Original Research Article

Levels of some heavy metals in borehole waters of Birnin Kebbi metropolis, Nigeria

.

ABSTRACT

The levels of Chromium (Cr), Lead (Pb), Copper (Cu), Zinc (Zn) and Iron (Fe) were determined in six different samples of Borehole waters obtained from six designated areas of Birnin Kebbi metropolis, Nigeria using atomic absorption spectrophotometer. The mean concentrations of metals ranged from 0.0005 mg/L Cr to 0.2108 mg/L Fe. The relative abundance of metals in Borehole waters followed the sequence of Fe (0.1769 mg/L)> Cr (0.0342 mg/L)> Cu (0.0298 mg/L)> Zn (0.0052 mg/L). The levels of Cr and other metals were found below the SON/WHO recommended safe limits for metals in water. The low concentration of Cr and absence of Pb in all the samples examined are indications that these Borehole waters contribute fewer toxic effects of metals. The pH values of the water samples were far below the recommended values by the SON/WHO and these could be adjusted through pH correction.

Keywords: Atomic absorption spectrophotometer, heavy metals, borehole waters, contamination.

1.0 INTRODUCTION

Water is one of the essentials that supports all forms of plant and animal life (Svanloon and Duffy, 2005) and it is obtained from two principal natural sources; surface water such as fresh water from lakes, rivers, streams, etc. and ground water such as borehole water and well water (McMurry and Fay, 2004; Mendie, 2005). Water has unique chemical properties due to its polarity and hydrogen bonds which means it can dissolve, absorb, adsorb or suspend many different compounds (WHO, 2007), thus, in nature, water is not pure as it acquires contaminants from its surrounding and those arising from humans and animals as well as other biological activities (Mendie, 2005). One of the most important environmental issues today is ground water contamination (Vodela *et al.,* 1997) and between the wide diversity of contaminants affecting water resources, heavy metals receive particular concern considering their strong toxicity even at low concentrations (Marcovecchio *et al.*, 2007).The World Health Organization (WHO) and UNICEF reports for 2012 ranked Nigeria as the third country, after China and India, with the largest population without adequate water and sanitation conditions (Maxwell *et al.,* 2012).Through rivers and streams, the metals are transported as either dissolved species in water or as an integral part of suspended substances causing the most detrimental effects on aquatic life (Duruibe *et al.,* 2007).

A study carried out by Jeje and Oladepo (2014) to assess the level of heavy metals of boreholes and hand dug well in Ife north Local government area of Osun State, Nigeria. The value of manganese (Mn) ranged from 0.02 to 0.06 mg/L with a mean value of 0.03 mg/L. The mean value of Mn (0.03 mg/L) falls within the maximum desirable limit of 0.5 mg/Lset by WHO. Also, a study conducted by (Maigari *et al.,* 2016) to assess the concentrations of eight heavy metals (Fe, Mn, Cu, Pb, Cd, Ni, Co and Zn) by using atomic absorption spectroscopy in water from Dadinkowa dam and Kwadon boreholes which are the major sources of drinking water to Gombe town in Gombe State, North-East, Nigeria. The concentrations of metals in water from Dadinkowa dam were in the order: Fe (1.86 mg/L), Mn(0.68 mg/L), Cu (0.92 mg/L), Pb (0.19 mg/L), Cd (0.50 mg/L), Ni (0.59 mg/L), Co (0.42 mg/L) and Zn (0.83 mg/L).The concentrations of the metals in water from Gombe Abba River were in the order Fe (0.21 mg/L), Mn (0.24 mg/L), Cu (0.29 mg/L), Pb (0.02 mg/L), Cd (0.10 mg/L), Ni (0.04 mg/L), Co (0.12 mg/L) and Zn (0.41 mg/L). The human health risk assessment was performed by determining the chronic daily intake (CDI), hazard quotient

