ASSESSMENT OF DOSE INTAKE OF TOXIC ELEMENTS IN GROUNDWATER SAMPLES FROM ABUJA, NORTH CENTRAL NIGERIA

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ABSTRACT
This study measured the concentrations of toxic carcinogenic and non-carcinogenic elements present in groundwater using Inductively Coupled-Plasma Mass Spectrometry (ICP-MS). The concentration values obtained were used to calculate the life average daily dose (LADD) exposure of the people whom rely on groundwater for consumption in Abuja, Nigeria. The highest LADD for the carcinogenic toxic element chromium (Cr) was 2.7 x 10^{-5} µg kg^{-1} day^{-1}, whereas it was 3.3 x 10^{-4} µg kg^{-1} day^{-1} for the non-carcinogenic toxic element lead (Pb), identified in water samples collected by the Water Board. These LADD magnitudes of 10^{-5} and 10^{-4} for both carcinogenic and non-carcinogenic toxic elements in groundwater are far below the International Reference Dose according to the United States Environmental Protection Agency (USEPA) in 2008, which has a value of 10^{-1}. The low magnitudes found in water samples may not pose significant health risks to the local population. The relevant authorities should, therefore, continue to monitor the impact of human activities on metal pollution in this area and take effective measures to control contamination of the public water supply.
Keywords: Africa, chromium, contamination, dose intake, groundwater, lead, Nigeria, radionuclides, toxicity risk.

1 INTRODUCTION
Undoubtedly, high exposure to heavy metals in water has negative effects on human health, such as cancers and damage of the nervous system [1], [2]. Excess cadmium (Cd) can cause kidney stones, while excess lead (Pb) can affect brain activity in children [2]. Once the heavy metals such as Cd and Pb are dispersed in water, soil and air, they could be accumulated by the crops [3], [4] if groundwater is used for irrigation. Toxicity to the human kidney by chronic ingestion of uranium (U) through drinking water in the range of 0.004 to 9µg L^{-1} per body weight per day may produce interference with kidney functions [4]. In more recent studies on humans [5], nephrotoxic effects of U in drinking water were found even for low concentrations, without a clear threshold. The activity concentration of radium (Ra) in groundwater depends on the activity concentration of Ra in the bedrock and on mechanisms such as precipitation-dissolution, complexation, and adsorption-desorption that affect the transport of Ra in water. These processes are related to the chemical composition of groundwater [6]. Heavy metals are very toxic, bio-accumulative, and resistant to biochemical degradation: they can pose a potential threat to human health [8]. Heavy metals in urban soils can be readily transferred to humans by ingestion, inhalation, or dermal absorption; accumulate in fatty tissues, and subsequently affect the nervous system, endocrine system, immune system, hematopoietic function, normal cellular

metabolism, etc. The International Commission on Radiological Protection (ICRP) [7] has estimated that gastrointestinal absorption of R from drinking water and food accounts for 15 – 21% of ingested R.

Based on the EU directive that includes U and R isotopes, since thorium (Th) does not or hardly oxidizes in groundwater. This study is aimed at providing the potential radiological risks and chemical toxicity effects of exposure to the inhabitants relying on groundwater within and around Abuja. The geographical coordinates of the study area lie within the latitude (lat.) of 8° 56' 45.6" N and longitude (long.) of 7° 13' 26.2" E for the Gosa area; whereas Lugbe lies within the lat. of 8° 59' 2.3" N and the long. of 7° 23' 7.8" E, respectively. Similarly, this study assesses the life average daily dose (LADD) of some toxic elements in the groundwater in Abuja. There is no available information on the life time average daily dose received by inhabitants that rely on groundwater-based drinking. The results of this study provided data on the toxicity risk exposure to inhabitants of Abuja.

