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Human Health Risk Assessment Data of Selected Trace Elements' Concentrations in Floodplain Water of Jebba-North, Central Nigeria

Oladele Ajiboro Omotoso[1*], Olusola Johnson Ojo[2], Olusegun Omoniyi Ige[1], Oluwadamilare Cole[1], Olumide Okunnoye[1], Adebola Oreoluwa Ariba[1], Michael Chukwudi Olelewe[1]

[1]Department of Geology and Mineral Sciences,
University of Ilorin, Ilorin, NIGERIA

[2]Department of Geology,
Federal University Oye-Ekiti, NIGERIA

*Corresponding Author

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Abstract: The consumption of the water from the floodplain of River-Niger by denizens of Jebba-North pose a significant health risk, as it is being exposed to waste from industries, agricultural facilities and households from the congested urban areas. The risk is more pronounced as people living near floodplain uses it for their domestic needs. The study uses ICP-MS method to analyse water from the samples' area; and the exploratory analyses of the water for the following trace elements: "Al, As, Ba, Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn" were carried out. The analyses showed that the mean daily intake by both adult and children, using the Hazard Index (HI) and Hazard Quotient (HQ) of the elements, except Cr and Pb was >1; this is above the standard prescription of <1 for non-carcinogenic health risk. The standard limits for carcinogenic elements, Cr and Pb, are 10^{-6} and 10^{-4} respectively. The test results for both adult and children showed that their intake of Cr and Pb elements from the flood plain is higher than the limit. Conclusively the consumption of water from River- Niger floodplain at Jebba-North pose a health risk that are both carcinogenic and non-carcinogenic in nature.

Keywords: River-Niger floodplain, hazard quotients and index, health risk, carcinogenic, non-carcinogenic element

1. Introduction of the Study

Floodplains are commonly known as, viable and large areas of agricultural activities in a developing world like Nigeria. Floodplains serve as areas where surface and groundwater could be exploited for various uses cutting across agriculture, domestic and industrial. However, in the process of various agricultural activities, the geochemistry of the water and soils are gradually being altered leading to increase in pollution of the water resources for drinking and irrigation purposes. Flooding is very rampant in Jebba floodplain at Jebba because of frequent release of dam water into the water ways from hydro-power station. This study evaluates the health risk of the floodplain water of River-Niger at Jebba-North, Nigeria.

In most developing countries like Nigeria, both surface water and groundwater are at risk of contamination as a result of an indiscriminate expansion of industries, urban centres and effluents from human institutions

*Corresponding author: omotoso.oa@unilorin.edu.ng

[1,2,3,4,5,6,7,8]. Consequently, these can lead to surplusage accumulation of contaminants on both water body and land surface; coupled with the ignorance of the public, regarding environmental issues like inappropriate application of agrochemicals [8].

There are usually two sources; geogenic and anthropogenic, from which trace metal or elements are derived from. The geogenic sources are from nature or natural sources while anthropogenic, are from human activities or artificial sources [9,10]. The dissolved traces of elements in a solution that are by nature introduced into the aquatic environment, come principally from rock/mineral weathering as well as soil erosion or leaching, while such dissolved metals move through aquatic environments independent of human activities and sometimes without any detrimental effects. However, as a result of heavy agricultural practices, rapid growth in population, urbanization, exploration and exploitation of natural resources as well as lack of adherence to environmental regulations, the level of these trace elements has increased in the environment over the past decades through various human actions [9,11,12,13]. The study seeks to establish the risk that water from the floodplain pose on people’s health. This study is aimed at determining, the human health risk of consuming water from the floodplain.

2. The Study Area

The location for this study is situated within longitudes 04°48’30’’E, 04°51’30’’E and latitudes 09°7’30’’N, 09°10’2’’N (Fig. 1 and 2). The climate alternates between dry and rainy season and lies within the middle belt of Nigeria with a total annual rainfall between 1270 mm and 1524 mm which spread over the month of April to October [14]. The rainy and dry seasons are the climate experienced the most in this area, which lie at the middle belt of the country, Nigeria. The region's annual rainfall alternates between 1270 mm to 1524 mm. The rainfall usually happens between the month of April and October. The rainfall usually reaches its peak in August with the lowest temperature of about 25°C, while the month of March usually records the highest temperature at 30°C [15]. The region's vegetation is guinea savannah. The vegetation, rich in shrubs of various species and tall forest plants, run along the depression and streams of the area [16]. Agricultural practices are very prominent in this area. The growing of crops (mechanized farming) and rearing of animals are the order of the day. Field mapping has established that the area of study is located on Nigeria’s basement complex at Bida’s sedimentary basin. The migmatite gneiss, quartzite complex, granitoids and minor acid dykes are what formed the basement rock of the area; while the sedimentary terrain is mostly made of sandstones, conglomerates and claystone which are most likely from Campanian to Maastrichtian age [17].

