World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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Heavy metals risk assessment of commercial boreholes water within Wukari Town of Taraba State Nigeria

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World Journal of Advanced Research and Reviews, 2022, 14(02), 672–679

Publication history: Received on 25 April 2022; revised on 27 May 2022; accepted on 29 May 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.14.2.0518

Abstract

Background: Water is an essential and the most important element of life with several biochemical relevancies in the body. It is an important solvent for most macro molecules in the body and is regarded as a universal solvent. The increase in the contamination of water with different sources such as pesticides, oil spillages, industrial wastes, and other pollutants has become an alarming issue in the environment. This study determined the concentration of some heavy metals (Mn, Cr, Cd, Pb and Fe) in water samples from Avyi, Puje and Hospital in Wukari local government area (LGA) of Taraba state.

Methods: Five samples were collected from each point and assayed for heavy metals using atomic absorption spectroscopy (AAS).

Result: The results obtained showed that Mn and Cr were higher in concentrations in the samples from the three locations with values ranging from 0.01 to 0.2 ppm. However, these values were below the permissible risk limit of W.H.O. Lead was the least in risk estimation calculation with values ranging from 0.003 to 0.009 HQ while cadmium was the highest in risk estimation with values ranging from 0.02 to 0.03 HQ which is closer to the limit of 1 that indicates toxicity. The result of cancer estimation showed that Cr has a high risk of carcinogenesis with value of 1.2x10-6 in hospital water, 4.8x10-7 in Puje and 6.3x10-7 in Avyi all with values higher than the other heavy metals.

Conclusion: This research is of public importance as individuals who consume water from these locations of Wukari LGA are at the risk of heavy metal toxicity such as renal, neural and respiratory disorders among others.

Keywords: Heavy Metal; Risk Assessment; Cancer; Toxicity

1. Introduction

Water is an essential component of life (Oyem *et al.,* 2014) and is regarded as a universal solvent (Umedum *et al.,* 2013). It is used for washing, cooking, agricultural and even for industrial activities. Water plays a significant role in maintaining human health and welfare. Clean drinking water is now recognized as a fundamental right of human beings. Around 780 million people do not have access to clean and safe water and around 2.5 billion people do not have proper sanitation. As a result, around 6–8 million people die each year due to water related diseases and disasters. Therefore, water quality control is a top-priority policy agenda in many parts of the world (World Health Organization, WHO, 2011). In the today world, the water use in household supplies is commonly defined as domestic water. This water is processed to be safely consumed as drinking water and use for other purposes. Water quality and suitability for use are determined by its taste, odor, color, and concentration of organic and inorganic matters (Dissmeyer, 2000).

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Contaminants in the water can affect the water quality and consequently the human health. The potential sources of water contamination are geological conditions, industrial and agricultural activities, and water treatment plants. These contaminants are further categorized as microorganisms, inorganic, organics, radio nuclides, and disinfectants (Nollet, 2000). The inorganic chemicals hold a greater portion as contaminants in drinking water in comparison to organic chemicals (Azrina *et al.,* 2011). Heavy metals tend to accumulate in human organs and nervous system and interfere with their normal functions. In recent years, heavy metals such as lead (Pb), arsenic (As), magnesium (Mg), nickel (Ni), copper (Cu), and zinc (Zn) have received significant attention due to causing health problems (WHO, 2011). Moreover, the cardiovascular diseases, kidney-related problems, neurocognitive diseases, and cancer are related to the traces of metals such as cadmium (Cd) and chromium (Cr) as reported in epidemiological studies (DeZuane, 1997). The Pb is known to delay the physical and mental growth in infants, while Asenic (As) and mercury (Hg) can cause serious poisoning with skin pathology and cancer and further damage to kidney and liver, respectively (DeZuane, 1997). Moreover, the presence of toxic and radioactive elements like uranium in the groundwater is another serious concern in many parts of the world such as USA, Canada, Germany, Norway, Greece, and Finland. It has high chemical toxicity and lethal effects on human skeleton and kidney (Tuzen *et al.,* 2006).

