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Full Length Research Article

HEALTH RISK ASSESSMENT OF HEAVY METALS IN THE SOURCES OF DRINKING WATER IN PARTS OF OBUBRA LOCAL GOVERNMENT AREA OF CROSS RIVER STATE, NIGERIA

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ABSTRACT
This study examined health assessment of heavy metals in the sources of drinking water in parts of Obubra Local Government Area of Cross River State, Nigeria. Twenty five (25) water samples were collected with ten (10) from borehole, eight (8) from spring and seven (7) from dug-well. The samples were analysed using standard laboratory methods. The results showed that Zn had the highest chronic daily intake for infant, child and adult and Cd the highest hazard quotient in borehole, spring and dug - well water. This indicates that infant is more vulnerable to health risk followed by child and least by adult. The carcinogenic risk results of Cd and Cr contamination were greater than the permissible range of $\leq 1 \times 10^{-6}$ to 1×10^{-4} indicating that the water sources are polluted with Cd and Cr. It was recommended that there should be awareness programmes on hygienic practices and pretreatment of water before use. Also the Cross River State Board Limited should supply quality water to the inhabitants and monitor their sources of drinking water.

Keywords: Health risk; heavy metals; drinking water; Obubra; pollution

INTRODUCTION

The importance of water to the sustenance of man, plants and animals cannot be over emphasised. This is due to the fact that water is essential for healthy living as such living without food is seemingly possible to living without water (Kaizer and Osakwe, 2010). In the past years, it has become very difficult, seemingly impossible, to meet increased demands and provide sufficient quality water to the people as a result of pollution (Stevanovic, 2010). Springs, streams, hand-dug wells and boreholes are some of the sources widely used for drinking purposes and in most cases untreated (Owamah et al., 2013).

Generally, microorganisms, organic compounds, and toxic heavy metals are the sources of contaminations of water (Verma et al., 2018), but some originate from natural elements like weathering reactions, biological activity, volcanic emissions, and rocks solubilisation (Meng et al., 2016; Kumar et al., 2017; Funes et al., 2018), as well as geological sources (Karakaya and Karakaya, 2014; Kostic et al., 2016) through mine drainage of waters that are rich in elements, which can mix into the surface water and groundwater through leachate. The existence of dissolved metals beyond permissible values in drinking water may lead to harmful risks to residents where human farming and metal-induced human activities have taken place (Wu et al., 2019; Kumar et al, 2021).

Global statistics has revealed that over 1.8 billion people use unimproved drinking water which consequently increases the risk of contracting diseases such as polio, diarrhea, typhoid, dysentery, cholera and other water-borne diseases(World Health Organization and United Nation Children's Fund (WHO and UNICEF, 2015b)). Estimates from World Health Organiation further reports that poor accesses to water sanitation and hygiene (WASH) facilities have been linked to 10% of total disease burden and 94% of diarrheal burden.

The need to access potable water has forced many developing nations into providing safe drinking water from boreholes (Attah, 2017). In rural areas like Obubra people drink from streams/rivers and dug - wells. Most of the water is not treated and monitored and as such may not be free from physical, chemical and bacteriological contamination (Emenike, 2017).

Recently, the incidence of outbreak of diarrhea and cholera, amongst other water borne - diseases has reportedly been confirmed in the study area, leading to a tremendous loss of lives(Vanguard Newspaper 21st January, 2023). There is an increasing awareness that contaminated water consumption is responsible for several health-related disorders such as water - borne infections like diarrhea and typhoid fever (Aroh et al, 2013; Musa et al, 2018).

Location and Study Area

Obubra Local Government Area is in the Central Senatorial District of Cross River State, Nigeria.. Obubra has an estimated population of about 200,000 people and has it headquarter at Obubra town. Obubra LGA is bounded in the north by Yala and Ikom Local Government Areas, in the south by Yakurr Local Government Area and in the west by Ebonyi state. It lies between latitudes 5^{0}44'N and 6°17' N, longitudes 8°11' E and 8^0 33'E with an elevation of 91m above sea level.
Obubra as a geo-political entity covers an area of 1122km^2. Obubra consists of a mono-cultural group of people of Mbembe descent. The Local Government Area has a rich cultural heritage with each village having unique cultural dancing troupe. The songs are composed in the local language and constitute the predominant music in the rural communities. Obubra lies within the rich fringes of the tropical rainforest zone of the south Eastern Nigeria with abundant natural resources including agricultural, forest and mineral resources. The area is also blessed with a lot of unharnessed tourist attraction including fascinating flora and fauna.

