Journal of
Chemistry
(JCHEM)

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International Journal of Chemistry
ISSN 2520-0345 (Online)
Vol.2, Issue 1, pp 1 - 13, 2023
www.ajpojournals.org

Carcinogenic and Non-carcinogenic Health Risk Assessment from Exposure of Heavy Metals in Hand Dug Wells in Gombe State

Lookman Oladimeji Balogun[2], Audu Haruna Sympa[1], Maryam Umar Maigari[2], Abdullahi Hameed Mohammed[1] and Dahir Abubakar[2]

[1]Department of Chemistry, Federal College of Education (Technical), PMB 60, Ashaka Road, Gombe, Gombe State, Nigeria,

[2]Department of Integrated Science, Federal College of Education (Technical), Gombe, Gombe State, Nigeria.

Corresponding Author' Email: balookman@fcetgombe.edu.ng

Article History

Date Received: 6th Feb 2023

Date Received in Revised Form: 25th Feb 2023

Date Accepted: 6th Mar 2023

Abstract

Purpose: Heavy metals are among the commonest cause of water pollution and impact human health worldwide. Therefore, this study aims to assess the probable health risk (non-carcinogenic and carcinogenic risk) for adults and children that are exposed to toxic heavy metals (Cu, Pb, Cd, Cr, Zn and Ni) through ingestion and dermal contact with dug well water in the locations.

Methodology: The hand dug wells serve as sources of drinking water, domestic and industrial purposes. In this study, composite samples from the locations were tested for the presence of heavy metals using Atomic Absorption Spectrophotometer (AAS). The health risk assessments were evaluated.

Findings: The results of the HQ values of heavy metals for combined pathways were below the safety level (HQ < 1) for adults, while the HI for children were higher than the safety limit in some stations. The average values of total carcinogenic risk index (CRI) through exposure to drinking water for children and adults were lower than 10−6. Overall, the CRI total through exposure to drinking water for children and adults are within safety level of WHO risk, negating the probability of carcinogenic risk for the children and adults to the carcinogenic elements via ingestion and dermal routes.

Recommendation: Appropriate purification, improvement in enlightenment programs and control measures should be implemented to protect the health of the residents in these localities.

Keywords: *Hand dug well, human health risk assessment, heavy metal, carcinogenic and non-carcinogenic effects, adult, children.*

BACKGROUND

Water is a chemical substance that is composed of hydrogen and oxygen atoms in a ratio of 2:1 that exists as liquid at room temperature with a density of $1gcm^{-1}$ and very vital to all forms of life (Moss, 2010). Water covers about 71% of the earth (Peel *et al*., 2004), most in oceans holding 97% of surface water, glacial and polar ice caps and other large water bodies; 1.6% below the ground in aquifers and 0.001% in the air as vapour cloud as well as precipitation. There are water bodies in the forms of rivers, lakes, ponds and other small amount that continually move through the cycle of evaporation, transpiration and run off, usually emptying into the ocean (CIA-the World Fact Book, 2008; Water in the Climate System, 2005).

There are basically two sources of water, namely; surface and ground water. The surface water includes water in the ocean, rivers, lakes, streams, ponds and reservoirs (Green Fact, 2018). The other category of source of water is the ground water. Any water that is underground is ground water. In the water cycle, some of the precipitation sinks into the ground and goes into the water shed aquifers. The quantity of water that seeps down to the ground water depends on the gradient, topography and soil type/texture (Ben-Niam *et al*., 2011). When water percolate and reaches a layer of the ground that is saturated, water begins to store. This saturated zone is called the water table which rises and fall depending on the season and quantum of rainfall (Onoh *et al*., 2018). Ground water is therefore a collection of water that seeps through layers of sand, clay, gravels and rocks which purifies the water and gives it the immunity against earthly impurities gaining unrestricted access to it. It is for this reason that it stays cleaner than the surface water (Kendra, 2018). The groundwater represents 26% of global renewable fresh water resources (Elbeih, 2015). According to Jagaba (2020), groundwater is the easiest and cheapest alternative water supply.

Dug well water is one of the oldest source of water in Sub-Saharan Africa emanating from groundwater. According to FAO/WHO (2018), water over its use for drinking, it functions as a solvent for wide variety of substances, facilitates industrial cooling, transportation and an approximate 70% of fresh water is used in agriculture. Muhammed and Rajwali (2018) posited that water is the second only to oxygen in importance to sustain life. Hand dug wells are usually 1-20 meter deep depending on the geological characteristics of the area (Ajibade *et al*., 2015).