A number of scientific procedures and tools have been developed to assess the water contaminants (Dissmeyer, 2000). These procedures include the analysis of different parameters such as pH, turbidity, electrical conductivity, total suspended solids (TSS), total dissolved solids (TDS), total organic carbon (TOC), and heavy metals. These parameters can affect the drinking water quality, if their values are in higher concentrations than the safe limits set by the World Health Organization and other regulatory bodies (WHO, 2011). Therefore, the investigation of the drinking water quality by researchers and governmental departments has been performed regularly throughout the world. Thus, an assured supply of water both qualitatively and quantitatively for these purposes greatly improves the social and economic activities of the people. Water can be obtained from many sources namely; oceans, rivers, lakes, springs, ponds, rain, as well as underground (borehole). Among the various sources of water, borehole water is known to be more appropriate and often meets the criteria of quality water as it is not exposed to the water pollutants associated with surface water (Umo *et al.,* 2006). However, underground water bodies are prone to contamination from both anthropogenic and natural activities; its vulnerability to contamination could be due to anthropogenic sources like broken septic tanks and pit toilets, sewage disposal on land, leachates from fertilizer applications, urban runoff, debris from erosion and polluted surface water (Geldreich, 2005). Industrial growth, urbanization and the increasing use of synthetic organic substances can also have serious and adverse impacts on fresh water bodies due to the introduction of various pollutants such as organic compounds, heavy metals, agricultural waters, etc. (Aremu *et al.,* 2010). No matter the source of water, it is consumed and used on a day to day basis.

Potable water supply to communities in Taraba State is the responsibility of the government which in most cases has been characterized by low productivity, small coverage and inefficient service delivery. Wukari local government area is one of the areas that is partially enjoying potable water supply. Most rural dwellers therefore depend on various available water sources such as streams, rivers, wells and boreholes. The qualities of these sources are generally not guaranteed and cases abound where health problems have risen as a result of consumers drinking from such sources. Thus, for people of Wukari local government area of Taraba State, Nigeria to meet their daily water needs and household's requirement, they source water from a few privately owned boreholes and wells while majority of the people depend largely on the streams and rivers that traverse the land of the rural areas. The parameters such as pH, conductivity, total suspended solids (TSS), total dissolved solids (TDS), and heavy metals such as Pb, As, and Hg, were analyzed in each water sample. The results of each parameter were compared to the guidelines and standards set by the WHO (WHO, 2011).

2. Material and methods

2.1. Study area

Wukari local government lies on the co-ordinates 7 ^{o}51'N 9 ^{o}47'E or 7.850 ^{o}N 9.783 ^{o}E. Covering an area of 4,308Km^2 and having a population of 318,400 based on the 2016 census. The local government headquarter is Wukari town which lies on the trunk A highway. The town is divided into three wards namely Avyi, Puje and Hospital (Ishaku *et al.,* 2010). A lot of agricultural products such as yams and fishes can be found in Wukari town because the people of Taraba are predominantly farmers (Ishaku *et al.,* 2009). It shares boundaries with Benue and Nasarawa States of Nigeria.

2.2. Sample collection and water treatment

Wukari town was divided into three wards, namely; Puje, Avyi and Hospital ward. Water samples were collected in pre-cleaned 1L plastic containers from the wells and boreholes in fives (5) across some selected areas of the three Wards.

They were pre-acidified with analytical grade of concentrated nitric acid (pH=1.5) (Aremu *et al.,* 2011). All samples were preserved in a refrigerator for further analysis.