2 GEOLOGY OF THE STUDY AREA

The Abuja area is located within the crystalline basement of Nigeria; with mainly migmatite, leucocratic granite, quartzmonite and granodiorite. The detailed geology and hydrogeology of the study area was reported elsewhere [9]. The drilling point coordinates of the Gosa area lie within the coordinate of lat.: 8° 56' 45.6" N and long.: 7° 13' 26.2" E; whereas Lugbe lies within lat.: 8° 59' 2.3" N and long.: 7° 23' 7.8" E. The boreholes drilled for this study, with lithologic units, are presented in Figs 1, 2, and 3, respectively.
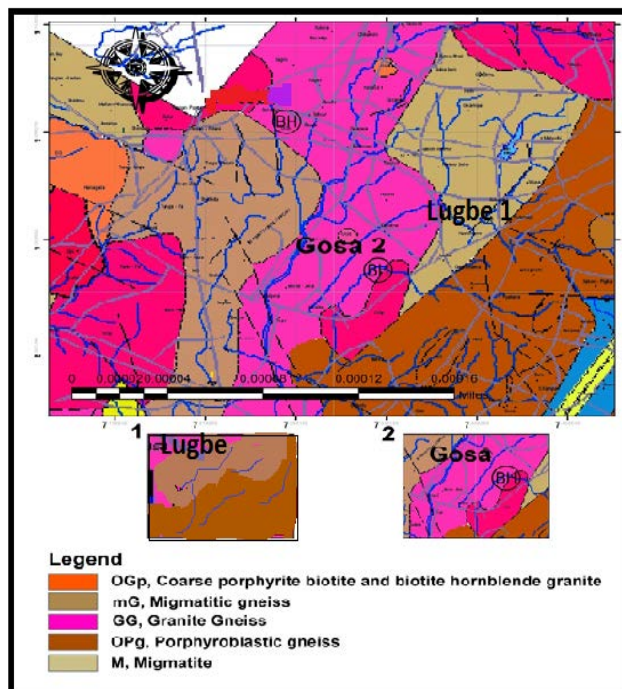

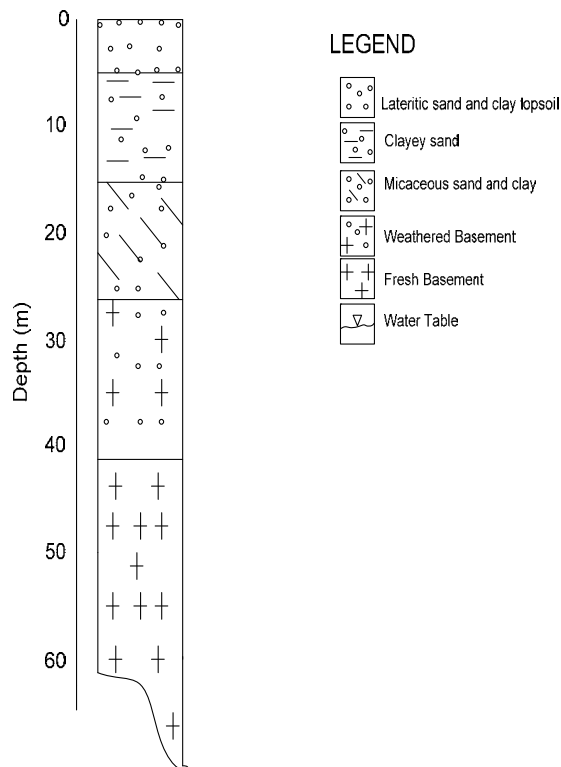Figure 1: Geological map of the study area.

Figure 2:   Lithologic log of representative borehole drilled around the Gosa area, to 50 m (lat.: 8º 56' 45.6" and long.: 7º 13' 26.2" E).

3 MATERIALS AND METHODS

3.1 Sampling and sample preparation

We collected six different water samples that could be used for consumption and domestic purposes in some parts of Abuja. The pH was measured on the spot, using a pH meter (model no. CONSORT C933). At the borehole points, water samples were collected in clean plastic bottles that had been washed several times with 20% nitric acid (HNO_3) and distilled water, for sterilization purposes. All the collected water samples were passed through filters and then 0.5 mL of HNO_3 was added to hold the water constituents until reaching the laboratory for analysis. For the Inductively Coupled-Plasma Mass Spectrometry (ICP-MS) analysis, all the water samples collected were kept in a refrigerator at about 4-6 ºC, in order to measure their heavy metal concentrations next [10].

