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Health Risk Assessment of Carcinogenic and Non-Carcinogenic Contaminants in Drinking Water from Hand Dug Wells in Gboko Local Government Area of Benue State

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Abstract

This research assessed the carcinogenic and non-carcinogenic risk factors associated with the ingestion of the heavy metals in water from hand dug wells in Gboko Local Government area of Benue State. The concentrations of selected heavy metals namely; arsenic, cadmium, chromium, lead and zinc in the water were determined using AAS, and the results obtained were used to carry out the assessment for both adults and children in the area. Hazard Quotient (HQ) and Hazard Index (HI) were used to assess the non-carcinogenic risk factors, while the Incremental Lifetime Cancer Risk (ILCR) factor was used to determine the carcinogenic risk factor. The research found that HQ ≤ 1 and HI ≤ 1 for both adults and children in the study area, and was lower than the reference dose for all the metals. The ILCR was found to be 9.85×10^{-4} and 9.1×10^{-4} for adult and children respectively in the wells studied. The values of ILCR obtained fell within the safe limit of 10^{-6} < ILCR < 10^{-4} for one or more heavy metals. The result of the research showed that, both the carcinogenic and non-carcinogenic contaminants in the wells are within safe limits and there is no cancer and non-cancer scare in the area under study. Based on these findings, continuous monitoring of the sources of water (groundwater and surface water) and types of pollutants discharged in the area should be maintained.

Keywords: Carcinogenic, Non-carcinogenic, Cancer risk, Hazard Quotient, Hazard index

Introduction

Water has been described as the vital natural resource with social and economic values for human beings [1]. According to [2], without water, man's existence would be threatened. Safe water is one of humans' most precious resources and is essential for survival [3]. Water derived from various sources may contain dissolved inorganic and organic substances which may cause health problems to the community [4]. The most important drinking sources in the world are surface water and groundwater [5]. The availability of safe drinking water is a fundamental requirement in maintaining the good health of humans. Urbanization, increase in population and industrialization has posed a great challenge to the quality of water not only in Gboko, but worldwide. Domestic wastes (solid and effluent) in Gboko like in several other places are discharged indiscriminately around homes and in the business areas. Although almost every compound has either a pit toilet or water closet toilet, free ranging animals litter the environment with faecal wastes [6]. These are bound to cause water pollution and poor sanitary conditions.

According to the environmental protection agency [7], human health risk assessment is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future.

It is very necessary to carry out the human health risk assessment of this area because urbanization, industrialization and increase in population have been substantial in recent years and this could pose a substantial risk to human health in the use of both the surface water and ground water in the area. The health risk in this area may pose either chronic or carcinogenic risk. Risk assessment, including Quantitative microbial risk assessment (QMRA), commences with problem formulation to identify all possible hazards and their pathways from sources to recipients. Human exposure to the pathogens (environmental concentrations and volumes ingested) and dose–response relationships for selected (or reference) organisms are then combined to characterize the risks. With the use of additional information (social, cultural, political, economic, environmental, etc.), management options can be prioritized. To encourage stakeholder support and participation, a transparent procedure and active risk communication at each stage of the process are important [8]. This research focuses solely on the ingestion pathway to evaluate the non-carcinogenic and carcinogenic health risk. Direct exposure to heavy metals (HMs) in drinking water beyond permissible limits has become a major public health concern, especially in the developing world. [9], identified the Anthropogenic activities causing the release of HMs from the naturally trapped sources into water sources. The most common routes of human exposure to HMs in industrial and residential areas are dermal, inhalation and oral ingestions of food and or water. These HMs can cause toxicity if their allowable levels are surpassed [10]. The HMs are non-biodegradable and may amass in the ecosystem reaching unsafe proportion for human health [11]. Besides raw sources of water, water packaging materials have become major sources of contaminants in bottled and sachet water.

The impact of heavy metal contaminants in drinking water and the attendant health risks are important factors to be considered when evaluating drinking water quality [12]. A proper risk assessment must involve establishing the capacity of a risk source to introduce contaminants into the environment, determining the quality of risk agents that came in contact with the human, animal, and plant environment boundaries, and then quantifying the health implications of the contact or exposure. Heavy metal entering the body through these routes could elicit carcinogenic and non-carcinogenic health risks [13].

The health risk assessment of each contaminant is normally based on the estimation of the risk level and is classified as carcinogenic or non-carcinogenic health hazards [14]. Arsenic (As) is known to be a naturally occurring ubiquitous metalloid and a Class I human Carcinogen. Approximately 200 million people around the world are exposed to unsafe levels of arsenic. Chronic exposure to arsenic has been correlated with cancers of the lung, liver, bladder, kidneys, skin, as well as non-carcinogenic diseases such as skin lesions, cardiovascular disease, reproductive defects, neurological injuries, and diabetes mellitus [15]. Arsenic is capable of inducing mutations by inhibiting DNA repair and causing chromosomal aberrations [16].