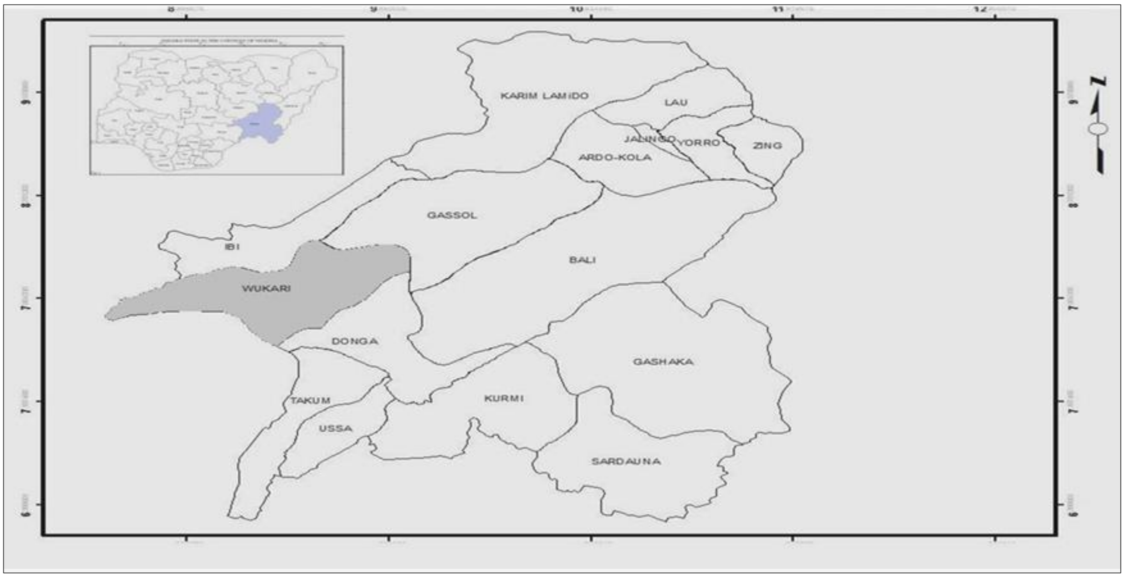

Figure 1 Map of Taraba state showing the location of Wukari

2.3. Heavy metal analysis

The water sample (100 ml) as collected was measured and transferred into a beaker and the concentrated HNO_3 (5 ml) was then added. It was warmed slowly and allowed to evaporate to about 20 ml in a fume cupboard. Heating with addition of concentrated HNO_3 continued until a light colored, clear solution was observed. The beaker wall was washed down with deionized water and then filtered. The filtrate was transferred to a 100 ml volumetric flask, allowed to cool and made up to the mark with deionized water (APHA, 1999). The samples were then analyzed with atomic absorption spectrophotometer after calibrations with appropriate standards.

2.4. Risk estimation and calculation

Hazard Quotient model to assess the risk of consuming heavy metals in yam. Hazard quotient is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected. The estimated daily intake (EDI) was calculated by the following equation given by Juan *et al.* (2010).

$$\text{Hazard Quotient } = \frac{\text{Estimated Daily Intake (EDI)}}{\text{Acceptable Daily Intake (ADI)}}$$

$$\text{EDI } = \frac{\text{(concentration of heavy metal as mg/ kg) x (daily intake of water in L/person)}}{\text{Adult body weight (60 kg)}}$$

Estimated daily intake (EDI) was calculated by the following formula (water consumption in L X concentration of heavy metal in the sample)/body weight of average adult (60kg)

A hazard quotient less than or equal to one indicates negligible hazard while greater than one stated the likelihood of harm but it is not the statistical probabilities of occurrence.

2.5. Target cancer Risk analysis

$$\text{TR} = \frac{\text{EFr} \times \text{EDtot} \times \text{YI} \times \text{MCS} \times \text{CPSo} \times 10 - 3}{\text{BWa} \times \text{ATc}}$$

Where

EFr = Exposure frequency (350 days/years)

EDtot = Exposure duration, total (30 years)
WI =Water consumption, liter per day (1 liter) × 1000mg/L
MCS = Metal concentration
BWa = Adult (65kg)
CPSo = Carcinogenic potency slope, oral (1mg/kg/day)
ATc = Averaging time, carcinogens (25,550 days)