3.2 Chemical analysis for heavy metals

The acidified water samples were analysed for heavy metals (As, Cd, Cr, K, Mg, Ni, Pb and Zn) by using ICP-MS under standard operating conditions. In view of data quality
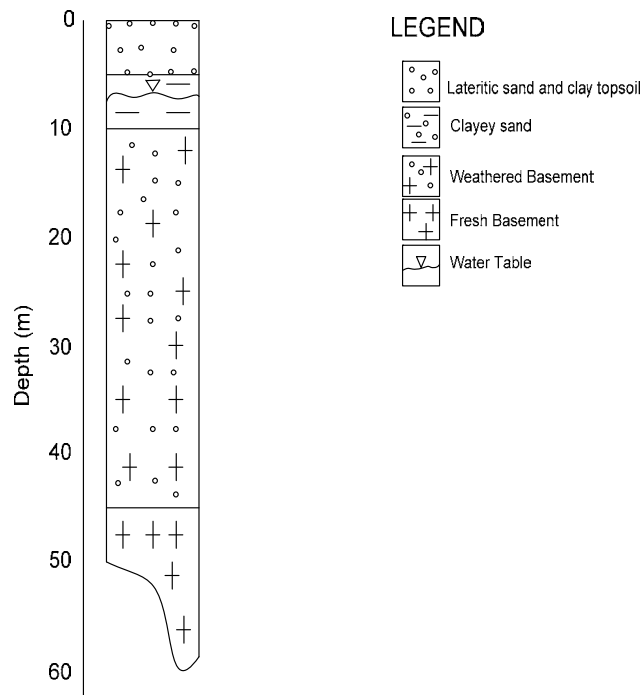
Figure 3:   Lithologic log of representative boreholes drilled around the Lugbe area, to 40 m (lat.: 8° 59' 2.3" N and long.: 7° 23' 7.8" E).

assurance, each sample was analysed in triplicate and after every 10 samples there were two standards, one blank and another of 2.5 µg/L of the respective metal, which were analysed on atomic absorption. Reproducibility was found to be at the 95% confidence level (95%CI). Therefore, the average value of each water sample was used for further interpretation. Standard solutions of all eight elements were prepared by dilution of 1000 mg/L of the certified standard solutions from the manufacturer for corresponding metal ions, with double distilled water. All the acids and reagents used were of analytical grade. The minimum detection limit of 0.22 BqL^{-1} counting for 4 hours, and 0.09 BqL^{-1} counting for 20 hours, which we adopted in this study according to previously published literature [10].

4 RESULTS AND DISCUSSIONS

4.1 The toxic element concentrations of water samples from the study area

Analysis of heavy metals from the water samples indicated there was variation in concentrations for As, Cr, Cd, Pb, Ni, Zn, Mg and K (Table 1). The concentrations were noted to vary respectively, from 0.0002 to 0.002 mg/L, 0.0003 to 0.01 mg/L, 0.00006 to 0.0003 mg/L, 0.0002 to 0.014 mg/L, 0.001 to 0.021 mg/L, 0.02 to 0.277 mg/L, 0.037 to 2.11 mg/L, and 0.0006 to 1.41 mg/L. It can be noted that samples collected from Sabon-Lugbe, Kuje and the Water Board were distinctly higher than other samples for As, Pb, Ni,

Zn, Mg and K, respectively. This could be from the tectonic occurrence that stirred the ultrabasic and mafic igneous intrusion. Comparing the present study with other work reported elsewhere (Table 1); the As, Pb, Ni and Zn concentrations in the waters were noted to be higher in the Sabon-Lugbe borehole sample than others samples. This higher level could be attributed to basaltic dyke intrusion. The higher concentration of Cr and Cd reported at the Giri borehole may be due to shallow sources infiltrating the borehole. At the same time, all the measured samples are within the normal range of permissible limits, when compared [12], [13], [16].

4.2 Chemical toxicity risk of carcinogenic and non-carcinogenic elements in groundwater from the study area.

The World Health Organization (WHO) proposes a very similar reference value, called the Tolerable Daily Intake (TDI), as an estimate of the amount of a substance in food or drinking-water, also expressed on a body weight basis that can be ingested daily over a lifetime, without any appreciable health risk [18]. The TDI values take into account both systemic and carcinogenic effects, but the risk index is calculated as systemic. The exposure assessment of this work only considers the ingestion of drinking water containing pollutants through the oral route, as the unique pathway. The oral dose for each contaminant present in water was calculated by eqn Di:

$$D_i = \frac{C_W \, x \, EF \, x \, ED \, x \, IR_W}{BW \, x \, AT \, x \, 365_{days/year}} \qquad (1)$$

Table 1: Concentrations of heavy metals in the water samples from the study area, compared with other studies elsewhere [12], [19].

