disposal, urban effluent, vehicle exhausts, sewage sludge, pesticides and fertilizers application [23-33].

Pindiga is a city found in Gombe, North-eastern Nigeria having about 106,322 inhabitants. It is located 9.98° North latitude, 10.93° East longitude and it is situated at elevation 523 *m* above sea level [34]. Therefore, in this study, the level of heavy metal (*Cd, Cr, Fe, As* and *Pb*) in soil from mining area of Gombe were determined using Atomic Absorption Spectrophotometer methods (AAS) to assess heavy metals contamination of soil due to mining activities around Gombe, Nigeria. This information will contribute to awareness of the potential impacts of heavy metals pollutants around the mining area.

II. Material And Methods

Sample Collection and Preparation: To measure level of heavy metals in water from Gombe state, a total of twenty four (24) samples were collected from water (bore-holes, wells and pond and dams) from three local government areas (Gombe, Pindiga and Yamalti-Deba) of Gombe state were mining activities are prominent. The samples were first taken during the month of July (wet season). Samples from water sources were collected in 2 *litre* polyethene bottles with tight covers which were carefully washed in a laboratory and rinsed three times with the distilled water. The sample collected were taken and acidified with few drops of 20 *mL* of 1*M HCl* immediately to preserve the water from biological growth and chemical action with the surface of the container and transferred to laboratory. This is necessary to fix the radioactive elements in the samples. Containers for the samples were washed with solution of detergent and then sensed with distilled water, freshly distilled hydrochloric acid (*HCl*) to remove any inorganic material that might have stuck to the walls of the container before the samples were collected. GPS (Global Positioning System) was used to record the exact position of the sampling sites. Table 1 showed sampling location sites with co-ordinates in the study area of water sampling.

Determination of metal content by AAS: Calibration curves were prepared to determine the concentration of the metals in the sample solution. The instrument was calibrated using series of working standards. The working standard solutions of each metal were prepared from standard solutions of their respective metals and their absorbances were taken using the AAS. Calibration curve for each metal ion to be analyzed was prepared by plotting the absorbance as a function of metal ion standard concentration. Concentration of the metal ions present in the sample was determined by reading their absorbance using AAS (Buck scientific model 210GP) and comparing it on the respective standard calibration curve. Three replicate determinations were carried out on each sample. The metals were determined by absorption/concentration mode and the instrument readout was recorded for each solution manually. The same analytical procedure was employed for the determination of elements in digested blank solutions and for the spiked samples.

Statistical Analysis: Data was analyzed using Microsoft Office Excel. Means and standard deviations (Mean±SD) were used to assess the contamination levels of heavy metals in water samples.

Table 1: Sampling location sites with co-ordinates in the study area of water sampling

Name of the Location	Type	Co-ordinates	
Gombe City		**Latitude**	**Longitude**
Shangwam Estate	Bore hole	10°17'38.96" *N*	11°7'18.21" *E*
Riyal	Bore hole	10°15'45.96" *N*	11°10'2.44" *E*
Pindiga, Akko LG			
Pindiga Dam	Dam	9°59'25.21" *N*	10°57'58.18" *E*

Madagaska Dam	Dam	9°59'6.76" *N*	10°56'50.22" *E*
Abbayo Quarters	Well	9°59'0.79" *N*	10°57'7.76" *E*
Abbayo Quarters	Bore hole	9°59'0.98" *N*	10°57'7.60" *E*
Unguwar Baka I	Bore hole	9°59'7.63" *N*	10°57'8.82" *E*
Unguwar Baka II	Bore hole	9°59'16.94"	10°56'47.74" *E*
Tumu	Bore hole	9°58'55.03"	11°8'53.32" *E*
Piyau I	Well	9°58'50.95"	11°8'58.89" *E*
Piyau II	Well	9°58'45.26"	11°8'54.88" *E*
Yamalti-Deba LG			
Dadin Kowa Dam	Dam	10°12'58.49" *N*	11°23'8.54" *E*
Maimida	Bore hole	10°12'58.49" *N*	11°23'8.538" *E*
Med'im B'eyondi	Bore hole	10°12'43.58" *N*	11°23'25.45" *E*
Kuta Gargajiya	Well	10°12'35.77" *N*	11°22'59.29" *E*
Jeka da Fari	Bore hole	10°17'5.08" *N*	11°9'45.73" *E*