3. Results

3.1. Heavy metals composition of Avyi, Puje and Hospital borehole waters based on Sampling Points

Table 1 Heavy Metals Composition of Avyi, Puje and Hospital Boreholes Waters

Heavy Metals	Location			
	Sampling points	Avyi (ppm)	Puje (ppm)	Hospital (ppm)
Pb	A	0.0020 ± 0.001	0.0030 ± 0.001	0.0210 ± 0.002
	B	0.0030 ± 0.002	0.0080 ± 0.003	0.0050 ± 0.001
	C	0.0020 ± 0.001	0.0100 ± 0.002	0.0010 ± 0.001
	D	0.0060 ± 0.002	0.0080 ± 0.003	0.0050 ± 0.001
	E	0.0030 ± 0.001	0.0140 ± 0.003	0.0100 ± 0.002
Cd	A	0.0014 ± 0.002	0.0032 ± 0.003	0.0069 ± 0.003
	B	0.0032 ± 0.001	0.0069 ± 0.002	0.0069 ± 0.003
	C	0.0069 ± 0.001	0.0069 ± 0.001	0.0014 ± 0.002
	D	0.0032 ± 0.001	0.0051 ± 0.002	0.0032 ± 0.003
	E	0.0037 ± 0.001	0.0051 ± 0.001	0.0051 ± 0.003
Cr	A	0.0120 ± 0.002	0.0080 ± 0.000	0.0060 ± 0.002
	B	0.0060 ± 0.001	0.0090 ± 0.002	0.0000 ± 0.000
	C	0.0080 ± 0.000	0.0020 ± 0.001	0.0060 ± 0.002
	D	0.0140 ± 0.001	0.0160 ± 0.002	0.0100 ± 0.002
	E	0.0200 ± 0.001	0.0110 ± 0.001	0.0040 ± 0.001
Mn	A	0.0100 ± 0.002	0.1300 ± 0.001	0.0300 ± 0.002
	B	0.0400 ± 0.001	0.0800 ± 0.002	0.0700 ± 0.000
	C	0.0300 ± 0.000	0.0300 ± 0.001	0.0300 ± 0.002
	D	0.0500 ± 0.001	0.0400 ± 0.002	0.0400 ± 0.002
	E	0.0300 ± 0.001	0.0300 ± 0.001	0.0500 ± 0.001
Fe	A	0.0020 ± 0.001	0.0020 ± 0.001	0.0020 ± 0.001
	B	0.0030 ± 0.002	0.0030 ± 0.002	0.0030 ± 0.002
	C	0.0020 ± 0.001	0.0020 ± 0.001	0.0020 ± 0.001
	D	0.0060 ± 0.002	0.0060 ± 0.002	0.0060 ± 0.002
	E	0.0030 ± 0.001	0.0030 ± 0.001	0.0030 ± 0.001

Results are expressed in mean standard deviation of ±0.005.

Table 1 shows the concentrations of heavy metals in the borehole water samples. In Avyi, sampling point D has the highest composition of Pb (0.0060 ppm), followed by B and E (0.0030 ppm) with A and C having the least (0.0020 ppm).

In Puje, the Pb content of the sampling points is in the order E>C>B=D>A, while that of Hospital is in the order A>E>B=D>C. The Cd content of Avyi sampling points is in the order C>E>B=D>A, Puje is in the order B=C>D=E>A, and that of Hospital is in the order A=B>E>D>C (Table 1).

In Cr content, Avyi sampling point D has the highest composition of Pb (0.0060 ppm), followed by B and E (0.0030 ppm) with A and C having the least (0.0020 ppm). In Puje, the Pb content of the sampling points is in the order E>C>B=D>A, while that of Hospital is in the order A>E>B=D>C.

3.2. Heavy metals composition of Avyi, Puje and Hospital borehole waters based on sampling location

Table 2 Mean Values of Heavy Metals Composition of Borehole Waters based on Sampled Locations

Heavy Metals	Location		
	Avyi (ppm)	Puje (ppm)	Hospital (ppm)
Lead	0. 00320 ± 0. 00073^{a}	0.00860 ± 0. 00397^{b}	0. 00840 ± 0.00773^{c}
Cd	0.00368± 0.00200^{a}	0.00544 ± 0.00154^{b}	0.0047± 0.00234^{c}
Cr	0. 0120 ± 0.00548^{a}	0. 0092 ± 0.00507^{b}	0. 0232 ± 0.04300^{c}
Mn	0. 0320 ±0.01483^{a}	0.0620 ± 0. 04324^{b}	0. 0440± 0.01673^{c}
Fe	0. 1600 ± 0.15166^{a}	0. 2450± 0.10954^{b}	0. 2600 ± 0.42190^{c}

