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Heavy Metal Contaminations of Drinking Water Sources due to Illegal Gold Mining Activities in Zamfara State - Nigeria

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Abstract

The assessment levels of concentration of metal such as Co, Cd, Zn, Cu, Ni, Pb, Mn, Fe, and Cr pollution in water were evaluated as results of sudden increase in gold mining activities in Bagega, Sunke and Dareta villages in Zamfara State, Nigeria. From our investigation, the water quality in Bagega showed high concentration of Pb with a value of 15600 ppm much above the limit set by WHO (2011a). The two remaining villages Sunke and Dareta had Pd concentration values of 549 and 445 ppm respectively far above the limit set by WHO, 2011a. These high concentrations of Pb indicate serious neurological and toxicological hazards. Also, the work revealed high concentration of Fe and Zn which are not directly poisonous to human health but can essentially stimulate the increase in concentration of other toxicological elements such as arsenic. This high concentration of Zn was observed in Sunke village with a value of 2560 ppm twice more than the limit set by WHO, 2011a. In terms of toxicological point of view, the concentrations of all the nine (9) heavy metals Co, Cd, Zn, Cu, Ni, Pb, Mn, Fe, and Cr were above the limit set by FEPA 1998 and WHO 2011a in the villages under investigation are of significant concern on the health of the local population.

Keywords: Heavy metals, illegal gold mining activity, water pollution, neurological health hazard

Introduction

The development of natural resources worldwide involves the manipulation of the environment to arrive at specific objectives.

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Minerals resources is the most exploited natural resources and it involves extraction, grinding, ore concentration and dispersal of tailings [1]. These activities carried through mining processes, generate lots of environmental hazards, chemical waste and cause various degrees of damages and threats to plants, animals and human. Mining can generate large concentration of highly soluble inorganic matter, some of which are considered toxic.

The composition and processing of ores also determined the nature of pollutants [2]. Besides the precious metals generally extracted from ores, varying concentrations of other undesirable toxic and non-toxic metals such as Chromium, Copper, Lead, Zinc, Sulphate, Potassium, Sodium and Calcium are often exposed to the weather/environment resulting into the mobilization of metals and other chemical compounds related to the ore into the nearby water-bodies [2]. Increase in concentrations of these elements in the water-bodies pose serious health hazards to the host communities. As a result in the variation in their physicochemical states and the prevailing chemicals conditions, these metals contaminants migrate and threaten human health by contamination soil, streams, ground-water and food crops. This work therefore, focus on the possible problems related to gold mining in the villages of Dareta, Bagega and Sunke, which are all settlements in Bukuyum Local Government area of Zanfara State, Nigeria. A specific attention was directed towards the possibilities of neurological and assessments of contamination hazards.

Gold mining can have devastating effects on the nearby water resources, the panning and sedimentation processes which are carried out in the middle of the stream bed enable us to be very curious. Water used for panning and sedimentation were obtained from the bore-hole project near the stream-bed as well as the dog holes at various locations in the bed itself. Heavy metals associated with Gold mining waste can dissolve and disperse into surrounding streams as a result of rainwater percolation through the waste [1] or dispersed as particles through erosion processes. Impact of Gold mines can be environmentally detrimental and can constitute serious neurological hazards to exposed or contaminated individuals.

All these three villages (Bagega, Dareta and Sunke) are characterized typically of Sudan savannah vegetation having short stunted trees with communities of grasses. They all experience two distinct seasons; rainy and dry seasons.

The rainy season commence in April and end September while hot seasons from March to May. The peak of the rainfall is in July-August. The average temperature variation is between 30^0 to 35^0. The coldest temperatures are experienced during the harmattan periods when the temperature drop to approximately 18^0. During the harmattan periods, the winds are cold, dry, dusty and strong.