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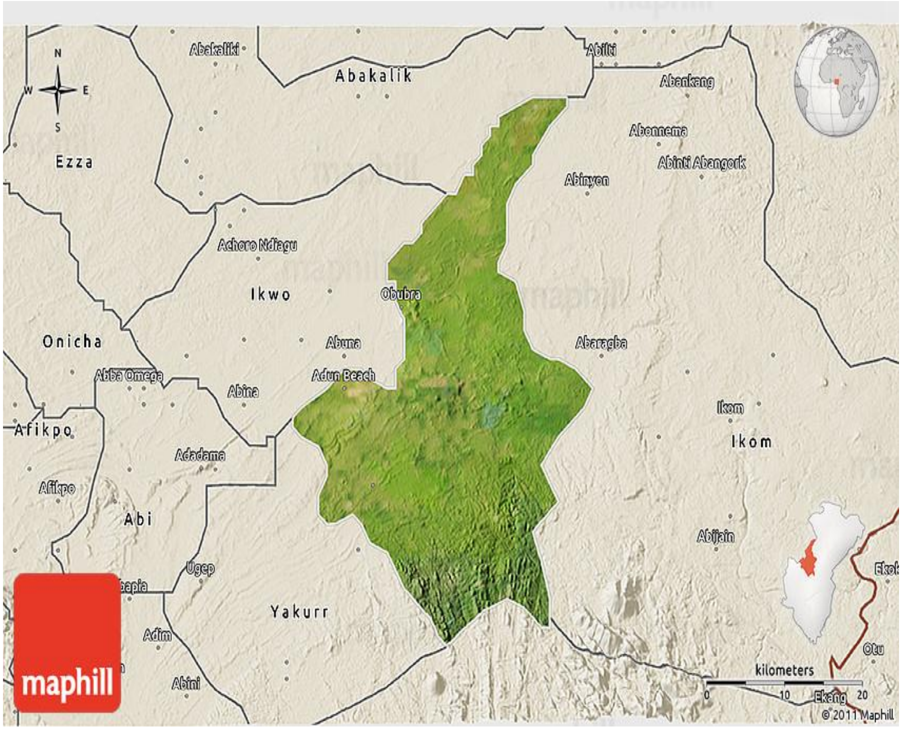

Figure.1 Satellite map of Obubra Local Government Area of Cross River State, Nigeria(retrieved from www.google.com)

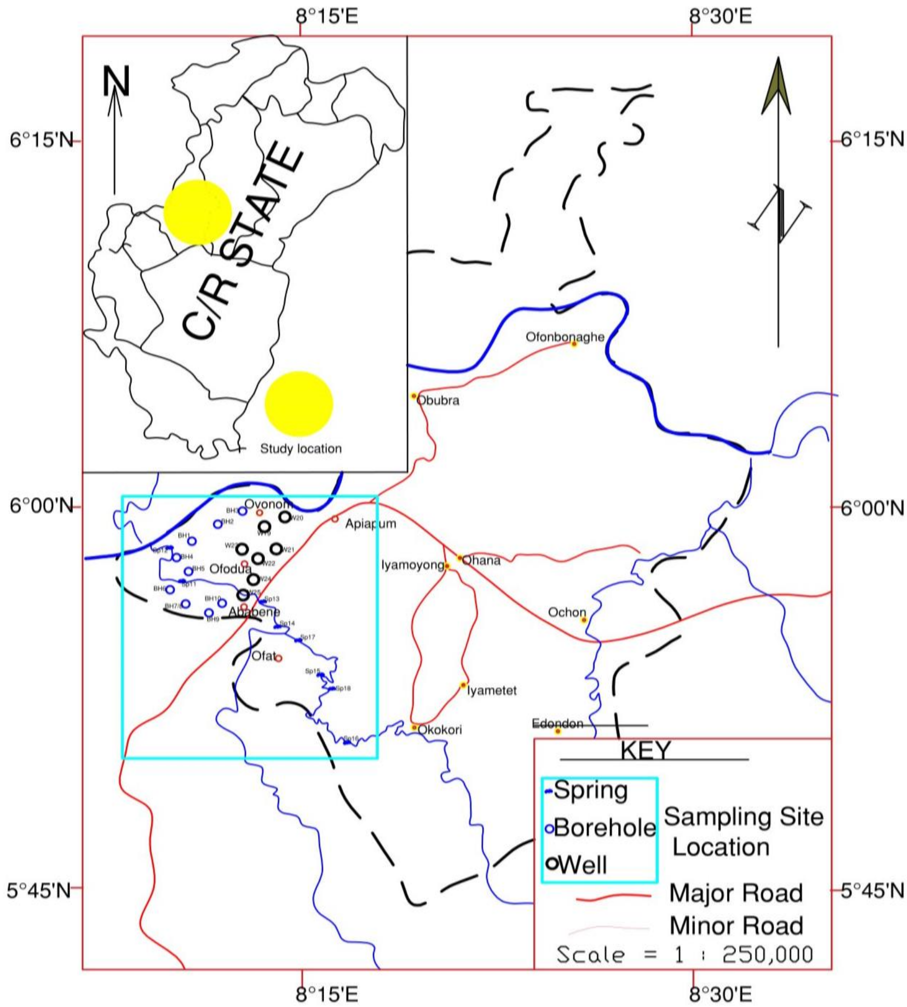

Figure 2 Location map of the study area (Drawing Unit, Geology Department, University of Clabar, Nigeria)