(HQ) and total hazard index (THI) of the metals through human oral consumption for both adults and children. The HQ of iron, manganese, nickel, and cobalt in water from Dadinkowa dam were all greater than unity and thus pose a potential health risk for both adults and children while cobalt was the only heavy metal of concern in water from Gombe Abba River as its HQ was greater than unity. The THI of water from all the sampled sites assessed were of considerable risk.
The sources of ground water contamination could be natural through ground water rock interaction or through anthropogenic source which involve human activities that can affect groundwater quality. Ground water pollution which is man-made is worse than natural pollution as it eventually renders water unsuitable for use than its original state (Abimbola *et al.,* 2005)
It is a frequent practice to apply agrochemicals or burn dumpsite wastes; this burning gets rid of organic matter and become ashes which are richer in metal contents. These ashes are either dissolved in rainwater and leached into the soil contaminating the underground waters, or washed away by runoff into streams and rivers, thereby contaminating the environment; it is based on these facts this study is aim at determining the levels of lead, copper, iron, chromium, and zinc in Boreholes water of Birnin Kebbi metropolis, Nigeria**.**

Heavy metals can be hazardous in their ability to cause cancer or neurological damage, the determination of such heavy metals in Boreholes water of Birnin Kebbi metropolis, Nigeria would assist in ascertaining the contamination level of these metals in the waters examined and so would help to ascertain the water quality.

2.0 MATERIAL AND METHODS

2.1 Sample collection

Batch sampling which involved taking samples from the environment and performing an analysis later in the laboratory ware used in this research work (Radojavic and Vladimir, 1992). The water samples used for this study were collected from six different areas in Birnin Kebbi town: Badariya, Gesse, Gwadangwaji, Kofa Sabuwa, Mobil Area, and Tudun wada. The samples were collected in plastic gallons (2 litres capacity) which had been thoroughly washed, and filled with distilled water, then taken to the sampling site. The plastic gallons were emptied and rinsed several times with the water to be collected. Also, the plastic gallons were partially filled with the collected water and vigorously shaken to note the odour (Radojavic and Vladimir, 1992). The plastic gallons were tightly covered immediately after collection and the temperature taken. They were then stored in a refrigerator at 4 ^oC (Haier Thermocool) to slow down bacterial and chemical reaction rates (Elinge *et al.,* 2011). All glass wares and plastic containers used were washed with detergent solution soaked overnight in 20% (v/v) nitric acid and then rinsed with tap water and finally with distilled water (Audu and Lawal, 2006).

2.2 Sample treatment and standard preparation

Nitric acid 69% (w/w) of analytical grade purity was used. Standard solutions of the metal salts and other reagents as well as distilled water used were prepared as described below. Approximately 1.0 g of Zn metal was dissolved in a covered 250 cm^3 glass beaker containing 50 cm^3 69% (w/w) nitric acid, and 100 cm^3 of distilled water was added to make 1000 mg/L stock solution. The resulting solution was boiled to expel nitrous fumes and diluted to 1 litre mark with distilled water. About 1.077 g of PbO was dissolved in 25 cm^3 69% (w/w) nitric acid and then diluted to 1 litre with distilled water to make 1000 mg/L Pb stock solution. Other stock solutions of Cr and Cu were prepared in a similar way by weighing and dissolving appropriate amount of their salts in distilled water respectively. The working standard solutions were prepared by serial dilution of various portions of the stock solutions to give standard solutions with concentration range of 0-13 mg/L.

The water pH was measured using a calibrated PHS-25 pH meter. The calibration of pH meter was done using two buffer solutions of pH 6.86 and 7. Fourty (40) cm^3 of water sample was placed in a beaker. The electrode of the pH meter was inserted, and the pH reading was taken. The procedure was repeated for all the other samples. Three replicate determinations were carried out on each sample (Shuaibu *et al.,* 2015).

Digestion of the sample is one of the storage steps taken to preserve the samples from bacterial activities and to release metals into the analytical solution (Itodo, 2009). For each sample, 50 cm^3 was measured into a beaker and 5 cm^3 of concentrated HNO_3 was added. The samples were digested using hot plate in a fume cupboard until the solution reduces to 5 – 6 cm^3 with a characteristic colour, indicating complete digestion. Each digest was then allowed to cool and transferred to a 50 cm^3 acid washed volumetric flask and the volume brought to the 50 cm^3 mark with deionized water. Diluted digest was then filter and kept in sample bottles ready for analysis (Udoh *et al*., 1986). The level of each metal in the three samples were determined using AA-6300 model AAS machine while result was presented as mean value for triplicate analysis (Elinge *et al.,* 2011).

