



Surveillance of the Extent of Heavy Metal Contamination of Bore-hole water in Borno South and the Health Implication on the populace.

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ABSTRACT

A surveyed of the extent of presence of heavy metals in bore-hole water sources in Borno South using Biu, Bayo, Huwul, Kwaya- Kusar and Shani local Government councils as case study was carried out whereby sample of Bore-hole water was fetched from the capital cities of the area council respectively and was taken for analysis in Laboratory using ED-XRF spectrometer and from the result it was found that the following metals Fe, Cu, Hg, Cd, As, Pb, Zn and Cr were present. Evidentially it was revealed that the concentrations of some of these metals is above the limit permissible according to WHO 2008 while some is low, In further analysis, the anticipated health implication were considered by computing the chronic daily intake (CDI), hazard quotient (HQ, hazard index (HI) and carcinogenic risk (CR) of some of the metal to ascertain the threshold level on the intake and make inference on the gross toxicological implications and carcinogenic risk likely to result from the continual intake of the metals into the body systems over a long period no matter how small and so inference is made on the health risk implication for the populace.

1.0 INTRODUCTION

Human exposure to heavy metals has been identified to be through food, water and air [1,2]. Water being a major constituent of the body which accounts for about 70-80% of the weight of most tissues like the muscles, brain, liver, among others; alone has been estimated on average to be about 61% of the whole body weight in an adult [3]. Despite the reality of how common and the importance of water to life, its quality and accessibility have posed a great problem to mankind in many parts of the world especially the developing countries due to its pollution [4] and that is why, lots of sources of water are being explored to ascertain good ones of which bore-hole is not an exception. Though some of these sources are bedeviled by lots of contaminants occasioned by both natural and human activities such as chemical pollution which has been increased with the increase in anthropogenic activities such as new farming techniques, industrialization, mining, fossil fuel application among others; natural processes such as volcanic activities and weathering of rocks also contributes significantly [4-10]. Heavy metals are individual metals and metal compounds that may influence human health. They are metals and metalloids with high atomic weight and specific gravity five times the specific gravity of water [5,7]. Most of these metals such as Hg, Pb, Cd, Ni, As and Sn are toxic in nature and can cause health problem to humans when exposed above the minimum standard concentrations and may consequently lead to diseases such as cancer, reproductive problem among others and even death [7,11,12]. Heavy metal contamination of water has posed a serious threat to human life because of their toxicity, bio-accumulative nature and persistence in the environment [13]. Several of these metals and their compounds are suspected to have carcinogenic potentials in humans [14] and their accumulation in selective tissues of the living organisms have overall potential to be toxic even at relatively low exposure or in take [15] and as such may lead to health risk of the populace [16].

Bore-hole water being a major source of water supply at least, 50% here in Borno south and the worldwide at large [17] needed surveillance to ascertain its suitability for consumption, that was why it became necessary to embark on a research to assess the extent of heavy metals contamination in the area and infer the probable health implications on the populace.

2.0 METHODOLOGY

This research was carried out in Borno state in five local government areas in southern Borno viz. Biu, Kwaya-Kusar, Bayo, Shani and Huwul respectively.

Samples of Bore-hole water were collected randomly from the study areas viz; Biu, Kwaya-Kusar, Bayo, Shani and Huwul in thoroughly cleaned plastic

container which were tightly covered, labeled and moved to Desert Research Monitoring and Control Centre located at Yobe State University, Damaturu for analysis.

2.1 Sample Preparation

100 ml of each of the water samples were pipetted into a separate container with a particular identification number and transported immediately to the laboratory for analysis at Desert Research Monitoring and Control Centre (DRMCC) located at Yobe State University, Damaturu. Energy Dispersive X-ray Fluorescence (EDXRF) Spectrometer (Model: Epsilon 5, PANalytical, The Netherlands) was the analytical technique used to determine the concentration of elements in various water samples.