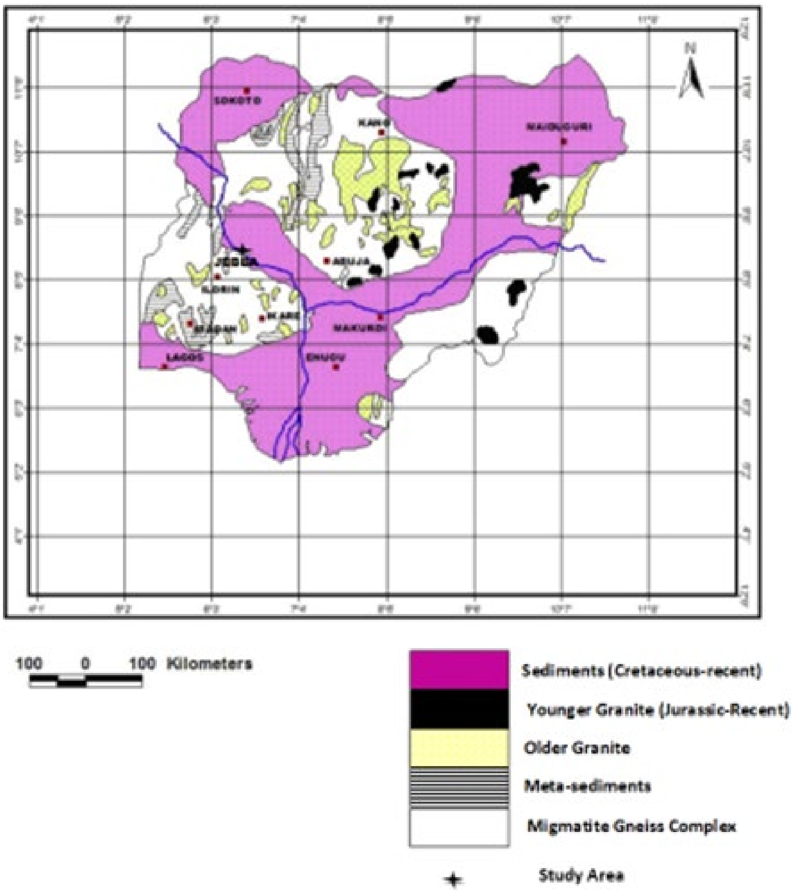

Fig. 1 - Generalized geological map of Nigeria [18].