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Long Term Assessment of Health Risk
According to Osipova et al(2015) and Ogundele et al.(2019), the evaluation of the degree of health effects and the chance of occurring as a result of consumption of ground water for a long period of time is given as:

$$CDI = \frac{C_{HM} \times WIR \times EF \times ED}{BW \times AT} \quad 1$$

Where CDI is the chronic daily intake, C_{HM} is the concentration of heavy metal in water (mg/l), WIR is the oral ingestion rate. The oral ingestion rate for infant, child, and adults are 0.751, 1 and 2 respectively (Egbueri, 2020). EF is the exposure frequency in the water (365 days/year), ED is the exposure time (70years as adult, and 10years as child ED) (Kumar et al, 2020b).
BW is average body weight (in Kg) which is equal to 5kg, 10kg and 60kg, respectively for infant, child, and adults (Ganiyu et al, 2021).
AT = mean time in days, AT=3650 days and 25,550 days for child and adults.
Since AT=EF×ED, eqn (1) becomes

$$CDI = \frac{C_{HM} \times WIR}{BW} \quad 2$$

The non-carcinogenic risk considered as hazard quotient (HQ) in contaminated ground water is given by:

$$HQ = \frac{CDI}{RfD} \quad 3$$

Where RfD= Oral reference dose of a particular heavy metal and the values are shown in Table

Table 1. Reference doses (RfD) of heavy metals (Duggal et al, 2017; Egbueri, 2020 and USEPA, 2016)

Heavy metals	**RfD (mg/kg/ day)**
Zn[a]	0.30
[b]Cu	0.04
[b]Cd	0.0005
Fe[a]	0.7
Cr[b]	1.5
Mn[a]	0.14

a (Duggal et al, 2017; Enuneku et al, 2018; Egburu, 2020)
b (USEPA, 2016)
The hazard index (HI) is used to estimate the total non-carcinogenic risk. The HI can be evaluated by combining the individual HQs and given by:

$$HI = \sum HQ_i \quad 4$$

In order to assess the risk associated with each heavy metal and their accumulative hazard, the scales of chronic risk assessment set by previous studies (Simeonov, et al., 2003) was employed:

Cancer Risk (CR)
The probability of cancer risk of drinking groundwater was determined as the incremental likelihood of human being developing cancer over a period of time due to the exposure to a prospective carcinogenic element (Enuneku et al., 2018; Ukah et al., 2019; Egbueri and Mgbenu 2020). The CR is evaluated using Equation. (5) as:

$$SF_i = CDI \times SF_i \quad 5$$

where SF_i is the slope factor (mg/kg/day). The tolerable CR value is within the range 1×10^{-6} to 1×10^{-4} (Ukah et al, 2019; Egbueri and Mgbenu, 2020).

Table 2. Slope factors (SF) of carcinogenic heavy metals (USEPA, 2016).

Heavy metals	SF(mg/kg)
Cd	6.30
Cr	4.20×10^{1}
Pb	8.5×10^{-3}
As	1.5

MATERIALS AND METHODS
Water samples were collected from borehole, spring and dug-well water using sterilised plastic containers. The containers for the samples were first rinsed with the water to be sampled before samples were collected. The coordinates of each sample point were taken before samples were taken (Table3). Water samples were collected in a sampling bottle to prevent floating of materials. The stoppers of the sample containers were tightly closed to prevent outside contamination. Prior to chemical analysis, the water samples were kept in an ice-crested cooler to avoid any kind of chemical/ biological reaction (Ukah et al., 2019). The control laboratory, Cross River State Water Board Limited Calabar, Nigeria, carried out the quantitative chemical analysis. The following parameters Zn, Cu, Cd, Fe, Cr and Mn, were analysed using Ultra Visible (UV-VIS) Spectrophotometer based on standard procedures and manufacturer's instructions.