2.2 Sample Analysis

1ml of each water sample was pipetted into a pellet-like container of 25 mm diameter, and a transparent X-ray foil cover (Polypropylene with a thickness of 6µm) was used to cover the pellet-like cup with a pellet maker (Automatic Hydraulic Presses, model: 3889-4NEI). The samples pellets like cups were loaded into the X-ray excitation chamber for irradiation with the help of an automatic sample changer system. A time-based program, controlled by a software package (PANalytica) provided with the systems was used to irradiate the real samples and the standard materials as well for the construction of the calibration curves for quantitative elemental analysis for the respective samples and afterward the generated X-ray spectra of the materials were stored into the computer.

Risk assessment is defined as the process of estimating the probability of occurrence of any probable adverse health effect over a specified period which is a function of the hazard and exposure [18,19]. Human exposure to heavy metals occurs through several pathways including direct ingestion, dermal absorption through skin and inhalation through mouth and nose. The US-EPA pointed out that the human body absorbed pollutant dose is calculated from chronic daily intake (CDI), which means the pollutant dose per kilogram of body weight per day that is absorbed through direct ingestion, dermal absorption or inhalation. Direct ingestion and skin absorption were used as the main exposure pathways and therefore we examined the risk of heavy metals in Bore-hole water in this research by computing the CDI of water through ingestion and dermal absorption using equations (1) and (2) [18-22].

$$CDI_{in} = \frac{C_i \times D_i \times ABS \times EF \times EP}{BW \times AT} \quad (1)$$

$$CDI_d = \frac{C_i \times SA \times K_p \times ABS \times ET \times EF \times EP \times CF}{BW \times AT} \quad (2)$$

The CDI_{in} and CDI_d are the chronic daily intake of water through ingestion and dermal absorption ($\text{mgKg}^{-1}\text{day}^{-1}$) respectively, C_i is the concentration of the i^{th} heavy metal (mgL^{-1}), D_i is the daily intake of the i^{th} heavy metal (Lday^{-1}), ABS is the absorption factor, EF is the exposure frequency (Daysyear^{-1}), EP is the exposure duration (Years), BW is the body weight (Kg), AT is the average time (Days), SA is the exposed skin area (Cm^2), K_p is the dermal permeability coefficient of metals (Cm^{-1}), CF is the conversion factor (LCm^{-3}), ET is the exposure time (Hoursday^{-1}). While that HQ was estimated by comparing chronic daily intakes of contaminants from each exposure route (ingestion and dermal) with the corresponding reference dose (RfD) for the same heavy metal using equations (3) and (4) respectively [18-22].

$$HQ_{in} = \frac{CDI_{in}}{RfD_{in}} \quad (3)$$

$$HQ_d = \frac{CDI_d}{RfD_d} \quad (4)$$

On the other hand, the hazard index, HI is computed according to US- EPA guidelines for ingestion and dermal absorption of water using equations (5) and (6)

$$HI_{in} = \sum_{i=0}^n HQ \quad (5)$$

$$HI_d = \sum_{i=0}^n HQ \quad (6)$$

Carcinogenic risk, CR was estimated using equation (7) [20].

$$CR = CDI \times SF \quad CDI \times SF < 0.01(7)$$

Where SF is the cancer slope factor ($\text{mgKg}^{-1}\text{day}^{-1}$)

3.0 RESULTS/DISCUSSION

The mean concentration of heavy metals (Fe, Cu, Hg, Cd, As, Pb, Zn, Cr) in water samples obtained from Borno South are presented in Table 1. The values of chronic daily intake for adults through ingestion and dermal exposure pathways are presented in Tables 5 and 6 while, the values of total chronic daily intake are presented in Table 7. The values of hazard quotient for ingestion and dermal pathways with the corresponding hazard index for adults are presented in Tables 8 and 9. The estimated total hazard quotient and total hazard index for adults are presented in Table 10. The carcinogenic risk assessment for adults via ingestion and dermal pathways are presented in Tables 11 and 12 while, the total estimated carcinogenic risk in the samples is given in Table 13.