In spite of the natural purification dug well water under-go, it has been indicted in a number ways that it contain some impurities. According to Kendra (2018), dug well water is prone to pollutants emanating from human activities such as discharge of industrial wastes (effluents), domestic agricultural remains. Nigeria, in the views of Blessing *et al*. (2020) is challenged with poor waste disposal culture. These discharges of pollutants find their ways into the ground water when rain water carries them through run-off and they percolate, seep or leach down and get into the aquifers (ground water) result in sub-lethal effects or death in local fish population (Xu *et al*., 2014). International Agency for Research in Cancer (2015) hinted that various studies have reported heavy metals in drinking water abound. Nnorom *et al.* (2017) submitted that many diseases associated to heavy metals poisoning have been traced to consumption of portable water in Nigeria have been well documented.

Heavy metal is a metal with density greater than 6 g/ml or atomic number more than 20. 35 metals pose threat to human health and 23 of them are heavy metals (Madkour, 2019). Heavy metals are toxic and poisonous at low concentrations which cannot be degraded. However, trace metals such as Zn, Cu, and Se are very essential to the body but, becomes poisonous at high concentrations.

They have the propensity to bio accumulate in vital organs of the body leading to health challenges. They gain access to the body via food consumption, drinking of water and air FAO/WHO/IAEA, 2014). This has been a cause for worry. According to Phan (2019), environmental health experts in Nigeria are concerned about heavy metals contamination of groundwater. Hand dug wells are rarely analyzed or treated before use. With the rate of anthropogenic activities emanating from small and medium scale commercial activities all over the place are harbingers environmental pollution calls for concern. This is the underlying factor for this study.

Actions of Heavy Metals in the Body

The most exposure of residues is by ingestion (oral consumption of contaminated food), inhalation, and dermal exposure. The ingestion pathway may be five orders magnitude higher than the other routes (Godwin and May (2019). Muhammed and Rajwali (2018) reported that the harmful effects of heavy metals to the body is manifested only when consumed above the bio-recommended limits. Oguwegbu and Ijioma (2003) reported that the poisoning of heavy metals is due to their interference with normal body biochemistry metabolic processes whereby the acid medium of the stomach converts the metals to their stable oxidation states (Zn^{2+}, Pb^{2+}, Cd^{2+}). These ions combine with other endogenous biomolecules such as proteins, enzymes, hormones to form strong chemical bonds; replacing hydrogen atoms or metal groups in the protein, enzyme or hormones with the intruding poisoning heavy metal leading to the formation of protein-metal$_{(poison)}$ compound which now acts as substrate and reacts with metabolic enzymes resulting in inhibiting the enzyme or protein from its normal functionalities.

Furthermore, Madkour (2019) traced the toxic manifestations of heavy metals to be primarily due to imbalance between pro-oxidant and anti-oxidant homeostasis (oxidative stress). Metal ions interfere with body functions via the production of free radicals. The metal ions deplete glutathione and protein-bound sulfhydroxyl groups; resulting in the production of Reactive Oxygen Species (ROS) as superoxide ion, hydrogen perioxide and hydroxyl radicals (O_2 $O_2°$, H_2O_2 °OH, OH^-). The toxicities of the metals can be increased by deficiencies of certain essential nutrient elements such as Ca, Fe, Zn and Se.

In this study, the ingestion and dermal routes are considered more probable pathways of exposures in view of domestic applications to which well waters are put to. Consequently, the human health risk associated with the exposure and to compare the levels with international safety regulations limits. The Health Index (HI) via their Target Hazard Quotient (THQ) and the non-carcinogenic and carcinogenic profiling of the heavy metal contents of the water samples are intended.

The ground water which hitherto does not require treatment as much as surface water but, has cut the fancy of this study due to ever-rising pollution index. Moreover, there is no available data on the heavy metal presence in the sampled dug wells in the Local Government Areas Gombe State. The study is aimed at determining the concentrations of heavy metals such as copper (Cu), lead (Pb), cadmium (Cd), chromium (Cr^{+6}), Zinc (Zn) and Nickle (Ni). The choice of the heavy metals is premised on the fact that most of them have been established to be very harmful even in very minute concentrations and their effects on human have been well documented (Sameeh, 2018). The study will help to ascertain the degree of safety of the dug well water in the locality. It also serves as a call on the danger of pollution and advice on curtailing the activities that are injurious to environment. The study will jolt attention of public health workers, policy makers and environmentalists on the need for constant monitoring and evaluation of the safety potentials of utilities as important as water. The results will in addition add to the database for further research exploits in the study area.

MATERIALS AND METHOD

Area of the Study

Gombe State was created out of Bauchi State on 1st October, 1996 with a population of 2.4 million (2,365,040) by the 2006 census figure and a Land Area of 20265sqm (16,639km^2) projected at a growth rate of 3.3%. Gombe State is located in the Centre of the north east of the country on latitude 9"30ˈ and 12"30ˈN. Longitude 8"5ˈ and 11"45ˈE. It is bordering the five other North-Eastern States. There are 11 Local Government Areas in Gombe State. The State capital is located in Gombe town (NHDR, 2018).