Sample location	Carcinogenic toxic elements (mg L^{-1})			Non-carcinogenic toxic elements (mg L^{-1})				
	As	Cr	Cd	Pb	Ni	Zn	Mg	K
Dawaki borehole	0.002	0.004	0.0001	0.005	0.003	0.02	Nil	Nil
Kuje borehole	0.0002	0.002	0.00002	0.0002	0.002	0.04	2.11	1.41
Giri borehole	0.0006	0.0003	0.0003	0.003	0.001	0.032	1.334	1.339
Sabon-Lugbe	0.002	0.004	0.0001	0.014	0.021	0.277	0.037	0.0006
Water board	0.001	0.01	0.0002	0.012	0.008	0.04	Nil	Nil
Hand-dug well	0.003	0.001	0.00006	0.002	0.005	0.03	Nil	Nil
Pereira-Barbosa et al. [12]	0.05	0.1	0.005	0.010	0.07	0.07	0.05	-
Gbadebo [20]	-	-	-	-	-	-	-	8.0

Table 2: The dose intake (Di) in µg kg^{-1} day^{-1} for carcinogenic elements.

Sample locations	Di µg kg^{-1} day^{-1} for carcinogenic elements versus the US EPA standard values		
	(As)	(Cr)	(Cd)
Dawaki borehole	5.4794×10^{-8}	1.0959×10^{-7}	2.7397×10^{-9}
Kuje borehole	5.4794×10^{-9}	5.4794×10^{-8}	5.4794×10^{-10}
Giri borehole	1.6438×10^{-8}	8.2191×10^{-9}	8.2191×10^{-9}
Sabon-Lugbe borehole	5.4794×10^{-8}	1.0959×10^{-7}	2.7397×10^{-9}
Water Board	2.7397×10^{-8}	2.7397×10^{-7}	5.4794×10^{-9}
Hand–dug well	8.2191×10^{-8}	2.7397×10^{-8}	1.6438×10^{-9}
US EPA [21]	6×10^{-1}	6×10^{-1}	6×10^{-1}

Di represents the dose intake of contaminant by water ingestion (µg Kg^{-1} day^{-1}), C_w is the annual average concentration of the contaminant in water (µgL-1), EF is the exposure frequency to the contaminated media (day year^{-1}), ED is the exposure duration (year), IR$_w$ is the rate of water intake (L day^{-1}), BW is the body weight of the receptor (Kg), and AT is the average lifetime of a person (year).The values obtained were compared with the reference dose (RFD) of 6×10^{-1} µg kg^{-1} day^{-1} [18], used as a standard criterion for toxic metal intake.

In Table 2, the Di for As ranged from 1.7×10^{-9} to 8.2×10^{-8} µg kg^{-1} day^{-1}, with the highest value noted in the hand-dug well, with a value of 8.2×10^{-8} µg kg^{-1} day^{-1}. The lowest value was observed in the Giri borehole water sample. Comparing this highest value noted at the hand-dug well water sample with the reference dose (RfD) of µg kg^{-1} per day is the maximum daily dose of a metal from a specific exposure pathway, for both adults and children [18] with a value of 6×10^{-1} µg kg^{-1} day^{-1}, the present study is far lower. The Di for Cr ranges from 8.2×10^{-9} to 2.7×10^{-7} µg kg^{-1} day^{-1} with the highest value noted in the Water Board sample well, a value of 2.7×10^{-7} µg kg^{-1} day^{-1}, and the lowest value reported in the Giri borehole water sample. The highest value is lower that the international standard, when compared with USEPA [18], with a value of 6×10^{-1} µg kg^{-1} day^{-1}. For Cd, The Di ranges from 5.5×10^{-10} to 8.2×10^{-9} µg kg^{-1} day^{-1}, with the highest value noted in the Giri sample with a value of 8.2×10^{-9} µg kg^{-1} day^{-1} and lowest value reported in the Kuje borehole water sample. The highest value is lower than that the international standard, when compared with the USEPA [18], with a value of 6×10^{-1} µg kg^{-1} day^{-1}.