Materials and Methods

Description of the Study Area

The study area for this research was Gboko Local Government Area of Benue State. It is one of the largest and most populous Local Government Areas in Benue State. It has a land mass of 1,835 km², Density, 196.9 in h./km² with a population of 361, 325 people according to National Population Commission census of (2006). It is bounded by Tarka Local Government on the North, Ushongo Local Government to the South, Buruku Local Government on the East and Gwer on the West. It lies between latitude 7°05′–7°31′N and longitude 9°13′–9°35′E in the savannah region of Nigeria with typical savannah vegetation and climate. The area has a landmass of 2,264 square kilometers and experiences two main seasons: dry and rainy. The local government is made up of Hills, including the Gboko Hills in the north and Mkar Hills in the east. The area is generally undulating, with valleys and streams that support agricultural activities. The local Government is situated in an area with significant mineral deposits, including limestone, barite, granite and alluvial clay. The research covered eighteen villages which are listed with their geographical locations and shown on the map of the local Government Area below

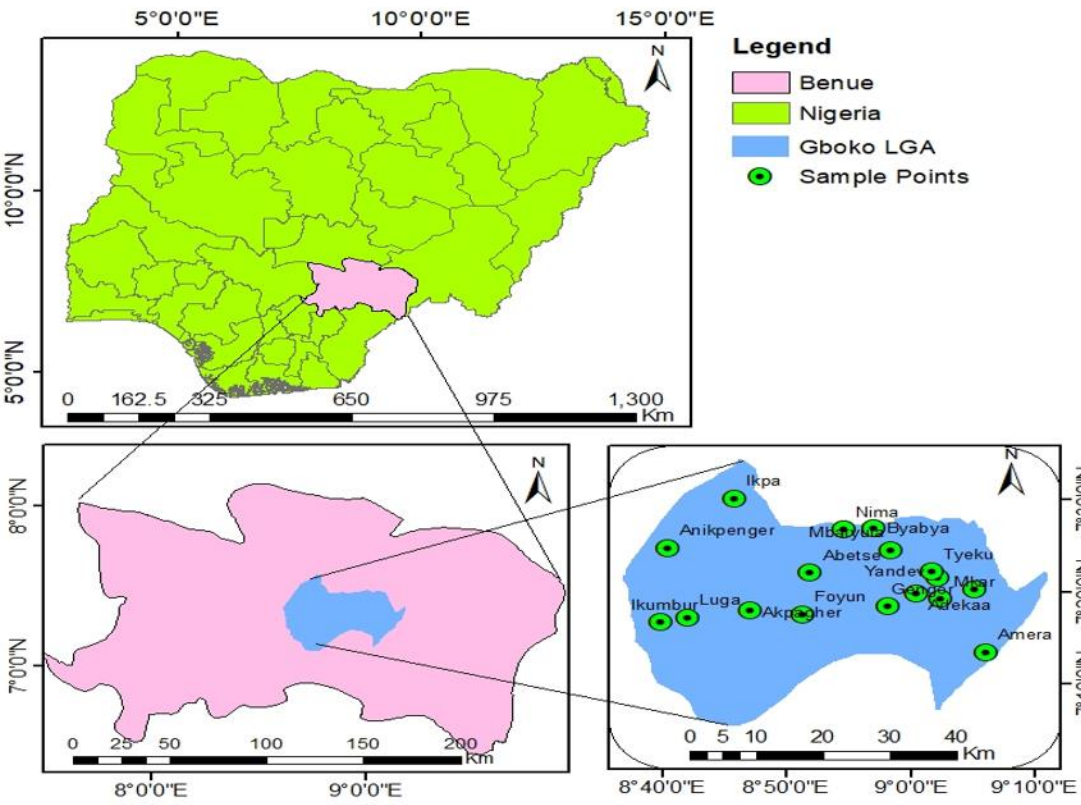

Fig. 1: Map of Nigeria Showing Benue and Sample Points in Gboko Local Government Area

Sampling

To evaluate the quality of water in Gboko Local Government Area of Benue State, 18 Wells were sampled from 18 villages within a period of six months covering two seasons (June to November for rainy season, and December to May for dry season. The water samples were collected using standard procedures of the American Public Health Association [17]. The sampling locations were marked with the help of global positioning system (GPS).