Beneath the water surface, 10cm below, was estimated and 100ml of the water sample were taken from dug wells in the major cities namely; Talesse, Gombe, Kaltungo, Shongum and Deba towns. Each sample was taken in presoaked polyethylene (plastic) container in 10% HNO_3 to prevent precipitation of the metals. The samples in the polyethylene bottle were kept and transported in an ice box to the laboratory and stored in the refrigerator at 4°C for further analysis. A freshly prepared Aqua Rega (a mixture of conc HNO_3/HCl in the ratio 1:3) for the wet digestion. The digestion was carried out in a block digester. 10ml Aqua Rega was added to 3ml each of the samples. Then, the mixture was boiled gently over a water bath (95°C) for 5hrs and filtered (Md Avenuddin, *et al*., 2018). Copper, lead, cadmium, chromium, zinc and nickel were determined using Atomic Absorption Spectrophotometer (AAS).

Human Risk Assessment Indices

Health Risk Characterization: Health risk is a measure of the tendency of harmful effects to human health as a result of exposure to pollutants from the environment. The risk assessment is undertaken to predict the carcinogenic and non-carcinogenic risks that may arise as a consequence of exposure of both adults and children to heavy metals living within the study area. This is achievable by the incorporation and intergradations of ingestion and dermal pathways through which the population is likely to get infested to enable the quantitative determination of the health hazard. The following equations and parameters as adopted by Li *et al* (2017) and Md Avenudin *et al* (2018) were perused to achieve the set objectives of the study.

Average Daily Dose ($ADD_{ingestion}$) (mg/kg/day) = $\frac{Cm \times IR \times ED \times EF \times CF}{BW \times AT}$ ……………………………1

$ADD_{(dermal)} = \frac{Cm \times SA \times Kp \times ABS \times EF \times ED \times CF}{BW \times AT}$ …………………………………………………..2

Target Hazard Quotient (THQ) = $\frac{ADD\ ingestion/dermal}{RfD\ ingestion/dermal}$ ………………………………………..3

Hazard Index ($HI_{ingestion/dermal}$) = $\sum_{i=1}^{n} HQ_{(ingestion/dermal)}$………………………………………………...4

$CRI_{ingestion} = ADD_{(ingestion)} \times CSF$…………………………………………………………………...5

$ADD_{(ingestion)}$ which represents the exposure through ingestion, Cm is the mean concentration of the element in the water, IR = both direct and indirect intake rate 2Lday^{-1} (adult) and 1Lday^{-1} (child); EF = exposure frequency to the pollutant 365days/year for both adult and child; BW = body weight 70kg (adult) and 15kg (child); ED = exposure duration 30years (adult) and 6years (child); CF = unit conversion factor 0.001Lcm^{-3}; AT = average lifetime expectancy = EDx365 for both adult and child (non-carcinogenic), and 70x365 (carcinogenic) for both adult and child; ABS = dermal Absorption factor 0.1 for both adult and child; SA = Area of Skin 18,000cm^2 (adult) and 6,600cm^2. Kp is the dermal permeability coefficient in water (cmh^{-1}) in the study 0.002 for Cr, 0.0001 for Pb, 0.0002 for Ni, 0.001 for Cd, As and Cu and 0.0006 for Zn (Asare-Donko *et al*., 2016).

Table 1: Reference Dose, RfD (DEA, 2010); Cancer Slope Factor, CSF (DEA, 2010); Nigerian Standards for Drinking Water Quality, NSDWQ (2015) and Food and Agricultural Organization/World Health Organization, FAO/WHO (2011) for ingestion and dermal pathways for the metals

Metal	RfD (ingestion)	CSF (ingestion)	RfD (dermal)	NSDWQ	FAO/WHO
Copper (Cu)	3.70E-2	2.00E-2	2.40E-2	2.00	2.00
Lead (Pb)	3.60E-3	8.50E-3	4.20E-4	1.00E-2	1.00E-2
Cadmium (Cd)	5.00E-4	6.10	5.00E-4	3.00E-3	5.00E-3
Chromium (Cr)	3.00E-3	5.00E-1	7.50E-5	5.0E-2	5.00E-2
Zinc (Zn)	3.00E-1	3.00E-1	7.50E-2	5.00	3.00
Nickel (Ni)	2.00E-2	1.70	5.60E-3	N.D	7.00E-2

N.D = Not determined

RESULTS AND DISCUSSION

Table 2: Concentration ± standard deviation) of the heavy metals in the sampled dug wells

Metal (mg/kg)	Balanga	Gombe	Kaltungo	Shomgom	Yamatu-Deba
Copper (Cu)	0.225±0.006	0.080±0.02	0.010±0.01	0.008±0.04	0.010±0.02
Lead (Pb)	0.012±0.15	0.030±0.44	0.010±0.06	0,006±0.05	0.010±0.03
Cadmium (Cd)	0.001±0.001	0.003±0.02	BLD	BDL	BDL
Chromium (Cr)	0.003±0.012	0.009±0.01	0.001±0.03	0.001±0.001	0.002±0.004
Zinc (Zn)	0.606±0.07	0.515±0.03	0.416±0.03	0.425±0.03	0.182±0.17
Nickel (Ni)	0.139±0.21	0.233±0.12	0.176±0.012	0.018±0.005	0.097±0.05