Basically, Bagega is a settlement on the North-Eastern part of Hawwal in Zamfara State, Nigeria. It is located on the Southern part of Anka, the Headquarters of Anka local Government area with coordinate of longitude 6^0East of the prime meridian and latitudes $11^0 43'$ north of the equator. This village is subjected to poor drainage system due to vast portions of clay, terrain that makes up its landscape and it is relatively big, more socially, accessible and economically more active settlement.

Materials and Method

In view of investigating possibilities of heavy metal exposure and contamination in Bagega, Dareta and Sunke mining operations and the extent of concentration of heavy metals of surface and underground water sources available to people who settled in these villages, atomic absorption spectroscopy (AAS) technique was employed. The technique has a special radiation source called the hollow cathode lamb and the sample to be analyzed is converted to gaseous atoms in a hot flame. A special equipment known as the nebulizer is used to introduce the sample into the hot flame. There is no specialization involved since all forms of the analyte are converted in part to the same gaseous atom. The AAS is useful for metallic elements and the precise wavelength associated with the atomic spectra lines provides excellent identification of the analyte.

This technique was used in this work to exploit the possibilities of heavy metal exposure and contamination in Bagega, Dareta and Sunke mining operations and the extent of concentration of heavy metals of surface and underground water sources available to people. A total of ten selected sites were identified in line with the AAS technique and the liquid samples were collected as shown in Table 1 below.

Table 1: Description of Sampling Sites

S/N	Identification Number	Sample Matrix Type	Sample Sites	Previewed Location	Dates of Sample Collection
1	SVW1	Liquid	Sunke Well	Problem Area	18-01-2011
2	SVW2	Liquid	Sunke Well	Affected Area	18-01-2011
3	SVW3	Liquid	Sunke Well	Non Affected Area	18-01-2011
4	SVB1	Liquid	Sunke Borehole	Non Affected Area	18-01-2011
5	SVB2	Liquid	Sunke Borehole	Non Affected Area	21-01-2011
6	SVB3	Liquid	Sunke Borehole	Non Affected Area	21-01-2011
7	DVW1	Liquid	Dareta Well	Washing Point	21-01-2011
8	DVW2	Liquid	Dareta Well	Washing Point	25-01-2011
9	DVW3	Liquid	Dareta Well	Off Washing Point	25-01-2011
10	BR1	Liquid	Bagega River	Used-by-Miners	25-01-2011

Problem Area: Mining Activity Present, **Affected Area**: Within Mining Site, **Non Affected Area**: Far from Mining Site, **Washing Point**: Washing point of the villagers, **Off Washing Point**: Far from the washing point of the villagers, **Used-by-Miners**: Washing point of mining materials

Experimental

The water samples were collected from the above described sites (Table 1) into 2.0 liters plastic container that were washed thoroughly and rinse several times with distilled water to prevent matrix contamination. Since these samples stayed more than a day, there were acidify with nitric acid (HNO_3) to ensured that the element present are in oxidation state and to set both the pH of the samples and standard equal. The water samples were analyzed using AAS equipped with lead hollowed cathode lamp, lamp current 10 mA, wavelength 217.0 nm, Band Pass 0.5 nm with flame type consisting of acetylene/oxygen with flame of approximately 3400 K and acetylene/nitrous acid with flame temperature of approximately 3100 K and stochiometric fuel flow at 0.9 – 1.21 minutes [3].

Because the atomic spectra are lines of absorbing and emitting wavelength identical to the characteristic emission wavelength which is less than the excitation wavelength, the followed stages were employed during the experiment; the analyte were prepare in aqueous solution; the solution aspirated into the flame using the nebulizer; the solvent then evaporates and the gaseous analyte decomposeds, some of it converted into gaseous atom; the gaseous atoms absorbed radiation from the cathode lamb; different hollow cathode lamp were used for each element that were under investigations; the absorbance of the sample were determined by comparing I_0 when there are no analyte present in the flame and I_{trans}. when analyte are present

Applying Beer's law in which the absorption is directly proportional to the path length in the flame and concentration of atomic vapour in the flame. Both of these variables are difficult to determine, but the path length can be held constant and the concentration of atomic vapour is directly proportional to the concentration of the analyte in the solution being aspirated.