III. Result

The level of heavy metals (*Cd, Cr, Fe, As* and *Pb*) in water from Gombe, Pindiga and Yamalti-Deba were determined using Atomic Absorption Spectrophotometer methods (AAS) and the results are shown in Table 2. The order of these heavy metals concentration in water samples is *Pb* > *Cr* > *Fe* > *Cd* > *As* and their concentration in water samples obtained from atomic absorption spectrophotometry (AAS) are interpreted as follows:

Lead (*Pb*): Table 2 showed the *Pb* concentration detected in all the water samples from the study area and the values range from 0.216±0.008 *mg/L* in Shangwam Estate to 1.191±0.010 *mg/L* in Madagaska Dam, with the average concentration of 0.553625 *mg/L*. Therefore, the concentrations of *Pb* detected in all the samples were greater than the standard permissible value of 0.01 *mg/L* given by WHO (2011).

Chromium (*Cr*): Observation of Table 2 showed that the concentration of *Cr* is detected in all the water samples with the maximum values of 0.973±0.008 *mg/L* and 0.959±0.016 *mg/L* in Madagaska Dam and Tumu respectively. The minimum value of *Cr* concentration detected from the samples is 0.173±0.009 in Shangwam Estate. The concentration of *Cr* has minimum value of 0.034±0.010 *mg/L* in Shangwam Estate and 0.037±0.000 *mg/L* in Riyal. The average value of *Cr* concentration found in this study was 0.4515 *mg/L* and this value is greater than WHO (2011) permissible limit (0.1 *mg/L*) in water.

Iron (*Fe*): It can be seen from the result in Table 2 that the concentration of *Fe* was detected in all the water samples with the maximum values of 1.238±0.012 *mg/L* and 1.216±0.024 *mg/L* in Madagaska Dam and Tumu respectively. The concentration of *Fe* has minimum value of 0.034±0.010 *mg/L* in Shangwam Estate and 0.037±0.000 *mg/L* in Riyal. The average value of *Fe* concentration in this study is 0.451 *mg/L* and this value of *Fe* concentrations in the water greater than the permissible limit of 0.01 *mg/L* set by WHO (2011).

Cadmium (*Cd*): The concentration of *Cd* was detected in all the water samples of Gombe, Pindiga and Yamalti-Deba and is ranging from 0.035±0.003 *mg/L* in Shangwam Estate to 0.230±0.002 *mg/L* in Madagaska Dam (Table 2). The average value of *Cd* concentration is 0.10325 *mg/L* and it greater than the permissible limit (0.05 *mg/L*) set by WHO (2011), (0.005 *mg/L*) set by USEPA, and (0.003 *mg/L*) set by NSDW(2003) [10,11,35-37].

Arsenic (*As*): Observation of Table 2 showed that the concentration of *As* is detected in all the water samples with the maximum values of 0.041±0.001 *mg/L* and 0.024±0.000 *mg/L* in Tumu and Dadin Kowa Dam respectively. The minimum value of *As* concentration detected from the samples is 0.000±0.000 in Shangwam Estate. The average value of *As* concentration found in this study was 0.013063 *mg/L* and this value is greater than WHO (2011) and USEPA permissible limit of 0.05 *mg/L* in water.