2.3 Atomic Absorption Spectrophotometric Analysis

The concentration of heavy metals in the samples were determined using Atomic Absorption Spectrophotometer (AA-6300 Model) equipped with a digital read-out system. Working standards were used, after serial dilution of 1000 ppm metal stock solution in each case. Calibration curves were constructed by plotting absorbance values versus concentrations. By extrapolation, the concentrations of the metals in sample digest were determined (Audu and Lawal, 2006). Atomic Absorption Spectrometry (AAS) is a technique for measuring quantities of chemical elements present in environmental samples by measuring the absorbed radiation by the chemical element of interest. This is done by reading the spectra produced when the sample is excited by radiation. The atoms absorb ultraviolet or visible light and make transition to higher energy levels. Atomic absorption methods measure the amount of energy in the form of photons of light that are absorbed by the sample. A detector measures the wavelengths of light transmitted by the sample and compares them to the wavelength which originally passed through the sample. A photomultiplier measures the intensity of the incident light and generates an electrical signal proportional to the intensity of light absorbed by the sample (www.intechopen.com). The atomic absorption spectroscopy is applied in water analysis for the determination of(e.g. Ca, Mg, Fe, Si, Al, Ba, content) , food analysis, analysis of animal feedstuff (e.g. Mn, Fe, Cu, Cr, Se and Zn) , analysis of soils, analysis of additives in lubricating oils and greases (e.g. Ba, Ca, Na, Li, Zn and Mg) and clinical analysis (e.g. blood samples: whole blood, plasma serum, Ca, Mg, Na, K and Fr).

3.0 RESULTS AND DISCUSSION

Data obtained were analyzed using Microsoft Excel and results were expressed as mean ± standard deviation.

3.1 *Water pH*

Water pH of the samples ranged from 3.83 to 4.66 indicating acidic. The results have shown that the water samples contain both dissolved organic and inorganic acidic compounds lowering the pH values far below the minimum standard values by SON/WHO (Table 1). This could be adjusted through pH correction in water treatment procedure.

Table 1: Table showing the mean values of some physiochemical parameters of water samples.

Sample ID	pH	Temperature (°C)
BDR	3.96 ± 0.060	31.70 ± 0.528
GWG	4.84 ± 0.035	30.09 ± 0.888
KSW	3.83 ± 0.069	31.00 ± 0.840
MOB	4.65 ± 0.670	30.03 ± 0.028
GES	4.66 ± 0.036	29.80 ± 0.200
TDW	4.50 ± 0.396	31.80 ± 0.262
Range	3.83 - 4.660	30.03 - 31.80
SON / WHO safe limit (1998)	6.50 - 8.50[a]	30[a]

BDR= Badariya area; GWG=Gwadangwaji area; KSW=Kofa Sabuwa area; MOB= Mobil area; GES= Gesse area; TDW=Tudun Wada area; °C=Degree Celsius; ID=Identity; Source a = Okparaocha *et al.* (2016)

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The results did not indicate any metal dominating in all Borehole water samples examined. MOB water sample recorded highest levels of Cr and Cu which are 0.195 and 0.066 mg/L respectively while BDR water sample recorded highest level of Zn which is 0.011 mg/L. Similarly, highest level of Fe was recorded by KSW water sample which is 0.211 mg/L (Table 2).

Table 2: Table showing the metal levels (mg/L) of the Borehole waters.

Sample ID	Cr	Pb	Cu	Zn	Fe
BDR	0.003±0.000	ND	0.023±0.017	0.011±0.039	0.161±0.029
GWG	0.001±0.000	ND	0.007±0.000	0.004±0.012	0.153±0.017
KSW	0.002±0.000	ND	0.023±0.008	0.003±0.000	0.211±0.063
MOB	0.195±0.025	ND	0.066±0.062	0.006±0.000	0.167±0.100
GES	0.003±0.000	ND	0.013±0.003	0.003±0.000	0.183±0.010
TDW	0.002±0.000	ND	0.047±0.000	0.004±0.000	0.186±0.051
Mean±SD	0.034±0.004s		0.030±0.015	0.005±0.009	0.177±0.045
Range	0.001-0.195		0.007-0.066	0.003-0.011	0.153-0.211
SON/WHO Safe limit (1998)	0.05[a]	0.01[a]	2[a]	3[a]	0.3[b]

BDR = Badariya area; GWG =Gwadangwaji area; KSW = Kofa Sabuwa area; MOB = Mobil area; GES = Gesse area; TDW = Tudun Wada area; ID=Identity; ND = Not detected; SD = Standard deviation; Source: a= Itodo *et al*. (2011); b = Okparaocha *et al.* (2016)

Figure 1 below shows the natural distribution of the metals examined in water samples; with Fe and Cr depicting the highest concentration while Zn shows the least concentration among the metals examined.