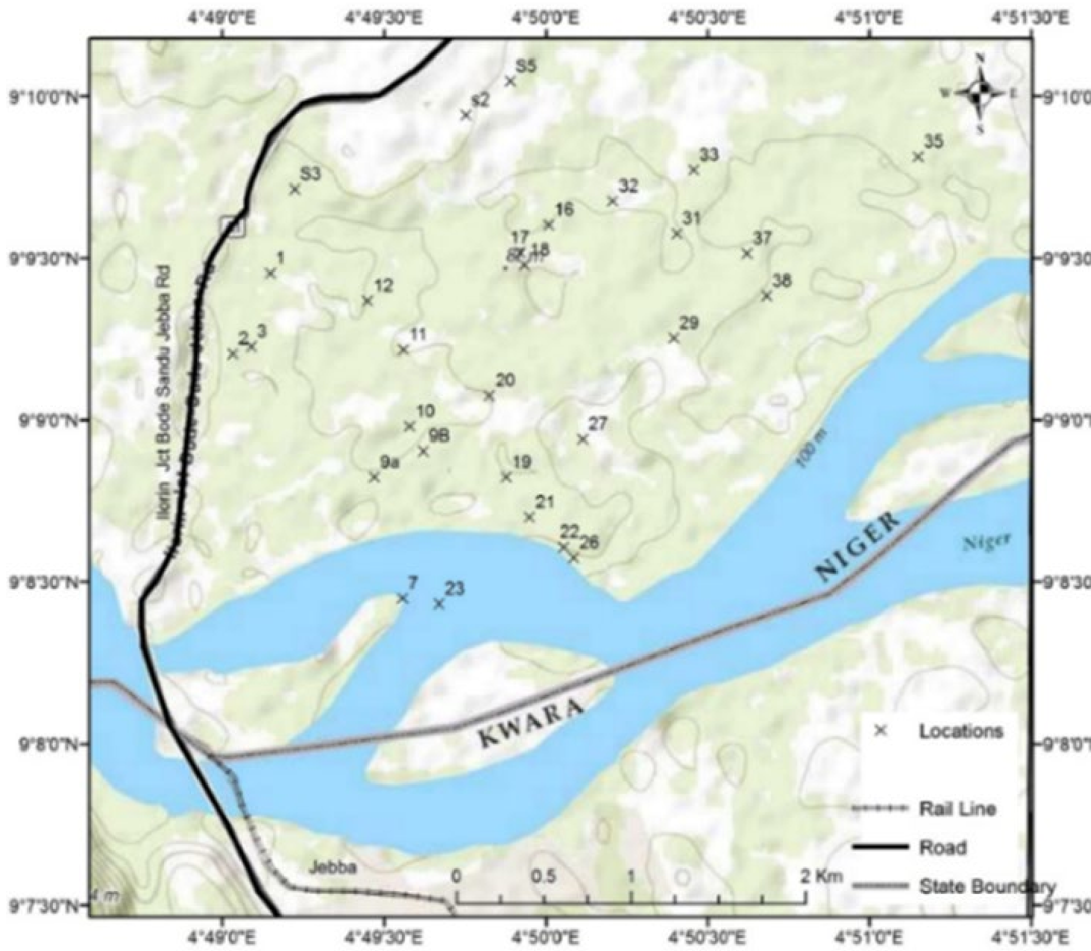

Fig. 2 - The topographical map of the area of study showing sampling points.

3. Research Methodology

3.1 Sample Collection and Preparation

The sample size, water from floodplain, was twenty-nine; these were randomly extracted, in-situ, during the dry season with the aid of GPS and base map. At the point of sampling, the white 60 mL bottles for the water sampling were washed severally with the water to be put in them to prevent cross contamination of the water samples. To avoid the precipitation of the metal solution in the sample, few drops of concentrated nitric acid was introduced. Each bottle was immediately covered to prevent airtight. The technique adopted in the analyses of trace elements of the samples was ICP-MS (inductively coupled plasma mass spectrometry). The analysis was conducted in ACME Laboratory, Vancouver, Canada, North America.

3.2 Data Evaluation

The scientific evaluation of selected hydrochemical data of the floodplain water samples received from the laboratory were carried out using the following: Contamination Indexes and Quantitative Health Risk Assessment. Table 1 presents the World Health Organization (WHO)'s Standards [19] and Nigerian Standards for Drinking Water Quality (NSDWQ) [20] and these were used as basis for recommendations in this research.

Table 1 - WHO and Nigerian standards for drinking water quality for potable water and mean composition of world rivers.

Trace Elements	WHO Standard (ppm), 2006	NSDWQ (ppm), 2007	Mean composition of world rivers in ppm (*after* Viers *et al*., 2009)
Aluminum, Al	0.2	0.2	0.32
Arsenic, As	0.01	0.01	0.00062
Barium, Ba	0.3	0.7	0.023
Chromium, Cr	0.05	0.05	0.0007
Copper, Cu	2	1	0.00148
Iron, Fe	0.3	0.3	0.066
Manganese, Mn	0.5	0.2	0.00042
Nickel, Ni	0.02	0.001	0.0008
Lead, Pb	3	0.01	0.00008
Cadmium, Cd	0.003	0.003	0.0006

3.2.1 Contamination Indexes

This is carried out by computing the contamination factor of the selected trace elements and degree of contamination of the elements in each sample.