BLD (Below Detection Limit)

Table 2 is result of the heavy metal concentration in each of the sampled dug wells in the study area. The result revealed that zinc metal ranked highest between 0.606mg/kg from Balanga water sample to 0.182mg/kg in Deba. In summary the ranking in terms of the heavy metals follow the pattern Zn>Cu>Ni>Pb>Cr>Cd. The concentrations of the heavy metals are generally low. The results are ways apart if compared with those reported by Philip et al (2020) on the water bodies around mining areas of Abakaliki, Nigeria. This may be due to absence of heavy industrial and other human activities that can result in pollution around the vicinities of the wells. Furthermore, the locations of these wells are now very far away from areas prone to abuse of any sort as the wells have been dug long ago and most of them are now at sites virtually surrounded by decent residential structures away from commercial activities. According to Hosein *et al* (2019) wastewater, especially from agricultural and industrial zones constitute the major sources of discharge into natural rivers and dams that eventually permeate through the groundwater resulting in rapid release of heavy metals and chemical toxins into sources and subsequently to human body via the food chain. However, the ranking is in the order of Balanga>Gombe, Kaltungo>Shongom>Yamaltu-Deba representing total amount of heavy metals in the respective dug wells. Similar reasons for the general low concentrations as adduced above will suffice. A similar result of heavy metal concentrations in water below regulatory standards have also been reported by (Jagaba *et al*., 2020).

The range of the concentrations of the heavy metals fall within the bracket of regulatory national and international standards, suggesting that the exposed population is within the safe net. The results are much different from those of Yusuf *et al* (2017) that discovered Pb, Ni, Cr, and Cd in samples of hand dug well water in some locations in Kashere, Gombe State, Nigeria. The results of this study is heart-warming, however, the fear and anxiety is on the accumulative effects due to continuous exposure as the environment is also continually being degraded. The health risk characterization determined for the heavy concentrations in the hand dug wells under investigation is presented in Tables 3 to 7. The results of the Health Indices revealed that HI < 1. This is an indication that the exposed population is not at risk of poisoning.

Table 3: Target Hazard Quotient (THQ), Health Index (HI) and Cancer Risk Factor (CRI) (mg/kg/day) for Ingestion Pathway for Adult Non-Carcinogenic Health Risk

	Balanga		**Gombe**		**Kaltungo**		**Shongom**		**Yamaltu-Deba**	
Metal	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**
Cu	1.74E-04	1.28E-07	6.19E-05	4.58E-08	7.73E-06	5.72E-09	6.19E-06	4.58E-09	7.73E-06	5.72E-09
Pb	9.53E-05	2.92E-09	2.38E-04	7.28E-09	7.94E-05	2.43E-09	4.75E-05	1.45E-09	7.94E-05	2.43E-09
Cd	5.72E-05	1.74E-07	1.71E-04	5.23E-07	N.D	N.D	N.D	N.D	N.D	N.D
Cr	2.86E-05	4.29E-08	8.57E-05	1.29E-07	9.53E-06	1.43E-08	9.53E-06	1.43E-08	1.90E-05	2.86E-08
Zn	5.77E-05	5.19E-06	4.93E-05	4.44E-06	3.97E-05	1.51E-05	4.03E-05	3.63E-06	4.03E-05	3.63E-05
Ni	1.99E-04	6.41E-06	3.33E-04	1.13E-05	2.52E-04	8.55E-06	2.57E-05	8.55E-06	1.35E-04	4.57E-06
$\sum$	**6.12E-04**	**1.18E-05**	**9.39E-04**	**1.64E-04**	**3.88E-04**	**2.37E-05**	**1.29E-04**	**1.22E-05**	**2.81E-04**	**4.09E-05**

N.D = Not Determine

Table 4: Target Hazard Quotient (THQ), Health Index (HI) and Cancer Risk Factor (CRI) (mg/kg/day) for Ingestion Pathway for Child Non-Carcinogenic Health Risk