For the non-carcinogenic elements presented in Table 3, the Di for Pb ranges from 5.5×10^{-9} to 3.3×10^{-4} µg kg^{-1} day^{-1}, with the highest value observed in the Water Board sample with a value of 3.3×10^{-4} µg kg^{-1} day^{-1}, and the lowest value reported for the Kuje borehole water sample. Comparing the highest value of Pb obtained in the study with the International Standard with a value of 6×10^{-1} µg kg^{-1} day^{-1}, the present study Di with a value of 3.3×10^{-4} µg kg^{-1} day^{-1} is lower. For Ni, the Di ranges from 2.7×10^{-8} to 5.8×10^{-7} µg kg^{-1} day^{-1}, with the highest value observed in the Sabon-Lugbe borehole water sample with a value of 5.8×10^{-7} µg kg^{-1} day^{-1} and the lowest value reported at the Kuje borehole. Comparing the highest value of Ni obtained in the Sabon-Lugbe with the International Standard value of 6×10^{-1} µg kg^{-1} day^{-1}, the present study Di with a value 5.8×10^{-7} µg kg^{-1} day^{-1} was found to be lower. The Di for Zn ranges from 5.5×10^{-7} to 7.6×10^{-6} µg kg^{-1} day^{-1}, with the highest value observed in the Sabon-Lugbe borehole water sample, with a value of 7.6×10^{-6} µg kg^{-1} day^{-1} and the lowest value reported in the Dawaki borehole water sample.

Table 3: Dose intake (D_i in µg kg^{-1} day^{-1}) for non-carcinogenic elements.

Sample Locations	Di µg kg^{-1} day^{-1} for Non-Carcinogenic Elements			
	Di (Pb)	Di (Ni)	Di (Zn)	Di (Mg)
Dawaki borehole	1.3699×10^{-7}	8.2191×10^{-8}	5.4794×10^{-7}	Nil
Kuje borehole	5.4794×10^{-9}	5.4794×10^{-8}	1.0959×10^{-6}	5.7808×10^{-5}
Giri borehole	8.2191×10^{-8}	2.7397×10^{-8}	8.7670×10^{-7}	3.6548×10^{-5}
Sabon-Lugbe borehole	3.8356×10^{-7}	5.7534×10^{-7}	7.5889×10^{-6}	1.0137×10^{-7}
Water Board	3.2876×10^{-4}	2.1918×10^{-7}	1.0959×10^{-6}	Nil
Hand–dug well	5.4794×10^{-8}	1.3699×10^{-7}	8.2191×10^{-7}	Nil
[14] [18]	6×10^{-1}	6×10^{-1}	6×10^{-1}	6×10^{-1}

The D_i for Mg ranges from 1.0×10^{-7} to 5.8×10^{-5} µg kg^{-1} day^{-1}, with the highest value observed in the Kuje borehole water sample, with a value of 5.8×10^{-5} µg kg^{-1} day^{-1} and the lowest value reported in the Sabon-Lugbe borehole water sample. Comparing the highest value noted at the Kuje borehole water sample with the international standard, USEPA [18] with a value of 6×10^{-1} µg kg^{-1} day^{-1}, the present study for Mg is lower, with a value of ~5.8×10^{-5} µg kg^{-1} day^{-1}. These variations in D_i may be attributed to the formation of soluble complexes in aqueous solutions of the weathered and altered overburden, and by basements caused by the metamorphic process [17].

5 CONCLUSION

The toxic element concentrations in some parts of Abuja were investigated. The D_i derived from the measurements indicate slightly elevated Cr and Pb were reported at the Water Board location, with a magnitude of 10^{-7} and 10^{-4}, respectively, for cancer mortality and morbidity. There was no potential health risk, as the values are far below the International Reference Dose by a magnitude of 10^{-1}. The dose intake of heavy metals indicated that there may not be health risks associated with the heavy metals assessed in this present study, due to chemical toxicity in the water samples, but they may be mainly due to the radiotoxicity risk and its progeny. The long-term human exposure to harmful elements in water should be our concern, irrespective of how little the concentrations found were in water-based drinking collection areas in Abuja, Nigeria. The results of this study can be used as a baseline for future research in dose-related assessments of the area. It is recommended to determine the daughter elements of radionuclides in groundwater of other parts of Abuja, to know the long-term effect of these elements to human health in the study area.

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