3.2.1.1 Contamination Factor (Cf)

The C*f* is a single index express with the following function:

$$Cf = \frac{Cm}{Bm}$$

C*f*, in this function, connotes an object of interest that has been contaminated by trace elements; *Cm* denotes a very significance amount of the trace element in the sample, while background concentration of the trace element is denoted by B*m*. The level of contamination was divided into four, ranging from low, moderate, considerable, and high contamination factors; these levels are denoted by the following figures respectively <1, 1-3, 3-6, and >6.

3.2.1.2 Degree of Contamination (C_{deg})

C_{deg} is the summation of the contamination factors in the samples as represented with the following mathematical expression:

$$C_{deg} = \sum (Cm/Bm)$$

where *Cm* denotes a very significance amount of the trace element in the water, while background concentration of the trace element is denoted by B*m*; *m* in this symbols means being in-situ. Like the contamination level for C*f*, the level of contamination for C_{deg} was divided into four, ranging from low (<8), moderate (8-16), considerable (16-32) and high (>32) contamination factors [21].

3.2.2 Quantitative Health Risk Assessment

Scientists have reported that the risk pathway of human's exposure to trace elements are through these three means: nose and mouth inhalation, direct ingestion, and dermal absorption (skin exposure) [22]. Nevertheless, the most common risk pathways to exposure of these trace elements are dermal absorption and ingestion routes. Hence, this research which is a preliminary study, is based on assessment through ingestion route.

3.2.2.1 Exposure Dose Through Ingestion (The Average Daily Dose)

The average daily dose was determined using the mathematical formula shown below to estimate the health risk of the floodplain water in the samples:

$$Exp_{ing} = \frac{C_{water} \times IR \times EF \times ED}{BW \times AT}$$

where, Exp_{ing} is the degree of exposure through ingestion of water (µg/kg/day); C_{water} is the mean value of concentration of the estimated metals in water (µg/L); *IR* denotes the rate of ingestion in this research (2.2 L/day for adults while 1.8 L/day for children); *EF* denotes frequency of exposure measured as 365 days/year; *ED* is the duration of exposure (70 years for adults; and 6 years for children); *BW* stand for mean body weight (70 kg for adults; 15 kg for children); *AT* is the mean time calculated as: (365 days/year × 70 years for an adult; 365 days/year × 6 years for a child) [22-26].

3.2.2.2 Hazard Quotient (HQ)

The Hazard Quotient (HQ) is designed to measure the non-carcinogenic risk due to exposure to floodplain water consumption. The formula below is used to estimate the HQ of the floodplain water**:**

$$HQ = \frac{ADD}{R_f D}$$

The *ADD* in the formula, is the mean of the degree of daily exposure of trace elements in the water via ingestion. (µg/kg/day); R_fD denotes a reference dose of a specific element. The following represent a reference dose for each of the elements; Al: 1 mg/kg/day; As: 0.0003 mg/kg/day; Ba: 0.2 mg/kg/day; Cd: 0.001 mg/kg/day; Cr: 1.5 mg/kg/day' Cu: 0.04 mg/kg/day; Fe: 0.7 mg/kg/day; Mn: 0.046 mg/kg/day; Ni: 0.02 mg/kg/day; Pb: 0.0035 mg/kg/day; and Zn: 0.3 mg/kg/day [27]. If the coefficient of HQ is greater than unity (>1), it means an element pose a non-carcinogenic health risk, HQ; otherwise, an element is at a tolerable level. [27-29].

3.2.2.3 Hazard Index (HI)

While HQ seeks to measure the non-carcinogenic risk of concentration of each element; HI aggregates the HQ of each elements as an index. The index is represented by the following mathematical equation:

$$HI = \sum_{i=1}^{n} HQ$$

where HI > 1 is an indication of a potentially significant health risk. [23, 30, 31].

3.2.2.4 Chronic Daily Intake (CDI)

The following function depicts the mathematical expression of chronic daily ingestion of heavy metal:

$$CDI = Cwater \times \frac{DI}{BW}$$

C_{water}, *DI* and *BW*, in the formula, denotes the concentration of trace metal in water samples; mg/kg being the unit of measurement. The mean daily intake of water for adults, with the body weight of 70 kg, is 2.2 L/day, while children mean, with body weight of 15kg, is 1.8 L/day. [22].