The eighteen villages where samples were collected are listed below with their location described by their geographic coordinates:

S1-Mkar	7.3213°N, 9.0419°E
S2-Ameradu	7.3380°N, 9.0871°E
S3-Amera,	7.3162°N, 8.9017°E
S4-Akpaher	7.2997°N, 8.7853°E
S5-Ikumbur	7.4631°N, 9.3506°E
S6- Foyun	7.1930°N, 9.0180°E
S7-Yandev	7.3602°N, 9.0378°E
S8-Tyeku	7.7346°N, 8.5340°E
S9-Byabya	7.7136°N, 8.6230°E
S10-Abetse	7.3685°N, 8.8662°E
S11-Nima	7.2693°N, 8.9940°E
S12- Mbatyula	7.4782°N, 8.9388°E
S13-Adekaa	7.3307°N, 9.0090°E
S14-Akaajime	6.5930°N, 9.5149°E
S15-Genger	7.3072°N, 8.9703°E
S16-Ikpa	7.5035°N, 8.7633°E
S17-Luga	7.2881°N, 8.7004°E
S18-Anikpenger.	7.4324°N, 8.5003°E

Analysis of Carcinogenic and Non-carcinogenic Heavy metals

The water samples collected in sterile containers and were labeled as per the sampling station using standard methods. Some of the parameters which may change in their composition or status quickly like the pH, conductivity and BOD were analyzed in situ and since the analysis was to commence within six hours no preservatives were used to stop microbial activity. The samples were packed in an icebox and transported to laboratory for analysis.

Heavy metals in all the samples collected for this research were analyzed using a Perkin Elmer Atomic Absorption Spectrophotometer (AAS) Model Optima 8300 series using acetylene, nitrous oxide and compressed air for burning. Triplicate analysis was done on each water sample and the mean values recorded.

Non-Cancer Risk

This was determined by evaluation of hazard quotient and hazard index. The hazard quotient (HQ) was evaluated from equation: $HQ = \frac{CDI}{RfD}$ 1

where RfD is the reference dosage, CDI is chronic daily intake

The RfD values for Pb, Cd, Cr, As, Zn, Cu and Fe are 4.0x10-3, 1.0x10-3, 1.5x100, 3.0x10-4, 3.0x10-1, 4.0x10-2 and 7.0x10-1 (mgkg-1day-1) respectively.

$$CDI = \frac{C \times IR \times EF \times ED}{BW \times AT} \quad 2$$

Where C = Concentration of heavy metal (mg/L)

IR= Rate at which people drink water (3.53L/day for adults, 1.0L/day for children and 0.25L/day for infants.
ED = Duration of exposure; 70years for adults, 6years for children and 1year for infants.
EF = Exposure frequency in days; 365days for adults, children and infants.
BW = average body weight in kg; 50kg for adults, 15kg for children and 6.9 kg for infants.

AT =Average time (AT = 365 x ED)

Hazard index

$$HI = HQ1 + HQ2 + HQ3 + HQ4 \ldots \quad 3$$

HQ values show that there is no significant risk (non-cancer) if HQ ≤ 1, and considerable non-carcinogenic risk if HQ > 1.
The population is assumed to be safe when HI ≤ 1 and in a non-cancer risk concern when 1< HI <5 [18].

Cancer risk

The chances of cancer risk in the studied wells through the intake of heavy metals was determined using the incremental lifetime cancer risk (ILCR)

ILCR = CDI x CSF 4

CSF is the risk produced by a lifetime average dose of 1mg/ kg/BW/day of a specific contaminant. The level of acceptable cancer risk (ILCR) for regulatory consideration is within the range of 10^{-6} to 10^{-4} [19].

Results and discussion

Results

Tables 1 to Table 7 were entries used in determining the HQ, HI and the Incremental life cancer risk factor (ILCR). Table 1 shows the statistical average of the Heavy metals in all the samples. The input parameters stated in table 3 were adopted from EPA and are used to determine the CDI (Table 4) using the appropriate equations obtained from literatures. The HQ and HI shown in table 5 have been used in this research to determine the non-cancer risk factors. Cancer Risk was determined using the CDI and CSF and the values reflected in Table 7

Table 1: Concentration of Heavy Metals in Wells

Parameter	Mean (mg/L)
Arsenic	0.0018 ± 0.00022
Cadmium	0.00063 ± 0.00073
Chromium	0.00283 ± 0.00083
Lead	0.00158 ± 0.00083
Zinc	0.35 ± 0.18

Table 2: Ingestion Reference Doses Source: [7]

Metal	RfD (mg/kg/day)
Lead	0.0004
Cadmium	0.0005
Chromium	1.5
Arsenic	0.0003
Zinc	0.3

Table 3: Input Parameters for Calculation of CDI Source: [7]