Table1: Mean concentration of heavy metals in the study areas

Location(s)	Fe(mg/l)	Cu(mg/l)	Hg(mg/l)	Cd(mg/l)	As(mg/l)	Pb(mg/l)	Zn(mg/l)	Cr(mg/l)
Biu	0.30	1.20	0.003	0.0050	ND	0.070	5.9	0.30
KwayaKusur	0.20	1.70	0.002	0.0070	0.05	0.030	6.3	0.40
Bayo	0.40	1.90	0.004	0.0090	0.06	0.080	6.7	0.30
Shani	0.40	1.30	0.002	0.0060	0.08	0.070	6.4	0.20
Hawul	0.50	2.00	0.004	0.0100	0.09	0.070	7.2	0.50
Mean Value	0.36	1.62	0.003	0.0074	0.07	0.064	6.5	0.34
WHO 2008 value	0.30	1.50	0.005	0.0030	0.05	0.050	5.0	0.05

WHO 2008 value[22]

Table2: Estimated chronic daily intake via ingestion for average adults

Location(s)	Fe	Cu	Hg	Cd	As	Pb	Zn	Cr
Biu	1.100E-05	4.400E-05	1.10E-07	1.83E-07	0.00E-00	2.57E-06	0.00021633	1.10E-05
KwayaKusur	7.333E-06	6.233E-05	7.33E-08	2.57E-07	1.83E-06	1.10E-06	0.00023100	1.47E-05
Bayo	1.467E-05	6.967E-05	1.47E-07	3.30E-07	2.20E-06	2.93E-06	0.00024567	1.10E-05
Shani	1.467E-05	4.767E-05	7.33E-08	2.20E-07	2.93E-06	2.57E-06	0.00023467	7.33E-06
Hawul	1.833E-05	7.333E-05	1.47E-07	3.67E-07	3.30E-06	2.57E-06	0.00026400	1.83E-05

Table 3: Estimated chronic daily intake via dermal absorption for average adults

Location(s)	Fe	Cu	Hg	Cd	As	Pb	Zn	Cr
Biu	5.22E-09	2.088E-08	5.22E-08	8.70E-11	0.00E-00	4.87E-09	6.1596E-08	1.04E-08
KwayaKusur	3.48E-09	2.958E-08	3.48E-08	1.22E-10	8.70E-10	2.09E-09	6.5772E-08	1.39E-08
Bayo	6.96E-09	3.306E-08	6.96E-08	1.57E-10	1.04E-09	5.57E-09	6.9948E-08	1.04E-08
Shani	6.96E-09	2.262E-08	3.48E-08	1.04E-10	1.39E-09	4.87E-09	6.6816E-08	6.96E-09
Hawul	8.70E-09	3.480E-08	6.96E-08	1.74E-10	1.57E-09	4.87E-09	7.5168E-08	1.74E-08

Table 4: Estimated total chronic daily intake for average adults

Location(s)	Fe	Cu	Hg	Cd	As	Pb	Zn	Cr
Biu	1.10E-05	4.40E-05	1.62E-07	1.83E-07	0.00E+00	2.57E-06	2.16E-04	1.10E-05
KwayaKusur	7.34E-06	6.24E-05	1.08E-07	2.57E-07	1.83E-06	1.10E-06	2.31E-04	1.47E-05
Bayo	1.47E-05	6.97E-05	2.17E-07	3.30E-07	2.20E-06	2.94E-06	2.46E-04	1.10E-05
Shani	1.47E-05	4.77E-05	1.08E-07	2.20E-07	2.93E-06	2.57E-06	2.35E-04	7.34E-06
Hawul	1.83E-05	7.34E-05	2.17E-07	3.67E-07	3.30E-06	2.57E-06	2.64E-04	1.83E-05
Mean value	1.32E-05	5.94E-05	1.62E-07	2.72E-07	2.05E-06	2.35E-06	2.38E-04	1.25E-05