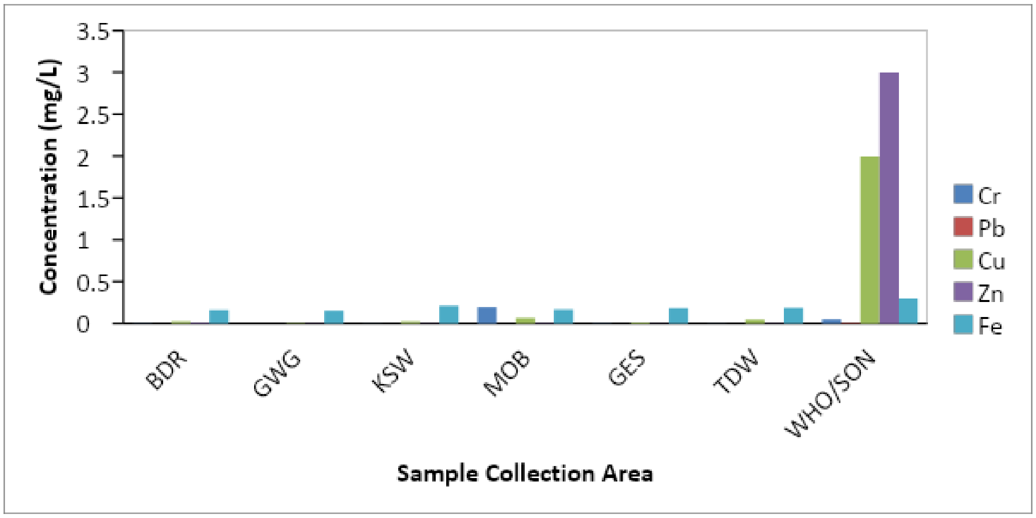

Figure 1: Figure showing the mean distribution of the metals in the Borehole water samples

The sequence of metal concentrations examined in the water samples was Fe> Cr> Cu> Zn presented in figure 2.

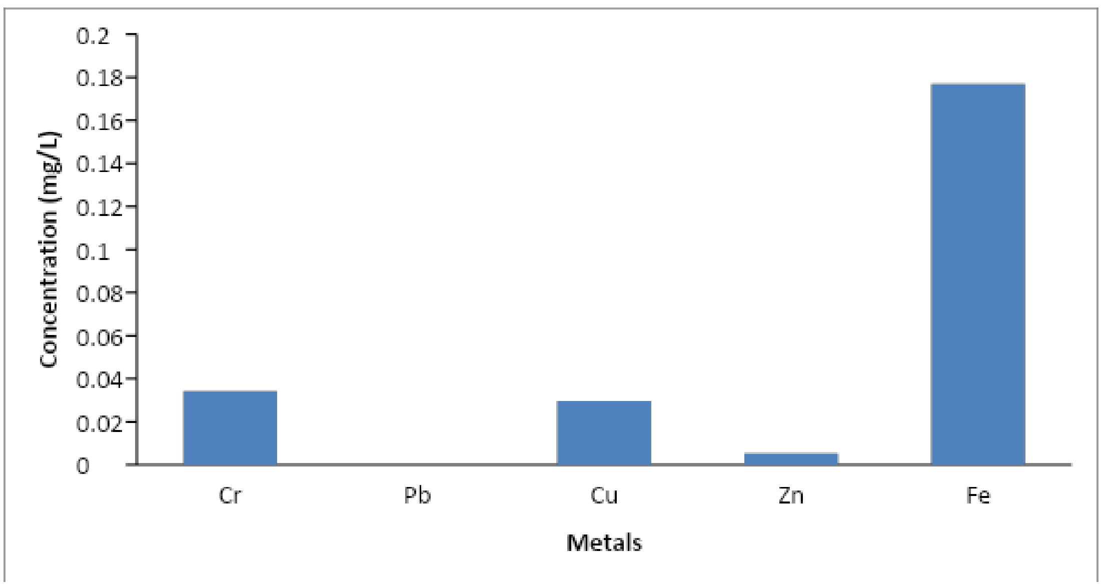

Figure 2: Figure showing the general trend for the mean levels of the metals in the Borehole waters.