Parameter	Symbol	Units	Adult	Children
Exposure duration	ED	years	70	6
Exposure Frequency	EF	Days/year	365	365
Average Time	AT(365 x ED)	Days	25550	2190
Body Weight	Kg	Kg	50	15
Ingestion Rate	IR	L/day	3.53 L/day	1.0L/day

Table 4: Chronic Daily Intake (CDI) of Metals Analyses (Source this study)

Metal	Adults	Children
Lead	0.000112	0.000105
Cadmium	0.000045	0.000042
Chromium	0.000201	0.000189
Arsenic	0.00013	0.000120
Zinc	0.0249	0.0233

Table 5: Hazard Quotients (HQ) and Hazard index (HI) of Samples from the Study

Metal	Wells	
Metal	**Adults**	**Children**
Lead	0.28	0.26
Cadmium	0.09	0.084
Chromium	0.0001	0.00
Arsenic	0.433	0.40
Zinc	0.083	0.078
HI	**0.80**	**0.822**

Table 6: Cancer slope factors (CSF) of heavy metals (Oral)

Metal	CSF(mg/kg/day)-1
Lead	0.0085
Cadmium	15
Chromium	0.5
Arsenic	1.5

Table 7: Incremental life cancer of adult and children (CDI x CSF)

Wells	
Adults	**Children**
0.00000095	0.0000001
0.00069	0.00063
0.000100	0.00009
0.000195	0.000192
9.85×10^{-4}	9.1×10^{-4}

Discussion

Risk factors are conditions or substances that increase the likelihood of developing a disease or health condition. Cancer and non-cancer risk factors can be categorized into various groups, including genetic, environmental, lifestyle, and occupational factors. Understanding cancer and non-cancer risk factors is crucial for preventing and mitigating diseases. By recognizing these risk factors, individuals can take proactive steps to reduce their likelihood of developing health conditions. Non-cancer risk factors were determined from values of Hazard Quotient (HQ) and Hazard Index (HI) obtained from the Exposure duration (ED) Exposure frequency (EF), Average time (AT), Body weight (BW) and Ingestion rate (IR). [20] averred that If HQ < 1, the exposed population is unlikely to experience obvious adverse effects. If HQ > 1, there is a potential health risk, and related interventions and protective measurements are needed to be taken. The combined non-carcinogenic effect of all metals considered in the study expressed as hazard index (HI) was >1, with values for children higher than those for adults. The result of the study showed that water sourced from wells were safe from adverse effects on humans that make use of these water. The input parameters used in calculating the CDI are presented in table 3. The chronic daily intake (as represented in table 4) of all metals analyzed showed higher values for adult than children. The results obtained from analysis done in this research shows that the calculated values for HQ and HI were less than one (1) for both adults and children in the area (Table 5). The HI vales were 0.80 and 0.82 for adults and children in the Wells. This signifies that there is no non-cancer scare in the area under study. The cancer risk factor was determined from the concentration of heavy metals in the area using the incremental lifetime cancer risk (ILCR). All values obtained as presented in table 7 shows 9.85×10^{-4} and 9.1×10^{-4} for adult and children respectively in wells. This is indicative that the sampled water from the wells in the area in the present research is not under any threat of cancer. [21] also used the same method to assess the cancer and non-cancer risks associated with heavy metal exposures from street foods. Their research showed that regular consumption of street roasted and vended meat in Kampala is a health risk with respect to Pb, Cd and As. The combined non-carcinogenic effect of all metals considered in their study expressed as hazard index (HI) was >1, with values for children higher than those for adults. [22] in their study in Iran found that in all the studied heavy metals, chromium has the highest chance of cancer risks (mean ILCR 6.54 X 10-3) and nickel has the lowest chance of cancer risk (mean ILCR 9.16 x 10-5). The results of their research showed that there was a cancer risk from the contaminants to residents through the cumulative ingestion and dermal contact routes in the drinking water of the region.

Conclusion

The non-cancer and cancer risks factors determined in this research provides means of judging the water quality for domestic use in the area. All parameters considered in this study had concentrations less than their Ingestion Reference Dose (RfD). The Hazard Quotient was also less than 1, indicating no considerable non-carcinogenic health impact. The hazard index (HI) was found to be less than one (1) for all water samples. The population is assumed to be safe when HI < 1 and in a non- cancer concern when 1< HI <5. The population in Gboko at the moment do not have any non-cancer concern using the water from the various wells analyzed. Incremental lifetime cancer risk was also found to be 9.85 x 10^{-4} and 9.1 x 10^{-4} for adult and children respectively from the wells studied. The well water in the area is therefore deemed by this study to be free from non-cancer and cancer risks.

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