The heavy metals in the water types from Boreholes, Wells and Rivers in Sunke, Dareta and Bagega were determined as described by [4]. The digested water samples were quantified for the heavy metals Co, Cd, Zn, Cu, Ni, Pb, Mn, Fe, and Cr in flame of the atomic absorption spectrometer (FAAS). Procedural blanks were prepared and aspirated along with the analytical samples in order to correct for background absorption. In cases where the concentration levels of the metals to be analyzed were too low, concentration methods were applied. Another procedure that was employed involved the extraction technique using organic salt-Ammonium Pyrolidinedithiocarbonate (APDC) for extraction of Cu, Fe, Pb, and Zn. The pH of the water samples were carried out in the field using Sension Platinum Series portable pH. The water samples were then stored in a refrigerator at 4 ^{0}C (Haier Thermocool) to slow down bacterial and chemical reaction rates.

Results and Discussion

The table of recommended standard published by World Health Organization [5] showed guideline values and the results of the report of the committee on protection of water criteria, Federal Environmental Protection Agency (FEPA), Nigeria for which the water samples analyzed in this work were compared with are presented in Table 2.

Table 2: WHO (2011a) Recommended Guideline Values and FEPA (1998)

Substances	WHO 2011-Guideline values (ppm)	FEPA, 1998-Guidline values (ppm)
Pb	0.01	Less than 0.5
Cu	002	1.50
Cr	0.05	0.05
Ni	0.07	-
Cd	0.003	0.01
Zn	005	15
Mn	0.05	Less than 0.5
Fe	0.10	Less than 0.3
Co	0.01	Less than 0.5
pH	-	6.5 - 9.2

The pH values of the three sites are shown in Table 3. The distribution of these values within the studied sites appeared to be acceptable with the results of the report of the committee on protection of water criteria, Federal Environmental Protection Agency, Nigeria (1998) with permissible criteria of pH range 6.5 - 9.2 [3].

Table 3: pH values of the water samples from Sunke, Dareta and Bajaga villages in Zamfara State

Sampling Sites	pH
SVW1	6.6
SVW2	6.7
SVW3	6.7
SVB1	6.6
SVB2	6.7
SVB3	7.5
DVW1	6.7
DVW2	6.9
DVW3	7.1
BVR1	7.7

The results of the analyzed water sample for the three villages practicing “illegal” Gold mining in Zamfara State of Nigeria are presented in Table 4, 5, 6, & 7.

Table 4: Elemental Concentration of Water Samples Collected from Wells in Sunke Mine

Heavy metals (ppm)	SVW1	SVW2	SVW3	Mean	max.	Range
Co	54	18	BDL	34	54	18 - 54
Cd	12	15	11	15	15	11 – 15
Zn	1	10	29	29	29	1 – 29
Cu	15	30	23	23	30	15 – 30
Ni	3	15	13	10	15	3 – 15
Pb	21	148	326	165	326	21 – 326
Mn	49	51	22	41	49	22 – 49
Fe	256	345	341	314	345	256 - 345
Cr	25	96	40	54	96	25 – 96