Table 5: Estimated hazard quotient and hazard index via ingestion

Location(s)	Fe	Cu	Hg	Cd	As	Pb	Zn	Cr	HI
Biu	1.571E-05	1.10E-03	3.67E-04	3.67E-04	0.00E-00	1.83E-03	7.21E-04	3.67E-03	8.07E-03
KwayaKusur	1.048E-05	1.56E-03	2.44E-04	5.13E-04	6.11E-03	7.86E-04	7.70E-04	4.89E-03	1.49E-02
Bayo	2.095E-05	1.74E-03	4.89E-04	6.60E-04	7.33E-03	2.10E-03	8.19E-04	3.67E-03	1.68E-02
Shani	2.095E-05	1.19E-03	2.44E-04	4.40E-04	9.78E-03	1.83E-03	7.82E-04	2.44E-03	1.67E-02
Hawul	2.619E-05	1.83E-03	4.89E-04	7.33E-04	1.10E-02	1.83E-03	8.80E-04	6.11E-03	2.29E-02

Table 6: Estimated hazard quotient and hazard index Via dermal absorption

Location(s)	Fe	Cu	Cd	Pb	Zn	Cr	HI
Biu	3.729E-08	1.74E-06	3.48E-05	1.16E-05	1.03E-06	1.39E-04	1.88E-04
KwayaKusur	2.486E-08	2.47E-06	4.87E-05	4.97E-06	1.10E-06	1.86E-04	2.43E-04
Bayo	4.971E-08	2.76E-06	6.26E-05	1.33E-05	1.17E-06	1.39E-04	2.19E-04
Shani	4.971E-08	1.89E-06	4.18E-05	1.16E-05	1.11E-06	9.28E-05	1.49E-04
Hawul	6.214E-08	2.90E-06	6.96E-05	1.16E-05	1.25E-06	2.32E-04	3.17E-04

Table 7: Estimated total hazard quotient (ΣHQ) and total hazard index (ΣHI) from the samples

ΣHQ	Biu	Kwaya-Kusar	Bayo	Shani	Huwul
Fe	1.580E-05	1.0501E-05	2.100E-05	2.100E-05	2.630E-05
Cu	1.102E-03	1.5608E-03	1.744E-03	1.194E-03	1.836E-03
Hg	3.670E-04	2.4444E-04	4.890E-04	2.440E-04	4.890E-04
Cd	4.010E-04	5.6205E-04	7.230E-04	4.820E-04	8.030E-04
As	0.000E-00	6.1111E-04	7.333E-03	9.778E-03	1.100E-02
Pb	1.845E-03	7.9069E-04	2.108E-03	1.845E-03	1.845E-03
Zn	7.220E-04	7.7110E-04	8.200E-04	7.830E-04	8.810E-04
Cr	3.806E-03	5.0745E-03	3.806E-03	2.537E-03	6.343E-03
ΣHI	8.260E-03	1.5100E-02	1.700E-02	1.710E-02	2.320E-02

Table 8: Estimated Carcinogenic risk via ingestion

Location(s)	Cd	As	Pb	Cr
Biu	1.12E-09	0.00E-00	2.18E-08	4.51E-07
Kwaya-Kusar	1.57E-09	2.75E-06	9.35E-09	6.01E-07
Bayo	2.01E-09	3.30E-06	2.49E-08	4.51E-07
Shani	1.34E-09	4.40E-06	2.18E-08	3.01E-07
Hawul	2.24E-09	4.95E-06	2.18E-08	7.52E-07

Table 9: Estimated Carcinogenic risk via dermal absorption

Location(s)	Cd	As	Pb	Cr
Biu	5.31E-13	0.00E-00	4.14E-11	4.28E-10
Kwaya-Kusar	7.43E-13	1.31E-09	1.77E-11	5.71E-10
Bayo	9.55E-13	1.57E-09	4.73E-11	4.28E-10
Shani	6.37E-13	2.09E-09	4.14E-11	2.85E-10
Hawul	1.06E-12	2.35E-09	4.14E-11	7.13E-10

Table 10: Total Estimated Carcinogenic risk in the samples

Location(s)	Cd	As	Pb	Cr
Biu	1.12E-09	0.00000E-00	2.19E-08	4.51E-07
Kwaya-Kusar	1.57E-09	2.75131E-06	9.37E-09	6.02E-07
Bayo	2.01E-09	3.30157E-06	2.50E-08	4.51E-07
Shani	1.34E-09	4.40209E-06	2.19E-08	3.01E-07
Hawul	2.24E-09	4.95235E-06	2.19E-08	7.52E-07