Table 3. Midpoint coordinates in the Study area

S/N	Location	Label	Latitude	Longitude	Elevation(m)
	Borehole water				
1	Mr. Njan Compound, Ovonum	BH 1	N05^{0}59'10.6"	E008^{0}16'26.6"	45.0
2	Mater Misericordia Catholic Church, Ovonum	BH 2	N05^{0}59'8.1"	E008^{0}15'18.0"	34.0
3	ObubemAdun Beach Ofodua	BH 3	N05^{0}59'17.2"	E008^{0}15'33.1"	29.0
4	ObubemAdun Beach Ofodua	BH 4	N05^{0}59'4.2"	E008^{0}15'19.6"	29.0

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5	Commercial Secondary School, Ofodua	BH 5	N05⁰58'57.2"	E008⁰15'31.8"	31.0
6	Obonigode, Ofodua	BH 6	N05⁰58'32.2"	E008⁰15'24.7"	32.0
7	Arobom 1	BH 7	N05⁰56'58.4"	E008⁰17'12.3"	40.0
8	Arobom 2	BH 8	N05⁰56'58.4"	E008⁰17'12.7"	40.0
9	Ababene Last bus top	BH 9	N05⁰57'15.1"	E008⁰15'48.9"	64.0
10	Mr. AbengOyama Street, Ofat	BH10	N05⁰57'26.4"	E008⁰16'25.5"	65.0
	Spring water				
11	Awusama /Mboto, Ovonum	SP 11	N05⁰59'17.5"	E008⁰16'24.1"	41.0
12	Igagana, Ofatura	SP 12	N05⁰59'38.0"	E008⁰16'35.8"	32.0
13	Behind Agronomy Green House, Ovonum	SP 13	N05⁰58'51.0"	E008⁰16'17.1"	46.0
14	Osusu, Ofodua	SP 14	N05⁰58'23.3"	E008⁰16'4.0"	49.0
15	Omar Spring, Ofudua	SP 15	N05⁰57'44.0"	E008⁰16'35.4"	50.0
16	Arobom	SP 16	N05⁰57'5.0"	E008⁰17'9.4"	27.0
17	Behind Commercial Sec. School, Adun, Ofat	SP 17	N05⁰57'54.1"	E008⁰15'31.8"	67.0
18	Raraca, Ofat	SP 18	N05⁰57'43.4"	E008⁰15'17.8"	68.0
	Dug – well water				
19	Ovoum Primary School, Ovonum	W 19	N05⁰59'24.3"	E008⁰16'11.2"	35.0
20	Behind Emenike Compound, Ofatura	W 20	N05⁰59'40.0"	E008⁰16'37.4"	32.0
21	Mr. Nonso Compound, Ofatura	W 21	N05⁰59'35.6"	E008⁰16'19.3"	31.0
22	One – man Country, Ofodua	W 22	N05⁰58'49.0"	E008⁰15'23.0"	36.0
23	Obonigode, Ofodua	W 23	N05⁰58'32.9"	E008⁰15'24.5"	39.0
24	Ababene last bus stop, Ababene	W 24	N05⁰57'20.1"	E008⁰15'48.1"	63.0
25	Olumba pit, Ababene	W 25	N05⁰57'13.6"	E008⁰15'37.4"	59.0

Long Term Assessment of Heavy Metals
Borehole Water

Table 4. Chronic Daily Intake (CDI), hazard quotient (HQ), and hazard index (HI) for borehole water

CDI				**HQ**		
Heavy metals	**Infant**	**Child**	**Adult**	**Infant**	**Child**	**Adult**
Zn	3.26×10^{-1}	2.17×10^{-1}	7.23×10^{-2}	1.09	7.23×10^{-1}	2.41×10^{-1}
Cu	5.78×10^{-2}	3.86×10^{-2}	1.29×10^{-2}	1.45	9.64×10^{-1}	3.21×10^{-1}
Cd	2.33×10^{-3}	1.56×10^{-3}	5.19×10^{-4}	4.67	3.11	1.04
Fe	1.41×10^{-2}	9.44×10^{-3}	3.15×10^{-3}	2.02×10^{-2}	1.35×10^{-2}	4.50×10^{-3}
Cr	9.33×10^{-4}	6.22×10^{-4}	2.07×10^{-4}	6.22×10^{-4}	4.15×10^{-4}	1.38×10^{-4}
Mn	2.27×10^{-2}	1.51×10^{-2}	5.04×10^{-3}	1.62×10^{-1}	1.08×10^{-1}	3.60×10^{-2}
HI				**7.38**	**4.92**	**1.64**

Table 4 indicates that the chronic daily intake for infant, child and adult was in this order: Zn > Cu >Mn> Fe > Cd > Cr. This shows that Zn has the highest intake while Cr is the least intake (Fig 3).