ppm: parts per million, BDL: Below the detection limit

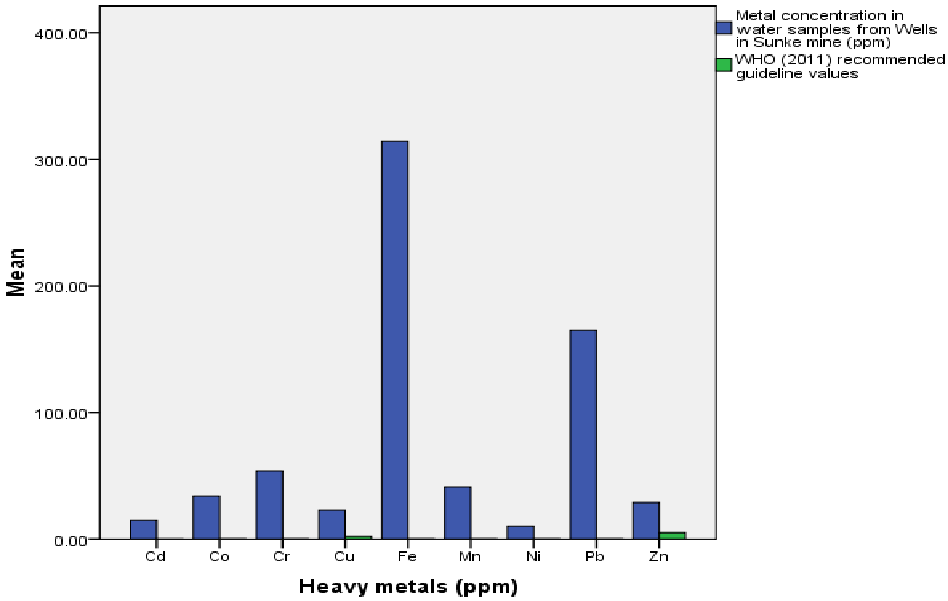

Figure 1: Comparison of Metal Concentration in Wells from Sunke with [5], Safety Limit

From the analysis of the water sample, nine elements were identified as shown in Table 4. As shown in Fig 1, all the nine (9) heavy metal were above the standard limit of [5].

The ranged of Pb from Wells in Sunke illegal mine site had a mean value for (SVW1, SVW2 & SVW3) of 365 ppm and the maximum value of 326 ppm was observed in SVW3. This result was not expected to be high because the Well in this site (SWV3) was the non affected area type. This anomaly could be due to the heavy metals associated with "illegal" gold mining dissolved in the soluble compounds or dispersed into surrounding streams which eventually are found in the Well water [1].

From the Fig 1, Fe is found to have the highest concentration with a mean value of 314 ppm. In these particular sites, SVW2 had the maximum value of 345 ppm in the affected area of the "illegal" gold mining. The ranged in the concentration of Fe observed was 256 – 345 ppm within the three Wells water in Sunke village.

Table 5: Elemental Concentration of Water Samples Collected from Boreholes in Sunke Mine

Elements (ppm)	SVB1	SVB2	SVB3	Mean	max.	Range
Co	54	120	179	118	179	54 – 179
Cd	15	13	8	12	15	8 – 15
Zn	2535	BDL	2560	2548	2535	2535 - 2560
Cu	26	29	14	23	29	14 – 29
Ni	83	9	45	46	83	9 – 83
Pb	297	549	336	394	549	297 - 549
Mn	264	23	61	116	264	23 – 264
Fe	660	256	2225	1047	2225	256 - 2225
Cr	48	40	83	57	83	40 – 83