3.2.2.5 Carcinogenic Risk (CR_{ing})

The mathematical equation below was adopted to estimate the Carcinogenic Risk (CR) through ingestion:

$$CR_{ing} = \frac{Exp_{ing}}{SF_{ing}}$$

where, CR_{ing} is carcinogenic risk through ingestion path, and SF_{ing} is carcinogenic slope factor where Pb, Cd, and Cr are: 8.5 × 10, 6.1 × 10^3, and 5.0 × 10^2 µg/kg/day respectively. [22, 26, 31, 32]. The CR_{ing} values for other trace elements were not computed in this study because of unavailability of the SF_{ing} values.

4. Results and Discussions

4.1 The Concentrations of Trace Elements in the Water

The concentrations of Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd as measured by their means are: 2.57 ppm, 0.00098 ppm, 0.34 ppm, 0.0061 ppm, 0.019 ppm, 4.69 ppm, 0.36 ppm, 0.0072 ppm, 0.0052 ppm, 0.78 ppm and 2.69 x 10^{-5} ppm respectively. The statistical summary of the selected trace elements, as depicted in Table 2 below. In the total selection of trace elements in the sample, Fe accounts for 54%, Al accounts for 29% and others are below 20%. Fig. 3 presents mean concentration of selected trace elements' profile. The average concentrations of Al and Fe are above the prescribed WHO's standards [19] and average concentration of Mn is higher than the recommendations of NSDWQ [20] that is higher than 0.2 ppm. The weathering of aluminosilicate minerals from the rock and the soils in the area is a contributing factor to increase in the concentrations of these trace elements. Also, various anthropogenic activities (rearing of cattle, applications of manure and fertilizers) are all contributing factors to the elevated concentrations of the trace elements. It has been reported by NSDWQ that Al and Mn could result to neuro-degenerative disorders. The reports showed that water with less than 0.3 mg/L of Fe concentration has a very small impacts on taste buds and equally has a marginal aesthetic impact on white cloth in laundry activities and other similar materials. More than 0.3 ppm on the average were, however, recorded, this could have a negative aesthetic effect and pose a serious health risk when ingested by the consumers in the area [22].

Table 2 - Statistical summary of the trace elements concentrations (in ppm) in Jebba floodplain water at Jebba.

Selected Trace Elements, ppm	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd
WHO, 2006	0.2	0.01	0.3	0.05	2	0.3	0.5	0.02	0.01	3	0.003
NSDWQ, 2007	0.2	0.01	0.7	0.05	1	0.3	0.2	0.001	0.01	3	0.003
Average	2.57069	0.000983	0.343853	0.006141	0.019359	4.693862	0.358212	0.007248	0.005176	0.782059	2.69E-05
Minimum	0.096	0	0.12292	0.0011	0.007	0.094	0.01101	0.0027	0.0019	0.1699	0
Maximum	38.151	0.0038	1.21191	0.0512	0.0659	51.321	2.01719	0.0383	0.0315	3.9714	0.00014
Standard deviation	7.054006	0.000949	0.253956	0.008965	0.010475	10.36647	0.503105	0.006822	0.005435	0.872648	4.35E-05
Variance	49.759	9.01E-07	0.064494	8.04E-05	0.00011	107.4636	0.253114	4.65E-05	2.95E-05	0.761514	1.89E-09
Median	0.788	0.007	0.2806	0.0163	0.0163	1.328	0.12983	0.0052	0.0037	0.4734	0