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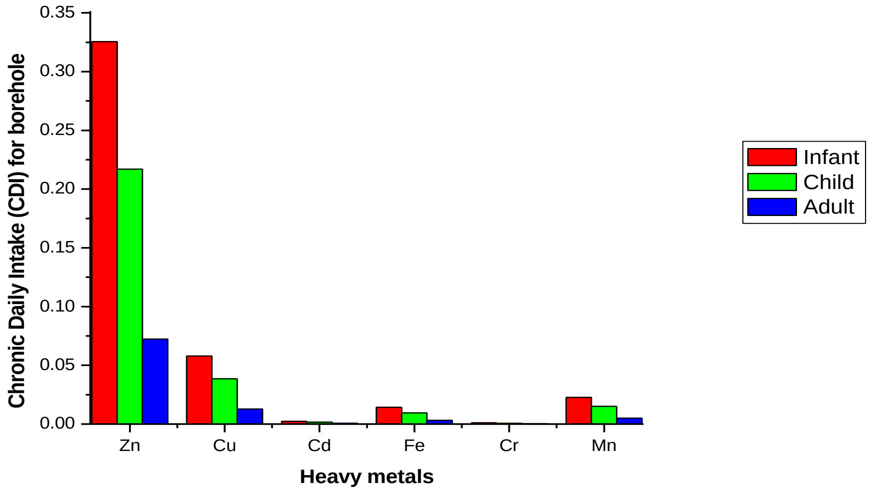

Figure.3. Bar chart showing the Chronic Daily Intake (CDI) for borehole water

The hazard quotient for infant, child and adult was in this order: Cd > Cu >Zn>Mn>Fe > Cr. This indicates that Cd has the highest hazard and Cr has the least hazard. The hazard index obtained for infant, child and adult were 7.38, 4.92 and 1.64 were > 1 for Zn, Cu and Cd in infant and >1 in Cd for both child and adult showing the likely health risk. Also the hazard index indicates that infant is more vulnerable to health risk followed by child and least by adult (Fig.4).

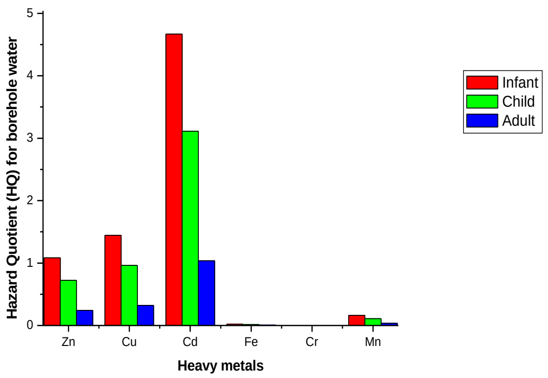

Figure.4. Bar chart showing the Hazard Quotient (HQ) for borehole water

Table 5. Carcinogenic risk (CR) for carcinogenic heavy metals in borehole water

Heavy metals	Infant	Child	Adult
Cadmium (Cd)	1.47×10^{-2}	9.84×10^{-3}	3.27×10^{-3}
Chromium (Cr)	3.92×10^{-4}	2.61×10^{-4}	8.69×10^{-5}

Table 5 indicates that the carcinogenic risk results of Cd and Cr contamination were greater than the permissible range of $\leq 1 \times 10^{-6}$ to 1×10^{-4}. Cd has more effect in assessment of health risk than Cr among the three groups in the study area.

Spring Water

Table 6. Chronic Daily Intake (CDI), hazard quotient (HQ), and hazard index (HI) for spring water

	CDI			**HQ**		
Heavy metals	**Infant**	**Child**	**Adult**	**Infant**	**Child**	**Adult**
Zn	2.26×10^{-1}	1.51×10^{-1}	5.03×10^{-2}	7.54×10^{-1}	5.03×10^{-1}	1.68×10^{-1}
Cu	2.36×10^{-2}	1.58×10^{-2}	5.25×10^{-3}	5.91×10^{-1}	3.94×10^{-1}	1.31×10^{-1}
Cd	1.87×10^{-3}	1.24×10^{-3}	4.15×10^{-4}	3.73	2.49	8.29×10^{-1}
Fe	3.28×10^{-2}	2.19×10^{-2}	7.29×10^{-3}	4.69×10^{-2}	3.13×10^{-2}	1.04×10^{-2}
Cr	2.06×10^{-3}	1.38×10^{-3}	4.58×10^{-4}	1.38×10^{-3}	9.17×10^{-4}	3.06×10^{-4}
Mn	2.50×10^{-2}	1.73×10^{-2}	5.75×10^{-3}	1.85×10^{-1}	1.23×10^{-1}	4.11×10^{-2}
HI				**5.31**	**3.54**	**1.18**

Table 6 indicates that the chronic daily intake for infant, child and adult was in this order: Zn > Fe >Mn> Cu > Cr >Cd. This indicates that Zn has the highest intake while Cd is the least intake (Fig 5).