Table 2: The mean concentration of iron (*Fe*), lead (*Pb*), chromium (*Cr*), cadmium (*Cd*) and arsenic (*As*) in water samples from sixteen (16) locations

Name of the Location	Concentration (mean ± SD), mg/L				
	Fe	***Pb***	***Cr***	***Cd***	As
Shangwam Estate	0.034±0.010	0.216±0.008	0.173±0.009	0.035±0.003	0.000±0.000
Riyal	0.037±0.000	0.219±0.000	0.178±0.000	0.037±0.000	0.001±0.000
Pindiga Dam	0.320±0.010	0.448±0.008	0.365±0.007	0.082±0.002	0.003±0.000
Madagaska Dam	1.238±0.012	1.191±0.010	0.973±0.008	0.230±0.002	0.021±0.000
Abbayo Quarters	0.441±0.002	0.546±0.001	0.445±0.001	0.102±0.000	0.015±0.000
Abbayo Quarters	0.203±0.003	0.353±0.003	0.287±0.002	0.064±0.001	0.006±0.000
Unguwar Baka I	0.636±0.009	0.703±0.007	0.574±0.006	0.133±0.001	0.021±0.000
Unguwar Baka II	0.524±0.006	0.613±0.005	0.500±0.004	0.115±0.001	0.017±0.000
Tumu	1.216±0.024	1.173±0.019	0.959±0.016	0.226±0.004	0.041±0.001
Piyau I	0.331±0.030	0.456±0.024	0.372±0.020	0.084±0.005	0.011±0.001
Piyau II	0.546±0.007	0.630±0.005	0.514±0.004	0.119±0.001	0.018±0.000

Dadin Kowa Dam	0.718±0.011	0.770±0.009	0.629±0.008	0.146±0.002	0.024±0.000
Maimida	0.290±0.001	0.423±0.001	0.345±0.001	0.077±0.000	0.009±0.000
Med'im B'eyondi	0.446±0.003	0.549±0.003	0.448±0.002	0.102±0.001	0.015±0.000
Kuta Gargajiya	0.047±0.000	0.227±0.000	0.184±0.000	0.039±0.000	0.001±0.000
Jeka da Fari	0.189±0.013	0.341±0.010	0.278±0.008	0.061±0.00	0.006±0.000
Average Concentration	**0.451**	**0.553625**	**0.4515**	**0.10325**	**0.013063**

Table 3: The permissible limits of *Fe*, *Pb*, *Cr*, *Cd* and *As* in drinking water

Permissible values	**Concentration (*mg/L*)**				
	Fe	***Pb***	***Cr***	***Cd***	As
WHO (2011)	0.1	0.05	0.1	0.05	0.05
USEPA	-	-	-	0.005	0.05
NSDW(2003)	0.3	0.01	-	0.003	-
Present study	0.451	0.553625	0.4515	0.10325	0.013063