ppm : parts per million, BDL: Below the detection limit

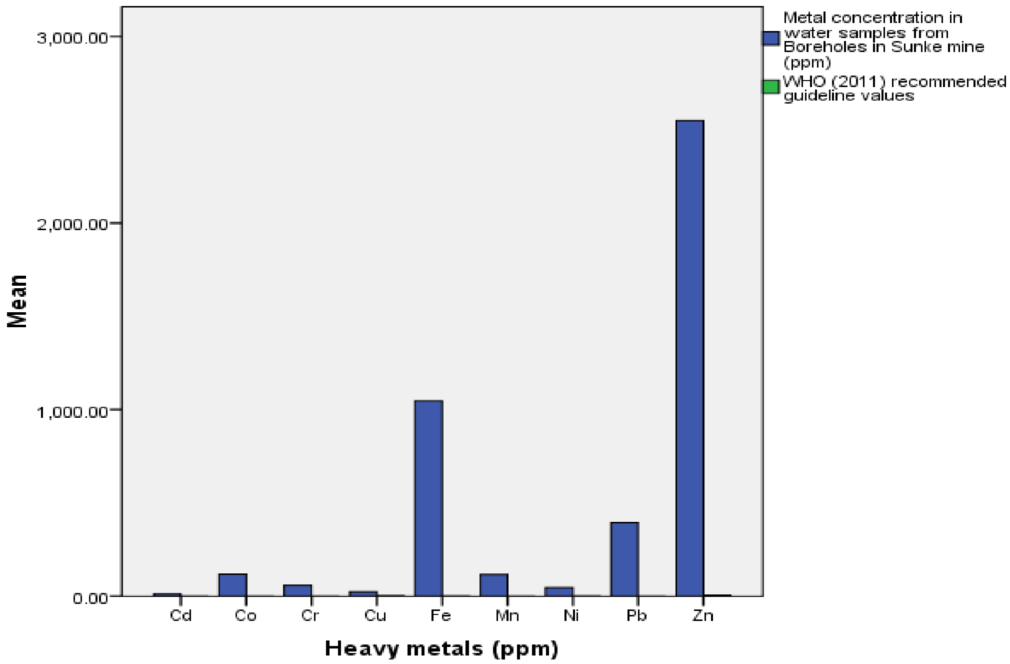

Figure 2: Comparison of Metal Concentration in Boreholes from Sunke With [5], Safety Limit

The results as seen in Fig. 2 of the Borehole water obtained from Sunke indicated that Zn had the highest value followed by Fe and Pb even though all the heavy metal obtained were above the standard limit set by [5] shown in Table 2.

The mean value of Pb obtained was 394 ppm and it ranged from 297 – 549 ppm. The highest value was obtained in SVB2 in the non affected area. This high value ranged of Pb in the non affected area could be due to the fact that the Pb is in the compound form which are soluble in water and have dissolved and dispersed into the surrounding streams and invariable ends up in underground water [7].

Table 6: Elemental Concentration of Water Samples Collected from Wells In Dareta Mine

Elements (ppm)	DVW1	DVW2	DVW3	Mean	max.	Range
Co	251	BDL	24	138	251	24 – 251
Cd	11	13	23	16	23	11 – 23
Zn	2817	17	14	949	2817	14 - 2817
Cu	14	2	55	24	55	2 – 55
Ni	45	12	BDL	29	45	12 – 45
Pb	148	178	445	257	445	148 - 445
Mn	66	57	16	46	66	16 – 66
Fe	653	15	471	380	653	15 – 653
Cr	38	63	38	46	63	38 – 63