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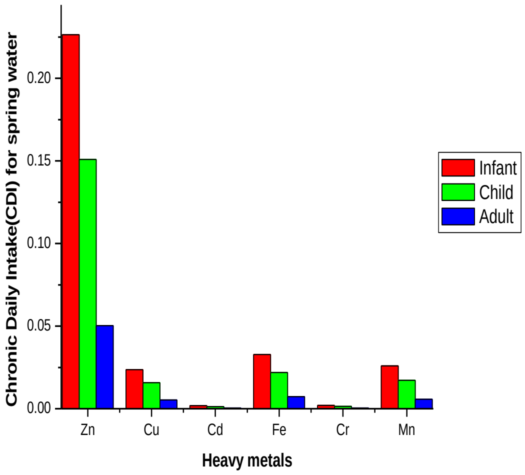

Figure 5 .Bar chart showing Chronic Daily Intake (CDI) for spring water

The hazard quotient for infant, child and adult was in this order: Cd > Zn > Cu >Mn> Fe > Cr. This indicates that Cd has the highest hazard and Cr has the least hazard. The hazard index obtained for infant, child and adult were 5.31, 3.54 and 1.18 and were > 1 for Cd for both infant and child indicating the likely health risk. Also the hazard index indicates that infant is more vulnerable to health risk followed by child and least by adult (Fig. 6).

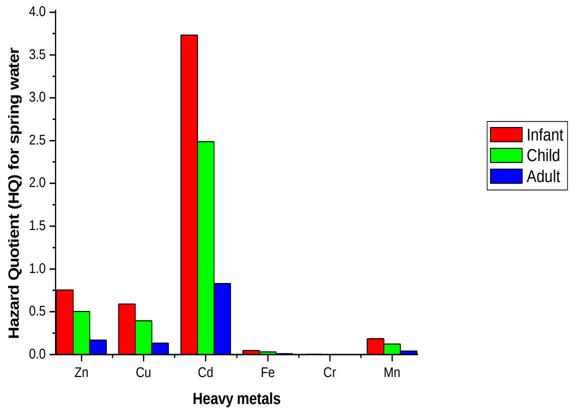

Figure 6 Bar chart showing Hazard Quotient (HQ) for spring water

Table 7. Carcinogenic risk (CR) for carcinogenic heavy metals in spring water

Heavy metals	Infant	Child	Adult
Cadmium (Cd)	1.18 x 10^{-2}	7.83 x 10^{-3}	2.51 x 10^{-3}
Chromium (Cr)	8.66 x 10^{-4}	5.78 x 10^{-4}	1.92 x 10^{-4}

Table 7 indicates that the carcinogenic risk results of Cd and Cr contamination were greater than the permissible range of ≤ 1 x 10^{-6} to 1 x 10^{-4}. Cd has more effect in assessment of health risk than Cr among the three groups in the study area.

Dug-well Water

Table 8 Chronic Daily Intake (CDI), hazard quotient (HQ), and hazard index (HI) for dug – well water

	CDI				HQ	
Heavy metals	**Infant**	**Child**	**Adult**	**Infant**	**Child**	**Adult**
Zn	5.43 x 10^{-1}	3.62 x 10^{-1}	1.21 x 10^{-1}	1.81	1.21	4.02 x 10^{-1}
Cu	5.61 x 10^{-2}	3.74 x 10^{-2}	1.25 x 10^{-2}	1.40	9.86 x 10^{-1}	3.12 x 10^{-1}
Cd	3.81 x 10^{-3}	2.54 x 10^{-3}	8.48 x 10^{-4}	7.63	5.09	1.70
Fe	2.68 x 10^{-2}	1.79 x 10^{-2}	5.95 x 10^{-3}	3.83 x10^{-2}	2.55 x 10^{-2}	8.50 x 10^{-3}
Cr	2.23 x 10^{-3}	1.49 x 10^{-3}	4.95 x 10^{-4}	1.49 x 10^{-3}	9.90 x 10^{-4}	3.30 x 10^{-4}
Mn	5.38 x 10^{-2}	3.59 x 10^{-2}	1.20 x 10^{-2}	3.84 x10^{-1}	2.56 x 10^{-1}	8.54 x 10^{-2}
HI				**11.27**	**7.51**	**2.50**

Table 8 indicates that the chronic daily intake for infant, child and adult was the same as in borehole water and in this order: Zn > Cu >Mn> Fe > Cd > Cr. This shows that Zn has the highest intake while Cd is the least intake (Fig 7).