IV. Discussion

The results of this study showed Madagaska Dam have the highest concentration of the examined heavy metals *Fe* (1.238 *mg*/*L*), *Pb* (1.191 *mg*/*L*), *Cr* (0.973 *mg*/*L*), *Cd* (0.230 *mg*/*L*) and *As* (0.021 *mg*/*L*) followed by and Tumu with the measured heavy metals *Fe* (1.216 *mg*/*L*), *Pb* (1.173 *mg*/*L*), *Cr* (0.959 *mg*/*L*), *Cd* (0.226 *mg*/*L*) and *As* (0.041 *mg*/*L*). The concentrations of heavy metals (*Fe*, *Pb*, *Cr*, *Cd* and *As*) were found much lesser in Riyal *Fe* (0.037 *mg*/*L*), *Pb* (0.219 *mg*/*L*), *Cr* (0.178 *mg*/*L*), *Cd* (0.037 *mg*/*L*) and *As* (0.001 *mg*/*L*), followed by Shangwam Estate *Fe* (0.034 *mg*/*L*), *Pb* (0.216 *mg*/*L*), *Cr* (0.173 *mg*/*L*), *Cd* (0.035 *mg*/) and *As*(0.000 *mg*/*L*), then Kuta Gargajiya *Fe* (0.047 *mg*/*L*), *Pb* (0.227 *mg*/*L*), *Cr* (0.184 *mg*/*L*), *Cd* (0.039 *mg*/*L*) and *As* (0.001 *mg*/*L*). Since the heavy metal concentration measured in all the water samples are greater than WHO, USEPA and NSDW permissible limits, the quality of the drinking water is contaminated with heavy metals (*Fe*, *Pb*, *Cr*, *Cd* and *As*). Therefore, the drinking water for the study area is not safe. The exposure to cadmium (*Cd*) and lead (*Pb*) is especially dangerous during prenatal development and infancy. Cadmium (*Cd*) causes skeletal disorders, liver damage, cardiovascular diseases, dysfunctions of the sexual glands, and disrupts a mineral balance in the body. Chronic exposure of *Cd* can have harmful effects such as lung cancer, prostatic proliferative lesions, bone fractures, kidney dysfunction, and hypertension. The bioaccumulation of *Pb* in the human body interferes with proper functioning of the mitochondria thereby impairing respiration as well as causing constipation, swelling of the brain, paralysis and could eventually lead to death. Lead (*Pb*) also causes cardiovascular diseases, kidney and liver dysfunctions and disorders of the immune and the reproductive systems. High concentration of chromium (*Cr*) can be responsible for non-carcinogenic health hazards such as neurological involvement, headache with liver disease. Human exposure to *Cd* above safe concentration limits is a recognized risk for the health. High concentration iron (*Fe*) in body tissues can lead to tissue damage. Several studies have suggested that inorganic arsenic (*As*) affects DNA repair mechanisms and acts as a comutagen in bacterial test systems by inhibiting the repair of damage to DNA caused by another agent. Arsenic (As) poisoning with is dominated by changes in the skin and mucous membranes and by neurological, vascular and haematological lesions. It involved in the gastrointestinal tract, increased salivation, irregular dyspepsia, abdominal cramps and in loss of weight.

V. Conclusion

The results of this study showed that, the heavy metal concentration measured in all the water samples are greater than WHO, USEPA and NSDW permissible limits, therefore, the study suggested that the quality of the drinking water in the study area of Gombe is contaminated with heavy metals (*Fe*, *Pb*, *Cr*, *Cd* and *As*). The uptake of these heavy metals through water in that area can lead to their accumulation in the tissues of organisms and the toxicity of cadmium (*Cd*), lead (*Pb*), iron (*Fe*), arsenic (*As*), chromium (*Cr*) can have harmful and even lethal effects on the human body at higher concentration. Heavy metal pollution is a global challenge that requires joint efforts of governments, scientists, and communities and there is need for continuous monitoring of water quality. Several researchers have subsequently shown that the accumulation of heavy metals and other chemical residues in the soils, water and air include mining, cement plant, fossil fuel, coal combustion chemical plants, smelting, waste disposal, urban effluent, vehicle exhausts, sewage sludge, pesticides and fertilizers application. Therefore, this study provides information that will contribute to awareness of the potential impacts of heavy metals pollution in drinking water around the mining area.