N = 5; Results are expressed as Mean ± Standard deviation (SD). Means having the same letters in a column are not significantly different (p≤0.05)

Table 3 Risk Assessment and Target Cancer Analysis of Heavy Metals in the Water Samples Collected

LOCATION/METAL	EDI	HQ	TCR
AVYI			
Pb	0.0000533	0.0036	3.4×10^{-11}
Cd	0.000061	0.020	2.9×10^{-8}
Cr	0.0002	0.004	6.3×10^{-7}
Mn	0.00053	0.0013	-
Fe	0.0027	0.0009	-
PUJE			
Pb	0.00014	0.0096	9.17×10^{-11}
Cd	0.00009	0.030	4.30×10^{-8}
Cr	0.00015	0.003	4.84×10^{-7}
Mn	0.0010	0.0026	-
Fe	0.00408	0.00136	-
HOSPITAL			
Pb	0.00014	0.0093	8.95×10^{-11}
Cd	0.000078	0.0261	3.7×10^{-8}
Cr	0.00039	0.0077	1.2×10^{-6}
Mn	0.00073	0.0018	-
Fe	0.0043	0.00144	-

W.H.O/FAO, (1999) NB: EDI= Estimated Daily Intake, HQ= Hazard Quotient, TCR= Target Cancer Risk

Table 2 shows the concentrations of heavy metals in Avyi, Puje and Hospital borehole waters. Puje borehole has the highest concentration of Pb (0.008600 ppm) which is not significantly ($p \leq 0.05$) different when compared to Hospital borehole (0.00840 ppm), but significantly ($p \leq 0.05$) different when compared to Avyi borehole (0.00320 ppm).Similarly, Puje borehole has the highest concentration of Cd (0.00544 ppm) which is significantly ($p \leq 0.05$) different when compared to Hospital borehole (0.0047 ppm) and Avyi borehole. With the least (0.00368 ppm) (Table 2). The highest amount of Cr was found in Hospital borehole (0.0232 ppm) and this is significantly ($p \leq 0.05$) higher than Avyi (0.0120 ppm) and Puje (0.0092 ppm). Puje also has the highest concentration of Mn (0.0620 ppm) which is significantly ($p \leq 0.05$) higher when compared with Hospital (0.0440 ppm) and Avyi (0.0320 ppm).

The highest concentration of Fe was found in Hospital (0.2600 ppm) which is significantly ($p \leq 0.05$) different from Puje (0.2450 ppm), with Avyi having the lowest Fe content.

4. Discussion

In this study, the concentrations of heavy metals in the borehole water samples from the three locations were compared based on five sampling points in each location and based on the mean values of the different locations. In Avyi, sampling point D has the highest composition of Pb (0.0060 ppm), followed by B and E (0.0030 ppm) with A and C having the least (0.0020 ppm). In Puje, the Pb content of the sampling points is in the order E>C>B=D>A, while that of Hospital is in the order A>E>B=D>C. The Cd content of Avyi sampling points is in the order C>E>B=D>A, Puje is in the order B=C>D=E>A, and that of Hospital is in the order A=B>E>D>C (Table 1). In Cr content, Avyi sampling point D has the highest composition of Pb (0.0060 ppm), followed by B and E (0.0030 ppm) with A and C having the least (0.0020 ppm). In Puje, the Pb content of the sampling points is in the order E>C>B=D>A, while that of Hospital is in the order A>E>B=D>C (Table 1).

Holistically, it could be observed that in Avyi, sampling point D has the highest concentration of Pb, Mn and Fe, while sampling point C and E have the highest concentration of Cd and Cr respectively. Also in Puje, sampling point D has the highest concentration of Cr and Fe, while E, B and A have the highest concentration of Pb, Cd and Mn respectively. In Hospital, A has the highest concentration of Pb and Cd, D is highest in Cr and Fe and B has the highest concentration of Mn.