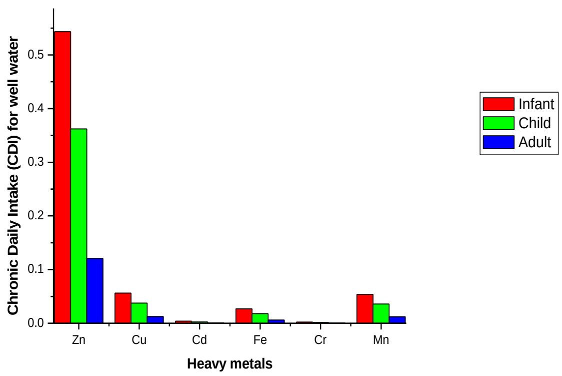

Figure 7. Bar chart showing Chronic Daily Intake (CDI) for dug - well wate

The hazard quotient for infant, child and adult were in this order: Cd > Zn > Cu >Mn> Fe > Cr. This indicates that Cd has the highest hazard and Fe has the least hazard. The hazard index obtained for infant, child and adult were 11.27, 7.51 and 2.50

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respectively and were > 1 for Zn, Cu and Cd in infant and >1 in Zn and Cd for child and >1 in Cd for adult showing the likely health risk. Also the hazard index has the same trend as spring water with infant more vulnerable to health risk followed by child and least by adult (Fig. 8).

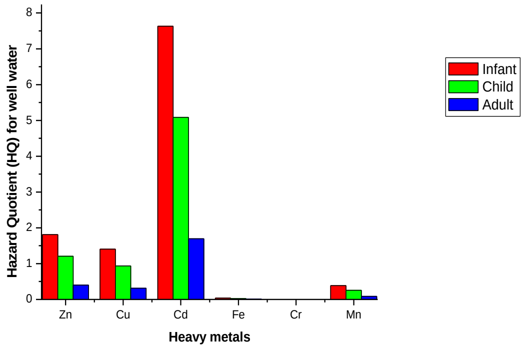

Figure 8 Bar chart showing Hazard Quotient (HQ) for dug - well water

Table 9. Carcinogenic risk (CR) for carcinogenic heavy metals in dug - well water

Heavy metals	**Infant**	**Child**	**Adult**
Cadmium (Cd)	2.4×10^{-2}	1.6×10^{-2}	5.34×10^{-3}
Chromium (Cr)	9.36×10^{-4}	6.24×10^{-4}	2.08×10^{-4}

Table 9 indicates that the carcinogenic risk results of Cd and Cr contamination were greater than the acceptable range of $\leq 1 \times 10^{-6}$ to 1×10^{-4}. Cd has more effect in assessment of health risk than Cr among the three groups in the study area.

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Table 10. Chronic Daily Intake (CDI), hazard quotient (HQ), and hazard index (HI) for dug - well water

	CDI				HQ	
Heavy metals	**Infant**	**Child**	**Adult**	**Infant**	**Child**	**Adult**
Zn	5.43×10^{-1}	3.62×10^{-1}	1.21×10^{-1}	1.81	1.21	4.02×10^{-1}
Cu	5.61×10^{-2}	3.74×10^{-2}	1.25×10^{-2}	1.40	9.86×10^{-1}	3.12×10^{-1}
Cd	3.81×10^{-3}	2.54×10^{-3}	8.48×10^{-4}	7.63	5.09	1.70
Fe	2.68×10^{-2}	1.79×10^{-2}	5.95×10^{-3}	3.83×10^{-2}	2.55×10^{-2}	8.50×10^{-3}
Cr	2.23×10^{-3}	1.49×10^{-3}	4.95×10^{-4}	1.49×10^{-3}	9.90×10^{-4}	3.30×10^{-4}
Mn	5.38×10^{-2}	3.59×10^{-2}	1.20×10^{-2}	3.84×10^{-1}	2.56×10^{-1}	8.54×10^{-2}
HI				**11.27**	**7.51**	**2.50**

Table 10 indicates that the chronic daily intake for infant, child and adult was the same as in borehole water and in this order: Zn > Cu >Mn> Fe > Cd > Cr. This shows that Zn has the highest intake while Cd is the least intake (Fig 9).