	Balanga		Gombe		Kaltungo		Shongom		Yamaltu-Deba	
Metal	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**
Cu)	4.05E-05	3.00E-08	1.44E-05	1.07E-08	1.80E-06	1.33E-09	1.44E-06	1.07E-09	1.80E-06	1.33E-09
Pb)	2.22E-05	6.80E-10	5.56E-05	1.07E-09	1.85E-05	5.67E-10	1.11E-05	3.40E-10	1.83E-05	5.67E-10
Cd)	1.33E-05	4.07E-08	4.00E-05	1.22E-07	N.D	N.D	N.D	N.D	N.D	N.D
Cr)	6.67E-06	1.00E-08	2.00E-05	3.00E-08	2.22E-06	3.34E-09	2.22E-06	3.34E-09	4.43E-06	6.65E-09
Zn)	1.33E-05	1.20E-06	1.13E-05	1.04E-06	9.23E-06	8.31E-07	9.43E-06	8.49E-07	4.03E-06	3.63E-07
Ni)	4.64E-05	9.08E-07	7.75E-05	2.81E-06	5.00E-05	1.99E-06	6.00E-06	2.04E-07	3.14E-05	1.07E-06
∑	**1.42E-04**	**2.19E-06**	**2.19E-04**	**4.01E-06**	**8.18E-05**	**2.83E-06**	**3.02E-05**	**1.06E-06**	**6.00E-05**	**1.44E-06**

Table 5: Target Hazard Quotient (THQ), Health Index (HI) and Cancer Risk Factor (CRI) (mg/kg/day) for Ingestion Pathway for Adult Carcinogenic Health Risk

	Balanga		Gombe		Kaltungo		Shongom		Yamaltu-Deba	
Metal	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**
Cu	7.46E-05	5.50E-08	2.64E-05	1.95E-08	3.28E-06	2.44E-09	2.64E-06	1.95E-09	3.30E-06	2.44E-09
Pb	4.06E-05	1.24E-09	1.02E-04	3.11E-09	3.39E-05	1.04E-09	2.03E-05	6.22E-09	3.39E-05	1.04E-09
Cd	2.44E-05	7.44E-08	7.32E-05	2.23E-07	N.D	N.D	N.D	N.D	N.D	N.D
Cr	1.23E-05	1.84E-08	3.67E-05	5.50E-08	4.07E-06	6.10E-09	4.07E-06	6.10E-09	8.13E-06	1.22E-08
Zn	2.46E-05	2.22E-06	2.11E-05	1.90E-06	1.69E-05	1.52E-06	1.73E-05	1.56E-06	7.40E-06	6.60E-07
Ni	5.00E-06	2.89E-06	1.42E-04	4.83E-06	1.08E-04	3.66E-06	1.10E-05	1.96E-06	5.75E-05	1.96E-06
∑	**1.82E-04**	**5.26E-06**	**4.01E-04**	**7.03E-06**	**1.66E-04**	**5.19E-06**	**5.53E-05**	**3.53E-06**	**1.10E-04**	**2.64E-06**

International Journal of Chemistry
ISSN 2520-0345 (Online)
Vol.2, Issue 1, pp 1 - 13, 2023
www.ajpojournals.org

Table 6: Target Hazard Quotient (THQ), Health Index (HI) and Cancer Risk Factor (CRI) (mg/kg/day) for Ingestion Pathway for Child Carcinogenic Health Risk

	Balanga		Gombe		Kaltungo		Shongom		Yamaltu-Deba	
Metal	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**	**THQ**	**CRI**
Cu	3.46E-05	2.56E-08	1.24E-05	9.14E-09	1.54E-06	1.14E-09	1.24E-06	9.14E-10	1.54E-06	1.14E-09
Pb	1.89E-05	5.80E-10	4.75E-05	1.45E-09	1.59E-05	4.85E-10	9.53E-06	2.92E-10	1.59E-05	4.85E-10
Cd	1.14E-05	3.48E-08	3.42E-05	1.04E-07	N.D	N.D	N.D	N.D	N.D	N.D
Cr	5.70E-06	8.55E-09	1.71E-05	2.57E-08	1.90E-06	2.86E-09	1.90E-05	2.86E-08	3.86E-06	5.70E-09
Zn	1.15E-05	1.04E-06	9.87E-06	8.88E-07	7.93E-06	6.90E-07	8.10E-06	7.29E-07	3.47E-06	3.12E-07
Ni	3.97E-05	1.35E-06	6.65E-05	2.26E-06	5.00E-05	1.70E-06	5.15E-06	1.75E-07	2.69E-05	9.13E-07
∑	**1.22E-04**	**2.46E-06**	**1.88E-04**	**3.29E-06**	**7.73E-05**	**2.39E-06**	**4.30E-05**	**9.34E-07**	**5.17E-05**	**1.23E-06**

Table 7: Target Hazard Quotient (THQ) and Health Index (HI) (mg/kg/day) for Dermal Pathway for both Adult and Child Non-Carcinogenic Health Risk