Furthermore, the concentrations of heavy metals in the borehole water samples from the three locations were compared based on the mean values of the different locations. Puje borehole has the highest concentration of Pb (0.008600 ppm), followed by Hospital borehole (0.00840 ppm), while Avyi borehole has the lowest concentration of Pb (0.00320 ppm). However, there is no significant ($p \leq 0.05$) different between the Pb content of Puje and Hospital boreholes, but significantly ($p \leq 0.05$) different when compared to Avyi borehole (Table 2). The range of Pb concentration in the three locations (0.00320-0.00860) is lower than the permissible limit of 0.01 ppm (WHO, 2008; 2011). These values are different from 0.250-0.031 reported by Samuel *et al.* (2015) and 11.42 mg/L reported by Obasi and Akudinobi (2020). The risk analysis and target cancer risk estimation was made in the mean values of the heavy metal concentration and it showed that cadmium has a HQ of 0.020 close to one compared to the others whose HQ are far from one, this implies likelihood of cadmium toxicity with continuous accumulation, also the TCR analysis showed that chromium has the highest cancer risk of 6.3x10-7.

Similarly, Puje borehole has the highest concentration of Cd (0.00544 ppm) which is significantly ($p \leq 0.05$) different when compared to Hospital borehole (0.0047 ppm) and Avyi borehole being the least (0.00368 ppm) (Table 2). The range of Cd concentration in the three locations (0.00154-0.00368 ppm) is lower than the permissible limit of 0.03 ppm (FAO, 2015, WHO, 2015). These values are also lower than 0.534-0.023 reported by Samuel *et al.* (2015) and 15.67 mg/L reported by Obasi and Akudinobi*.* (2020). The risk analysis calculation indicates that cadmium has the highest risk factor with HQ value of 0.030 closer to 1 that indicates high risk when the water is constantly consumed over time as these heavy metals can bio accumulate, the TCR calculation also indicates that chromium has the highest risk for cancer with the value of 4.84x10-7.

The highest amount of Cr was found in Hospital borehole (0.0232 ppm) and this is significantly ($p \leq 0.05$) higher than Avyi (0.0120 ppm) and Puje (0.0092 ppm) (Table 2). However, the range of Cr concentration in the three locations (0.0099-0.0232 ppm) is lower than the permissible limit of 0.05 ppm (WHO, 2011). These values are different from 14.60 mg/L reported by Obasi and Akudinobi (2020). The result from hospital showed that cadmium also has the highest risk fact for toxicity with HQ value of 0.02 close to the reference point of 1 that indicates higher risk. The TCR calculation indicated that chromium has the highest risk for cancer with the value 1.2x10-6.

Puje also has the highest concentration of Mn (0.0620 ppm) which is significantly ($p \leq 0.05$) higher when compared with Hospital (0.0440 ppm) and Avyi (0.0320 ppm) (Table 2). The range of Mn concentration in the three locations (0.0320-0.0620 ppm) is lower than the permissible limit of 0.4 ppm (WHO 2011). These values are different from 63.45 mg/L reported by Obasi and Akudinobi (2020)

The highest concentration of Fe was found in Hospital (0.2600 ppm) which is significantly ($p \leq 0.05$) different from Puje (0.2450 ppm), with Avyi having the lowest Fe content (Table 2). The range of Fe concentration in the three locations (0.1600-0.2600 ppm) is lower than the permissible limit of 0.3 ppm (WHO 2003).

5. Conclusion

This work has presented data on the concentration, risk analysis, and cancer estimation of some heavy metals in selected boreholes located in Puje, Hospital and Avyi settlements of Wukari metropolis, Taraba State, Nigeria. The results show that Puje bore has the highest concentration of Pb, Cd and Mn, while Hospital borehole has the highest concentration of Cr and Fe. However, the concentrations from all locations are below the permissible limits set by WHO and FAO, and therefore the boreholes water can be deemed suitable and safe for consumption, domestic and industrial activities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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