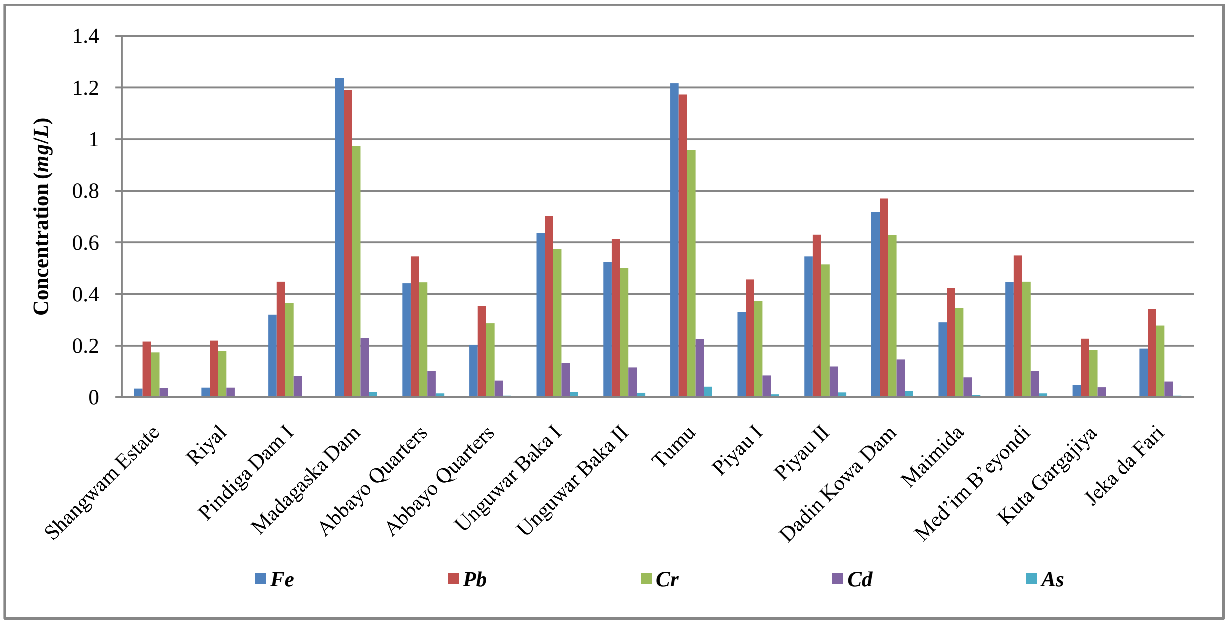

Figure 1: The mean concentration of *Fe*, *Pb*, *Cr*, *Cd* and *As* in water samples from sixteen (16) locations

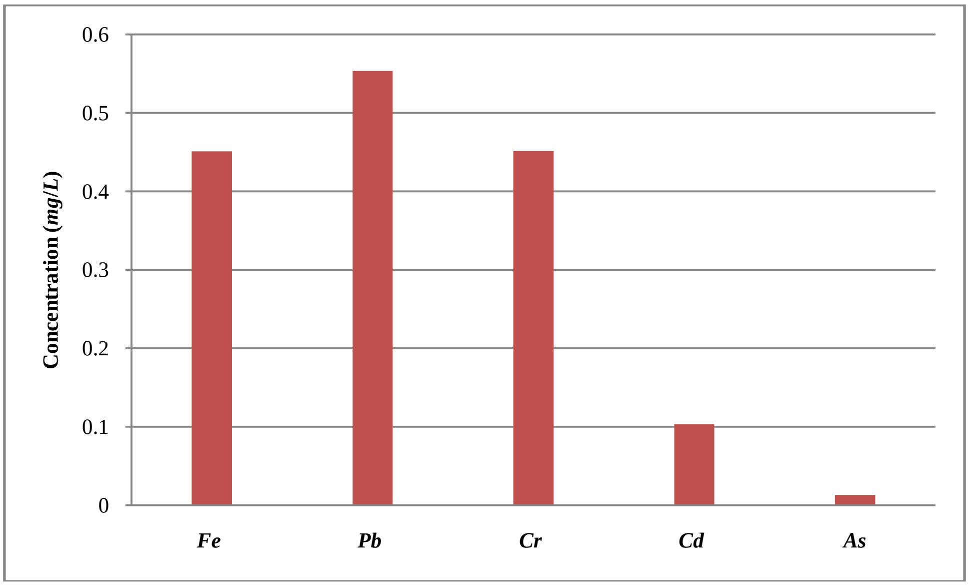

Figure 2: The average concentration of *Fe*, *Pb*, *Cr*, *Cd* and *As* in Bombe water source

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