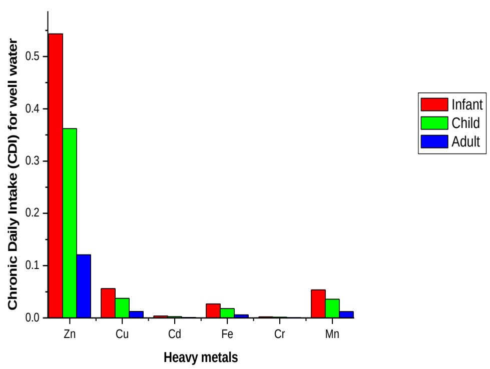

Figure 9 Bar chart showing Chronic Daily Intake (CDI) for dug - well water

The hazard quotient for infant, child and adult were in this order: Cd > Zn > Cu >Mn> Fe > Cr. This indicates that Cd has the highest hazard and Fe has the least hazard. The hazard index obtained for infant, child and adult were 11.27, 7.51 and 2.50 respectively and were > 1 for Zn, Cu and Cd in infant and >1 in Zn and Cd for child and >1 in Cd for adult showing the likely health risk. Also the hazard index has the same trend as spring water with infant more vulnerable to health risk followed by child and least by adult (Fig.10).

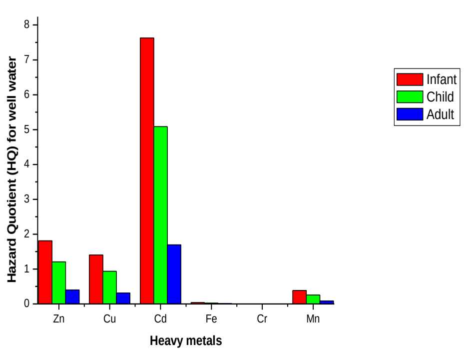

Figure 10 Bar chart showing Hazard Quotient (HQ) for dug - well water

Table 11. Carcinogenic risk (CR) for carcinogenic heavy metals in dug - well water

Heavy metals	**Infant**	**Child**	**Adult**
Cadmium (Cd)	2.4×10^{-2}	1.6×10^{-2}	5.34×10^{-3}
Chromium (Cr)	9.36×10^{-4}	6.24×10^{-4}	2.08×10^{-4}

Table 11 indicates that the carcinogenic risk results of Cd and Cr contamination were greater than the acceptable range of $\leq 1 \times 10^{-6}$ to 1×10^{-4}. Cd has more effect in assessment of health risk than Cr among the three groups in the study area.

DISCUSSION

The findings of the study reported that in terms of chronic daily intake (CDI), Zn had the highest intake in all sources of water and Cr the least intake in both borehole water and dug- well water and spring water which had Cd as the least intake. In terms of hazard quotient (HQ), Cd had the highest hazard and Cr the least hazard in all the three sources of water. The hazard index (HI) for three sources was in this order: infant > Child > Adult. This indicates that infants are more vulnerable to the adverse effect of heavy metals than child and adult.

For non-carcinogenic risk, HI>1 indicates likely high health risk which means that the non-carcinogenic risk of a particular heavy metal is higher than the acceptable safe limit of $\leq 1 \times 10^{-6}$ to 1×10^{-4} (Ukah et al, 2019). But if HI <1 it indicates that the non-carcinogenic health risk of a particular heavy metals falls within the acceptable safe limit (Wu et al, 2019; Egbueri and Mgbenu, 2020). In this study, the HI was >1 for Zn, Cu and Cd infant and Cd >1 in both child and adult in borehole water. In spring water, HI >1 for Cd in both infant and child; other heavy metals Zn, Cu, Mn, Fe and Cr were <1 in infant, child and adult. In dug - well water, HI was >1 for Zn, Cu and Cd in infant, HI>1 for Zn and Cd in child and HI>1 for Cd in adult. This implies that Zn, Cu, Cd may likely have high health risk on the inhabitants of the area.

The carcinogenic risk results of Cd and Cr contamination were greater than the acceptable range of $\leq 1 \times 10^{-6}$ to 1×10^{-4} (Ukah et al, 2019; Egbueri and Mgbenu, 2020). Cd has more effect in assessment of health risk than Cr among the three groups in the study area. The body needs only small amount of heavy metals for various biochemical reactions and due to long biological half-lives, Cd and Cr pose health risk to the proper functioning of the body tissues leading to diseases (Shankar, 2019; Barzegar et al, 2019; Kumar et al, 2020b).

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Conclusion
This study has revealed that Zn has the highest chronic daily intake (CDI) in borehole, spring and well water. In terms of hazard quotient (HQ), Cd the highest hazard and Cr the least hazard in all the three sources of water. The hazard index (HI) for three sources was in this order: infant > Child > Adult. This indicates that infants are more vulnerable to the adverse effect of heavy metals than child and adult. The carcinogenic risk results of Cd and Cr contamination were greater than the acceptable range of $\leq 1 \times 10^{-6}$ to 1×10^{-4} indicating significant risk. It was recommended that there should be awareness programmes on hygienic practices and pretreatment of water use. Also the Cross River State Board Limited should supply quality water to the inhabitants and monitor their sources of drinking water.

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