	Balanga		Gombe		Kaltungo		Shongom		Yamaltu-Deba	
Metal	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**
Cu	6.20E-04	2.13E-05	2.20E-04	7.60E-07	2.75E-05	9.50E-07	2.20E-05	7.60E-07	2.75E-05	9.50E-07
Pb	4.33E-04	1.09E-05	7.86E-04	2.71E-05	2.61E-04	9.05E-06	1.57E-04	5.43E-06	2.62E-04	9.05E-06
Cd	2.20E-04	7.60E-06	6.60E-04	2.28E-05	N.D	N.D	N.D	N.D	N.D	N.D
Cr	8.80E-03	3.04E-04	2.64E-02	7.79E-04	2.93E-03	1.01E-04	2.93E-03	1.01E-04	5.87E-03	2.03E-04
Zn	5.33E-04	2.11E-05	4.57E-04	1.57E-05	3.67E-04	1.26E-05	3.75E-04	1.29E-05	1.64E-04	5.53E-06
Ni	5.46E-04	1.89E-05	9.16E-04	3.16E-05	6.91E-04	2.39E-05	7.07E-05	2.45E-06	3.70E-04	1.28E-05
∑	**1.12E-02**	**3.84E-04**	**2.94E-02**	**8.77E-04**	**4.28E-03**	**1.48E-04**	**3.55E-03**	**1.23E-04**	**6.69E-03**	**2.31E-04**

Table 8: Target Hazard Quotient (THQ) and Health Index (HI) (mg/kg/day) for Dermal Pathway for Adult and Child Carcinogenic Health Risk

	Balanga		Gombe		Kaltungo		Shongom		Yamaltu-Deba	
Metal	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**
Cu	1.44E-05	2.48E-04	5.15E-06	1.38E-05	6.43E-07	1.10E-06	5.15E-07	8.13E-07	6.43E-07	1.10E-06
Pb	7.33E-06	1.26E-04	1.84E-05	3.14E-05	6.12E-06	1.05E-05	3.08E-06	6.29E-06	6.12E-06	9.52E-06
Cd	5.14E-06	8.80E-06	1.54E-05	2.64E-05	N.D	N.D	N.D	N.D	N.D	N.D
Cr	2.05E-05	3.52E-04	6.17E-04	6.37E-04	6.55E-05	1.17E-04	6.85E-05	1.17E-04	6.85E-05	1.17E-04
Zn	1.27E-05	2.13E-05	1.07E-05	1.83E-05	8.55E-05	1.47E-05	8.73E-06	1.49E-05	3.75E-06	6.40E-06
Ni	1.20E-05	2.18E-05	2.14E-05	3.66E-05	1.62E-05	2.77E-05	1.65E-06	2.82E-06	8.65E-06	1.48E-05
∑	**7.21E-05**	**7.78E-04**	**6.88E-04**	**7.64E-04**	**1.74E-04**	**1.71E-04**	**8.25E-05**	**1.42E-04**	**8.77E-05**	**1.49E-04**

N.B = Not Determined

However, juxtaposing the results above with the 7 Risk Levels based on Delphi Method as employed by both Li *et al* (2017) and Md Ayenudin *et al* (2018) all cases and categories fall within the extremely low risk range of risk value of <10^{-4}. This ranked as extremely low risk grade which indicates complete acceptability. However, the analysis of carcinogenic dermal exposure pathway for adults revealed on the average, a rather disturbing resulting of 1.0E-2. By the Delphi Method, this is a Grade VI risk grade (High Risk). This is suggestive of a situation that needs the attention of the government and all stakeholders to take action to mitigate the spate of environmental pollution or other measures to secure the environment. Another case of note is the average risk value of 9.64E-05 for carcinogenic ingestion pathway for adult across the study area. The risk grade is medium risk level which demands regular monitoring and periodic evaluation. The reason for the results on adults appear to be slightly higher than those of the children counterpart may be due to small body weight (15kg) of the children.

The carcinogenic analysis across both for all categories is found to be favourable as the CRI are all less than 10^{-6}. According to Payne-Sturges (2004), the general *De minimus* benchmark level for cancer is 1.00E-6. The 3 Cancer Risk Level are: CRI < 10^{-6} - Negligible, CRI < 10^{-4} – Acceptable or Tolerable and CRI > 10^{-4} – High Risk. It suffices it to state therefore, that the exposed population is not at the risk of being infected with any form of cancer in their lifetime.

Hand Dug Well Water Remediation

In order to keep and maintain quality and safe drinking water in our communities especially, in the hinterlands, removal of heavy metals from hand dug wells before and during use is a must do. Adsorption of the heavy metals using adsorbents that are available for this purpose abound (Madkour, 2019). Other methods include chemical precipitation by which dissolved contaminants are converted to insoluble solids and subsequently removed by physical methods such as clarification and filtration (Yusuf *et al.*, 2018). Ion exchange technique is a reversible chemical reaction whereby ions from the water is exchanged for a similar charged ion attached to an immobilized solid material. Reverse osmosis provides a membrane process that acts as a molecular filter to remove over 99% of all dissolved minerals. In this process, water is made to pass through the membrane while the dissolved and particulate matters are left behind. In this process, metal recovery is very practicable. Other methods such as membrane filtration, membrane distillation and hybrid methods are veritable options (Primal, 2015).