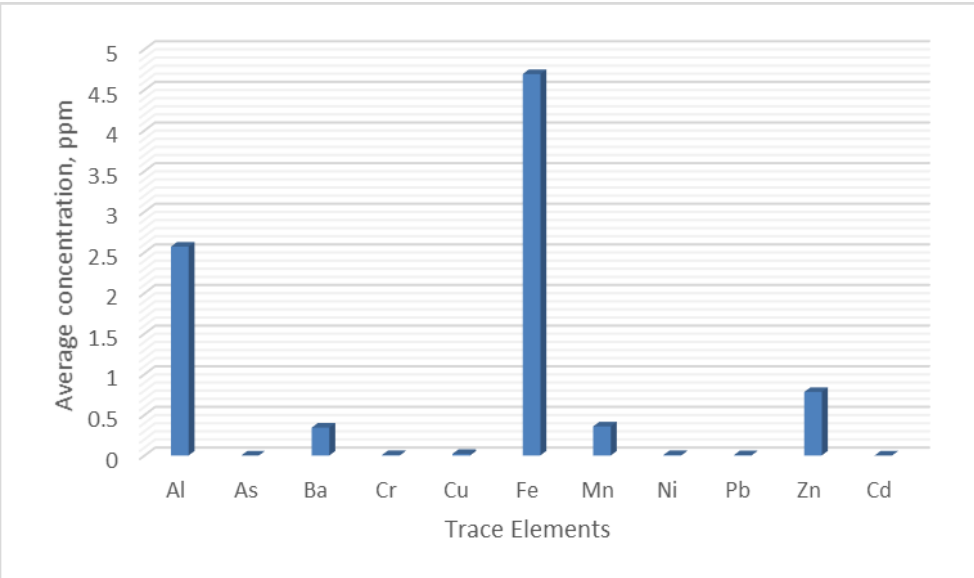

Fig. 3 - Profile of trace elements' average concentration in water.

4.2 Contamination Indexes

The contamination factors and the degree of contaminations of the trace elements, selected for this research, in each of the samples were computed and depicted in Table 3 to ascertain the degree of contamination of the trace elements in the floodplain water. Contamination factors computed for the trace elements (Al, As, Ba, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn) ranged from 0.3 to 119, 0 to 6, 5 to 52, 0 to 11.75, 1.5 to 73, 4.7 to 44.5, 1.4 to 777, 26 to 4802, 3 to 47.9, 23.8 to 393.8 and 283 to 6619 respectively. The respective average contamination factors of the selected trace elements are: 8, 1.6, 15, 0.3, 9, 13, 71, 852.9, 9, 64.7 and 1303.

Based on the average contamination factors, the trace elements range from low contamination factor (in Cd = 0.3) to very high contamination factor (in Zn = 1303). Contamination factor higher than 1 indicates greater effects of activities which are anthropogenic in nature, on the floodplain water which is above the weathering of rocks and sediments' minerals in the study area into the water phase [9]. The degree of contamination also ranges from 422 to 8801 with a mean value of 2348; this indicates a very high level of contamination). Based on the Fig. 4, and 5, the contamination factors' profile and degree of contamination of the computed values respectively. According to Fig. 5, locations 2, 15, 16, 19, 33 and S3 have the highest values of degree of contamination of these trace elements of interest in the samples. These computed elevated values are due to various agricultural activities and weathering of granite gneiss, quartz schist, muscovite and quartzite in the area of study area.

Table 3 - Statistical summary of trace elements' contamination factors and degree of contaminations.

Selected Trace Elements	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd	Degree of Contamination	
Average	8.03341	1.58509	14.9501	8.7734	13.0801	71.1191	852.886	9.06034	64.6983	1303.43	0.33621	Average	2348
Minimum	0.3	0	5.34435	1.57143	4.72973	1.42424	26.2143	3.375	23.75	283.167	0	Min	422
Maximum	119.222	6.12903	52.6917	73.1429	44.527	777.591	4802.83	47.875	393.75	6619	1.75	Max	8801
Standard deviation	22.0438	1.53078	11.0416	12.8064	7.07786	157.068	1197.87	8.52737	67.9365	1454.41	0.54394	Stdev	2164
Variance	485.928	2.3433	121.916	164.005	50.096	24670.2	1434889	72.7161	4615.36	2115316	0.29587	Var	4683352
Median	2.4625	1.12903	12.2	5.71429	11.0135	20.1212	309.119	6.5	46.25	789	0	Med	1531