Since heavy metal contamination in water has the potentials to increase human health risks through various exposure routes, this research explores the carcinogenic and non-carcinogenic health risks caused by oral ingestion and dermal exposure to water. In table4, a wide variation in the mean values of heavy metals was observed with a maximum concentration for

Zn whose mean value for the five locations was 6.5mgL^{-1} and minimum concentration for Hg whose mean value for the five locations was 0.0035mgL^{-1} respectively. The order of toxicity of heavy metals measured from the study area was: $\text{Zn} > \text{Cu} > \text{Fe} > \text{Cr} > \text{As} > \text{Pb} > \text{Cd} > \text{Hg}$. Also, contrast of the mean values of heavy metals and the WHO (2008)

standard values showed that;Biu had low values for Fe, As and Cu.Kwaya-Kusar had low values for As and Pb. Shani had low value for Cu. All locations had high values for Cd, Zn and Cr. Conversely, all locations had low values for Hg.

Non-Carcinogenic Risk Analysis

Human health risk assessment encompasses the determination of the nature and magnitude of the adverse health effects in humans who may be exposed to toxic substances in a contaminated environment. This research uses US-EPA methodology to assess the exposure and resulting health risks of heavy metals on humans. Since the degree of toxicity of heavy metals to human health is directly related to their daily intake, ingestion through drinking and dermal absorption were adopted for this research. The non- carcinogenic risk analysis was done by calculating the chronic daily intake, hazard quotient and hazard index respectively. The results of chronic daily intake through ingestion and dermal pathways are presented in Tables 5 and 6. The values of total chronic daily intake, $CDI_{total}(mgKg^{-1}day^{-1})$ are presented in Table7. The CDI_{total} of the heavy metal concentration for adults were found in the order of: Zn>Cu>Fe>Cr>Pb>As>Cd>Hg. The results of hazard quotient and hazard index for ingestion and dermal pathways as presented in Tables 8 and 9shows that, there is no noticeable harmful health risk in all the samples since their values were all below the threshold value of 1. In order to estimate the total potential non-carcinogenic impact induced by more than one metal, the values of HQ computed were summed and expressed as a hazard index, HI [19] as presented in Table10. The total HI values: 8.26E-03, 1.51E-02, 1.70E-02, 1.71E-02 and 2.32E-02 for Biu, Kwayakusar, Bayo, Shani and Huwulrespectively implied a negligible risk on residents.

Carcinogenic Risk, CR Analysis

The heavy metals Cd, As, Pb and Cr can enhance the risk of cancer in humans [13,18,19,21-23]. Long term exposure to low amount of toxic metals could result in many types of cancers. The results of carcinogenic risk assessment through ingestion and dermal absorption for adults are presented tables11 and 12 while, the total cancer risk for adults is presented in Table 13. A value of CR less than 1.0E-06 is considered insignificant and the cancer risk is negligible while a value of CR above 1E-04 is considered harmful and the cancer risk is troublesome. Among all the studied heavy metals, none has a CR value greater than 1.0E-04 which implied negligible cancer risk.

4.0 CONCLUSION

From the result, the order of heavy metal toxicity in the borehole water in the study area was as presented:

Zn>Cu>Fe>Cr>As>Pb>Cd>Hg and based on the evaluation of the health risks exposureon heavy metals from borehole water on the people of the area, coupled with the analysis of the risk assessment which was carried out by computing carcinogenic and non-carcinogenic risk of the water through ingestion and dermal pathways using a defined formula, both the computed total values of chronic daily intake, CDI_{total} of heavy metals and the hazard quotient and hazard index as obtained from the exposure routes which is by dermal and ingestion, have potentials of harmful cancer risk ,but however, it may be clearly stated that there is a risk factor for continual intake of some of these metals no matter how little over a long period because of their toxic nature as such something is still needed to be done in order to reduce some these metal contaminants in water.

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