CONCLUSION

This review presents the analysis and characterization of certain heavy metals found in hand dug wells via health and cancer risk indices. Water is ubiquitous and very important to the proper functioning and survival of every biotic entity. Safe drinking water is fast becoming a source of national and international concern, hand dug well water in particular has been neglected overtime as analysis of its water for the presence of poisonous xenobiotic agents are usually not carried out before use. These xenobiotic metals under consideration are known to be cytotoxic and carcinogenic were found to be present in the water samples.

However, the results of the characterization by the determination of the health index and cancer risk index revealed that the exposed population is safe and do not generally face any threat. The general outlook, nevertheless, does not preclude few cases where the results are too close to regulatory redlines. Such cases call for the attention of all and sundry to forestall and prevent escalating and further heightening the pollution index.

RECOMMENDATIONS

In view of the of the outcome of the study on the hand dug wells presented above, coupled with the sacrosanct role water play, it has become imperative that measures be taken to guarantee safety of the water in our environment. The study in this connection therefore, recommends as follows:

1. Government should set up institution for the removal of heavy metals by both physical and chemical means as well as regular monitoring of the pollution index of hand dug wells. These are very paramount and steps in ensuring safe drinking water,
2. Both government and non-governmental institutions shhould encourage environmental education to further enlighten the general populace on the dangers of indiscriminate waste disposal and poor waste management is advocated,
3. Government and relevant international bodies or agencies should make research fund flow their priority to encourage periodic evaluation of public sources of water,

REFERENCES

Ajibade, L. T. Ogunkolu, A. B. & Ogundare, I. O. (2014). Physio-chemical and biological Characterization of hand dug well water in Ilorin metropolis, Nigeria. *Nigeria Geographical Journal*. 9; 146-162.

Ananda, S. P. 2001. Zinc and cell mediated immunity. First International Bio-Minerals Symposium: Trace Elements in Nutrition, Health and Disease (April 19-20, 2001) by *Institute Rosell and the International Association of Bioinorganic Scientists (IABS)*

Asare-Donkor, N. K. Boadu, T. A. & Adimado, A. A. (2016). Evaluation of groundwater and Surface water quality and human risk assessment for trace metals in human settlement Around the Bosomtwe Crater Lake in Ghana. Springer Plus. 5; 10. DOI 10.1186/5400

Ben-Naim, A. & Ben-Naim, R. P. H. (2011). Alice`s adventures in water-land. World Scientific Publishing. P. 31 DOI: 10 1142/8068. ISBN 978-981-4338-96-7

Berdenier, C. D., Dwyer, J. T. & Haber, D. (2016). *Handbook of nutrition and food*. 3rd ed. CRC Press. Pp 211-226.

Blessing, E., Emmanuel, D., Betty, M., Tagang, A, & Chidebere, U. (2020). Risk analysis of Heavy metals contamination in soils, vegetables and fish around Challawa area in Kano State, Nigeria. *Elsevier, Scientific Africa*. 7(2020) ie00281.

CIA. The world facebook @ http://www.cia.gov/library/publications/the worldfacebook/geos/xx. Htm#Geo. Central Intelligence Agency.

Elbeih, S. F. (2015). An overview of integrated remote setting and GIS for groundwater mapping In Egypt. *Ain Shema Engineering Journal*. 6(1); 1-15.

FAO (2018). Water at a glance: the relationship between water, agriculture, food security and Poverty. Rome. http://www.fao.org/nr/water/docs/waterataglance.pdf

Godwin, O. O. & Mary, A. A. (2019). Organochlorine pesticide residues and heavy metals in leguminous food crops from selected markets in Ibadan, Nigeria. *Legume Science.* 1(1): 61-79.

Green Fact (2018). Biodiversity: A Global Outlook. Retrieved from greenfacts.org: https://www.greenfacts.org/en/globalbiodiversity.outlook/1-2//biodiversity-loss.htm.

Gupta, N., Kruhna, K, Y., Vinit, K., Sandeep, K. Richard, P. C. & Amit, K. (2019). Trace Elements in soil-vegetable interference: translocation, bioaccumulation, toxicity Amelioration- A review. *Science of the Total Environment*. 651; 2927-2942.

Hosein, A., Segedah, B. T. S., Batoul, Z. G. O. Tafaghadi, M., Hosein, S. & Maryam, F. (2019). Health risk assessment of arsenic and toxic heavy metals exposure in drinking water in North_East Iran. *Environmental Health and Preventive Medicine*. 24; 59.

Hosni, H., El-gafy, I., Ibrahim, A. & Abowarda, A. (2014). Maximizing the economic value Of irrigation water and achieving self-sufficiency of main crops. *Ain Shams Eng. J*. 5(4); 1

Institute of Medicine (29 September, 2016). *Dietary reference intakes. The essential guides to Nutrient requirement*. National Academic Press. Pp 313-319.