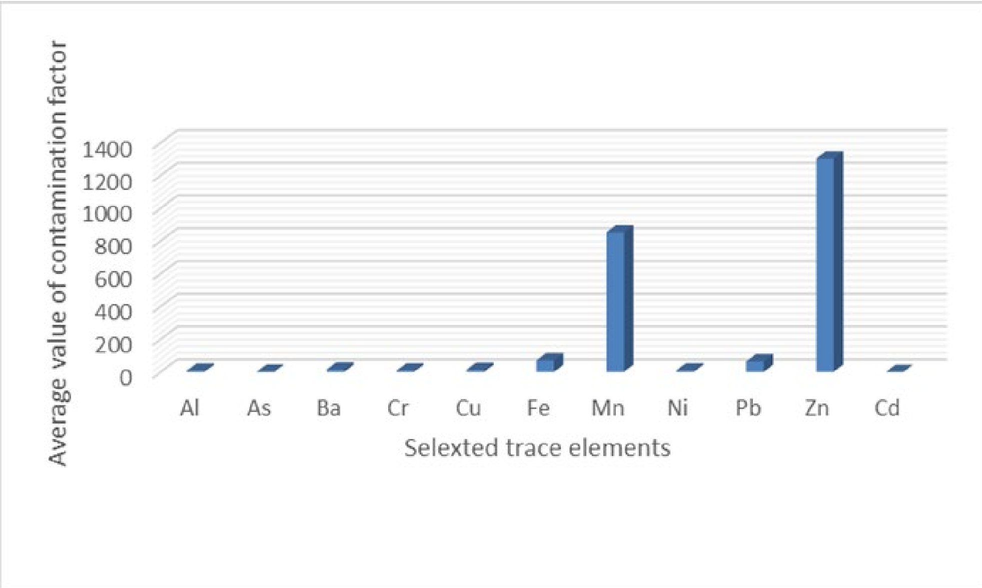

Fig. 4 - Profile of average contamination factor.

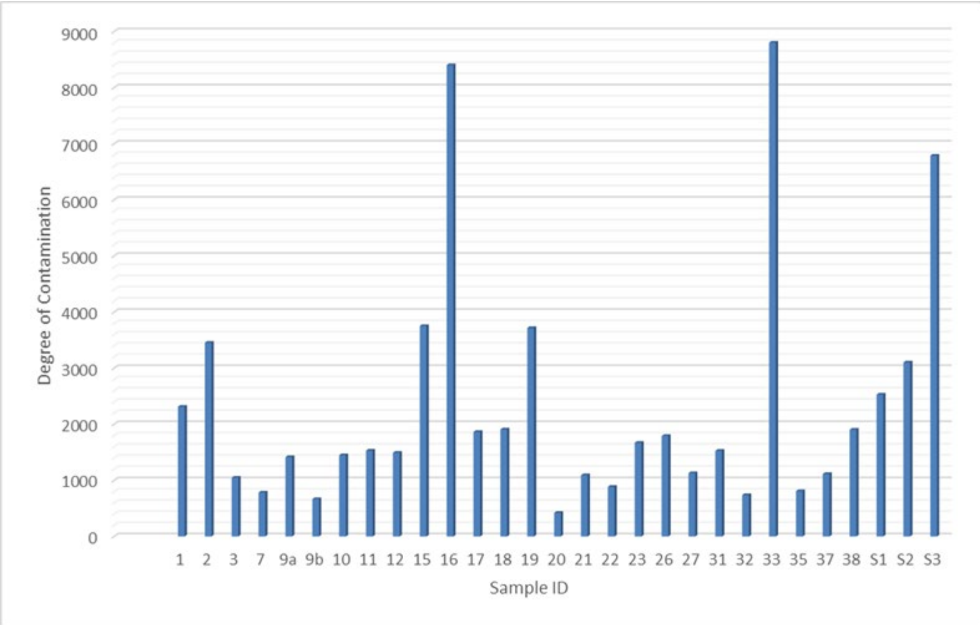

Fig. 5 - Profile of degree of contamination in the water samples.

4.3 Quantitative Assessment of Health Risk

The quantitative assessment of the health risk pose by the nature of water from the floodplain of Niger-Basin River at Jebba, was based on evaluation of exposure dose via ingestion, HQ, HI, CDI, and health risk pose by carcinogenic elements. The assessment was conducted for both adults and children with the aid of health risk assessment model introduced by the USEPA [23].

4.3.1 Exposure Dose through Ingestion

The exposure dose through ingestion was computed for adults and children in this research and this is presented in Table 4 and the profiles are presented in Fig. 6 and 7. In adults, based on the average values, Al, Ba, Fe, Mn and Zn have their values higher than prescribed limit of unity. Others have their average values less than unity. Any value > 1 may have adverse health risk on the consumers. In children, the respective average values are: 308 µg/kg/day, 0.088 µg/kg/day, 31.8 µg/kg/day, 0.54 µg/kg/day, 2.3 µg/kg/day, 389 µg/kg/day, 42 µg/kg/day, 0.68 µg/kg/day, 0.65 µg/kg/day, 44.7 µg/kg/day and 0.0028 µg/kg/day. It was observed that Al, Ba, Cu, Fe, Mn, and Zn have values higher than recommended value of unity while others have values less than unity. Al, Ba, Cu, Fe, Mn and Zn may have certain health hazard risk (non-carcinogenic) on the consumers if ingested orally.