ppm : parts per million, BDL: Below the detection limit

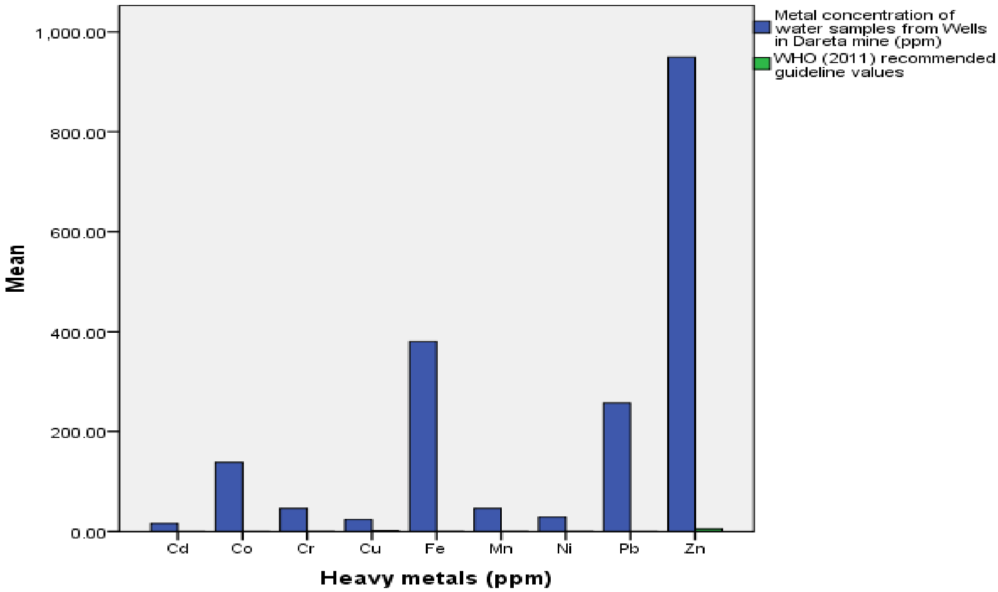

Figure 3: Comparison of Metal Concentration in Wells from Dareta with [5] Safety Limit

The result for Dareta village as revealed in Fig. 3 shows that the water samples from the Wells had all the concentrations elemental values of Co, Cd, Zn, Cu, Ni, Mn, Fe and Cr to be above the limit set by the [5] and Zn, Fe, Pb and Co were relatively high. The value for Pb had a mean value of 257 ppm and the maximum value of 445 ppm obtained in DVW3 while the list of 148 ppm was obtained DVW1.

Table 7: Elemental Concentration of Water Samples Collected from River in Bagega Mine

Elements (ppm)	BVR1	WHO 2011a
Co	BDL	0.01
Cd	17	0.003
Zn	11	5.00
Cu	170	2.00
Ni	BDL	0.07
Pb	15600	0.01
Mn	120	0.05
Fe	4027	0.10
Cr	3	0.05

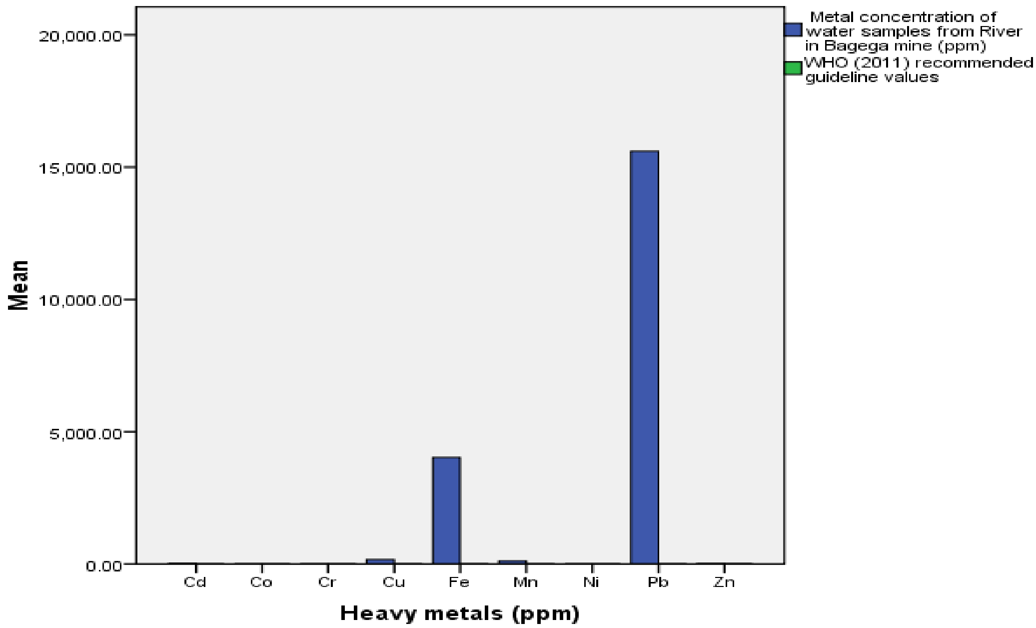

Figure 4: Comparison of Metal Concentration in River from Bagega with [5] Safety Limit

From the results presented in Fig. 4, two elements showed significant concentration above the standard recommended value shown in Table 2. These two elements are Pb and Fe with value of 15600 ppm and 4027 ppm respectively from BVR1 sample.