International Agency for Research on Cancer (IARC) (2016). Monographs on the evaluation of Carcinogenic risks to human. 1-115.

Jagaba, A. H., Kutty, S. R. M., Hayder, G., Baloo, L., Abubakar, S., Ghaleb, A. A. S., Lawal, I. M., Noor, A., Umar, I. & Almabashi, N. M. Y. (2020). Water quality hazard assessment For hand dug wells in Raffin Zurfi, Bauchi State, Nigeria. *Ain Shams Eng. Journal*. 11(4).

Kendra, Y. (2018): Different sources of water https://sciencing.com/different-sources-water-7624

Li, F. Z., Oiu, J., Zhang, C., Liu, C. & Xia, M. (2017). Spatial distribution and fuzzy health risk assessment of trace elements in surface water from Honglu Lake. *Int. Journal of Env. Research in Public Health.* 14. 10.3390/ijerph14091011

Madkour, L. H. (2019). Exotoxicology, nanotoxicology and reactive oxygen species (ROS) Stress conservation of free radicals and nanoparticles towards antioxidant defense. Therapeutics. *Journal of Target Drugs delivery*. 3(1): 213-227.

Muhammed, S. & Rajwali, K. (2018). Heavy metal in drinking water of diary buffaloes at Pashwar, Pakistan. Heavy-metal-in-drinking-water-of-diary-pdf.Adobe Reader

Md Avenuddin, H., Md Abusaye, J., Zannatul, F., Moni, B., Md Iqbal, H. & Subraten, M. (2018) Carcinogenic and non-carcinogenic human health risk from exposure to heavy metals in Surface water of Padma River. *Research Journal of Environmental Toxicology*, 12: 18-23.

Moss, B. (2010). Ecology of freshwaters: a view for the twenty-first Century. 4th ed. Wiley.

NHDR (2018). National Human Development Report 2018.

Ogwuegbu, M. O, and M. A Ijioma., 2003. Effects of Certain Heavy Metals on the Population Due to Mineral Exploitation. In: International Conference on Scientific and Environmental Issues in The Population, Environment and Sustainable Development in Nigeria, University of Ado Ekiti, Ekiti State, Nigerian, pp. 8-10.

Onoh, P. A., Omeire, C. O., Echetama, J. A. Nwaihu, E. C., Ugwoke, F. O. & Akalonu, E. C. (2016). Dry season vegetable production by women of Okigwe agicultural zone of Imo State, Nigeria. *Nigerian Journal of Agriculture, Food and Environment*. 12(3): 89-94.

Peel, M. C., McMahon, T. A., & Finlayson, B. L. (2004). Continental differences in the variability Of annual runoff: update and reassessment. *Journal of Hydrology*. 295(1-4): 185-197.

Phan, K., Phan, S., Se, S., Sieng, H., Hony, L. & Kim, K. W. (2019). Assess of water quality And trace metal contamination in Mondolkiri Province in North-Eastern part of Cambodia. *Environmental Geochemical Health.* 41(2); 401-409.

Philip, N. O. & Bennard, B. A. (2020). Potential risk and level of heavy metals in water resources Of lead-zinc mining communities of Abakaliki, South-East, Nigeria. Applied Water Sci. 10; 184

Primal, P. (2015). Groundwater Arsenic Remediation: Treatment technology and scale up. *Elsevier Inc*. Oxford OX5 UK

Payne-Sturges. D. C. (2004). Personal Exposure Melt Risk Assessment: A Comparism of Measured and Modeled Exposures and Risk in an Urban Community. *Environmental Health Perspective*. 112(5): 589-601.

Sameeh, A. M. (2018). Heavy metals contamination as a global problem and the need for prevention/Reduction measurement. *Environmental Tox. Res. Unit (ETRU),* National Research Council, Cairo, Egypt.

Sharma, R. K., Agrawal, M. & Marshel, F. N. (2009). Heavy metal in vegetable collected from Production and market sites of tropical urban area of India. *Food Chem and Tox*. 47; 563

WHO (2011). World Health Organization. Groundwater guidelines for drinking water quality 3rd ed. Geneva.

WHO (2004). Rolling revision of World Health Organization guidelines for drinking water Quality. Geoge Hallberg, USA.

WHO/FAO/IAEA (2014). World Health Organization, Swizaland, Geneva, 1996. Trace Elements in human nutrition and health. Guidelines for drinking water quality. 4thEd. Geneva.

Xu, Y. J., Liu, X. Z. & Ma, A. J. (2014). Current research on toxicity effect and molecular Mechanism of heavy metals in fish. *Marine Science*. 28(10): 67-70.

Yusuf, A., Olasehinde, A., Mboringung, M. N., Tabale, R. P. & Daniel, E. P. (2018). Evaluation Of heavy metal concentration in groundwater around Kashere, and its environs, Upper Benue trough, North-East, Nigeria. *Global Journal of Geological Sciences*. 16; 26-36.