To ascertain contamination of water samples with heavy metals, one should have a reference level of each metal beyond which water can be considered as contaminated. Fortunately, reference levels or specifications for heavy metals in water are available or rather feasible. However, the extent of contamination due to anthropogenic activities can be judged far better by comparison with SON/WHO standard reference values. Thus, the extent of contamination was determined through comparison with safe limit values (Table 2).

3.2.1 *Chromium*

Hexavalent chromium is toxic and mutagenic. However, trivalent chromium is an essential trace element and is required for the proper metabolism of sugar in human (Waziri *et al.,* 2013). The chromium distribution pattern in the water samples is as shown in fig.1, with a mean of 0.034 mg/L and range of 0.001 to 0.195 mg/L. The mean chromium level is below the natural concentration limit of 0.05 mg/L in water (SON/WHO, 1998). This finding is similar to the studies reported by (Ekere *et al*., 2014). The reported value for Cr was 0.01 mg/L. The lower level of chromium can be attributed to the lower concentrations of chromium compounds in the soil of the studied areas.

3.2.2 *Copper*

Copper is an essential nutrient which support plants and animals' growth, but at high doses it has been shown to cause stomach and intestinal distress, liver, kidney damage, and anaemia (US EPA, 2003). The copper distribution pattern in the water samples is as shown in fig.2, with a mean of 0.030 mg/L and a range of 0.007 to 0.066 mg/L. The mean copper level is below the natural concentration limit of 2.0 mg/L in water (SON/WHO, 1998). This finding is like the studies reported by Casimir *et al*., (2015). The reported value for Cu ranged from 0.031 and 0.596 mg/L. The low level of copper may be due to geological factors of the studied area.

3.2.3 *Zinc*

Zinc is essential for the normal growth and reproduction of all higher plants, animals, and humans; it is therefore called a micronutrient (JEPTO, 2006). Zinc imparts an undesirable astringent taste to water at a taste threshold concentration of about 4 mg/L; as zinc sulphate (Casimir *et al.,* 2015). The zinc distribution pattern in the water samples is as shown in fig.3, with a mean of 0.0052 mg/L and a range of 0.003 to 0.011 mg/L. The mean zinc level is below the natural concentration limit of 3.0 mg/L in water (SON/WHO, 1998). This finding is similar to the studies reported by Okparaocha *et al.* (2016). The reported value for Zn ranged from 0.020 to 0.090 mg/L.

3.2.4 *Iron*

Iron is a biologically essential component of every living organism; it is toxic at very high concentration (Lieu *et al.,* 2001; Annem, 2017). The iron distribution pattern in the water samples is as shown in fig.4, with a mean of 0.177 mg/L and a range of 0.153 to 0.211 mg/L. The mean iron level is below the natural concentration limit of 0.3 mg/L in water (SON/WHO, 1998). This work agrees with the research reported by Okparaocha *et al.* (2016). The reported value for Fe was 0.270 mg/L.

4.0 Conclusion

The pH of the Borehole water samples showed that the samples contain both dissolved organic and inorganic acidic compounds and this could be corrected. However, all the levels of heavy metals examined are below the recommended safe limits prescribed by SON/WHO. It has also been observed that the general trend for the mean levels of metals examined in the Borehole waters showed that: Fe >Cr > Cu > Zn.

The following recommendations will help to better understand the effect in monitoring and evaluation of heavy metal levels in water samples at regular intervals and maintaining database. These includes strengthening of laboratories in the higher institutions with adequate and up to date equipment to handle the environmental samples and to ensure quality assurance as well as providing enough funds to encourage environmental research for a better and cleaner environment by government and corporate bodies.

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Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.