This site (BVR1) do not have mean because this village does not have other means of drinking water or other household work other than the river which is also used for the “illegal” gold mining. The anomalously high value of Pb in this water sample (river water washing point) could be linked with the sedimentation of the washed gangues from the mine ore zone [8, 9 & 10].

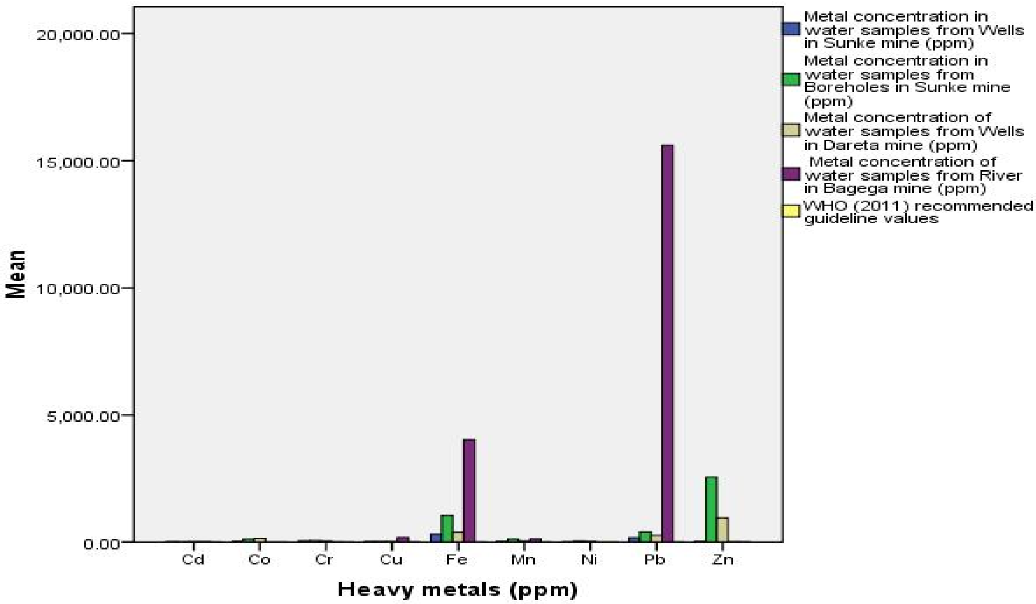

Figure 5: Comparison of Metal Concentration from the four Water Types with [5] Safety Limit

Fig. 5 shows the summary of three (3) heavy metals obtained generally in all the water sample types. Their concentration could give rise to serious health problems. From the results, Pb appear to show the highest concentration obtained from Wells in Sunke mine, followed by Fe and finally Zn (Pb > Fe > Zn).

5.0 Conclusion

Background knowledge of the sources, chemistry, and potential risks of toxic heavy metals in contaminated water is necessary for the selection of appropriate remedial options. Remediation of water contaminated by heavy metals is necessary in order to reduce the associated risks.

The data collected from the different sampling areas of Sunke, Dareta and Bagaga involved in illegal Gold mining activities in Zamfara State, Nigeria shows that the values of concentration of the following heavy metals; Co, Cd, Zn, Cu, Ni, Pb, Mn, Fe, and Cr in the water types (Boreholes, Wells, and River) were above the limit of [5] and that of the report of the committee on protection of water criteria, Federal Environmental Protection Agency (FEPA), Nigeria, 1998. From our investigation, the water quality in Bagega showed high concentration of Pb with a value of 15600 ppm.

The two remaining villages Sunke and Dareta had Pd concentration values of 549 and 445 ppm respectively which were all above the limit set by [5]. High concentrations of Pb indicate serious neurological and toxicological hazards to the inhabitant and the workers of the illegal mines [6]. Also, high concentration of Fe and Zn are not directly poisonous to human health but can stimulate the increase in concentration of other toxicological elements such as arsenic.

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