Table 4 - Statistical summary of the exposure dose through ingestion in adults and children (in µg/kg/day).

Exposure Dose Through Ingestion in Adults (Exp_{ing}) µg/kg/day											
Trace Elements	**Al**	**As**	**Ba**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Cd**
Average	80.7931	0.030887	10.80682	0.193015	0.608414	147.5213793	11.25809	0.227803	0.16267	24.57899	0.00084532
Min	3.017143	0	3.8632	0.034571	0.22	2.954285714	0.346029	0.084857	0.059714	5.339714	0
Max	1199.031	0.119429	38.0886	1.609143	2.071143	1612.945714	63.3974	1.203714	0.99	124.8154	0.0044
Stdev	221.6973	0.029828	7.981479	0.281742	0.329221	325.8032031	15.81186	0.214403	0.170812	27.42607	0.001367629
Variance	49149.71	0.00089	63.70401	0.079378	0.108387	106147.7271	250.015	0.045968	0.029177	752.1892	1.87041E-06
Median	24.76571	0.022	8.818857	0.125714	0.512286	41.73714286	4.080371	0.163429	0.116286	14.87829	0
Exposure Dose Through Ingestion in Children (Exp_{ing}) µg/kg/day											
Trace Elements	**Al**	**As**	**Ba**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Cd**
Average	308.4828	0.088	31.8114	0.538	2.342	389.28	41.951	0.676	0.654	44.694	0.0028
Min	11.52	0	20.2896	0.468	1.812	53.76	1.3212	0.372	0.3	23.64	0
Max	4578.12	0.252	38.46	0.648	2.916	674.28	123.4524	1.032	0.924	94.596	0.0084
Stdev	846.4807	0.108311	7.844596	0.069317	0.437855	238.8324882	51.86904	0.2402	0.225874	27.19381	0.004337741
Variance	716529.6	0.011731	61.53768	0.004805	0.191717	57040.95744	2690.398	0.057696	0.051019	739.5034	0.000018816
Median	94.56	0.048	35.7084	0.522	2.472	399.96	15.8172	0.666	0.648	33.474	0

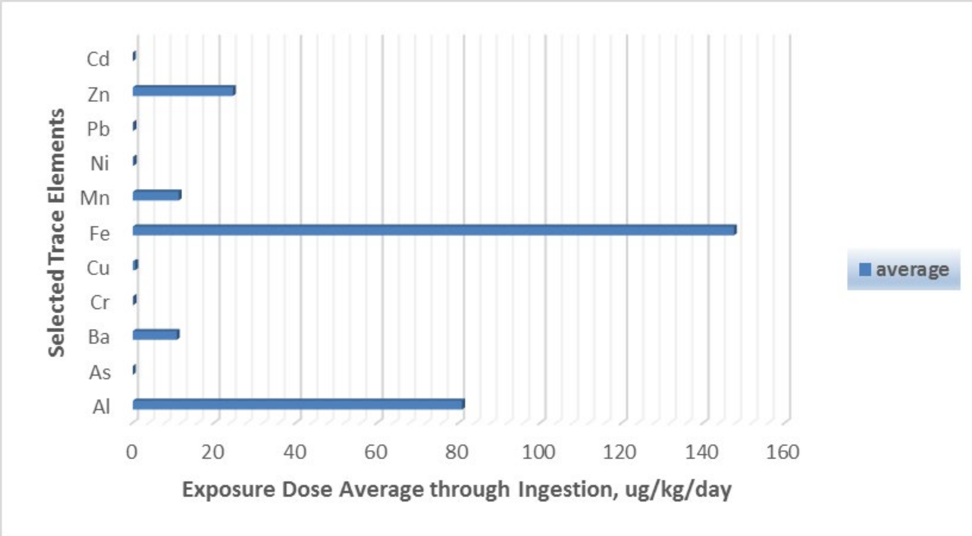

Fig. 6 - Profile of the average exposure dose through ingestion in adults.

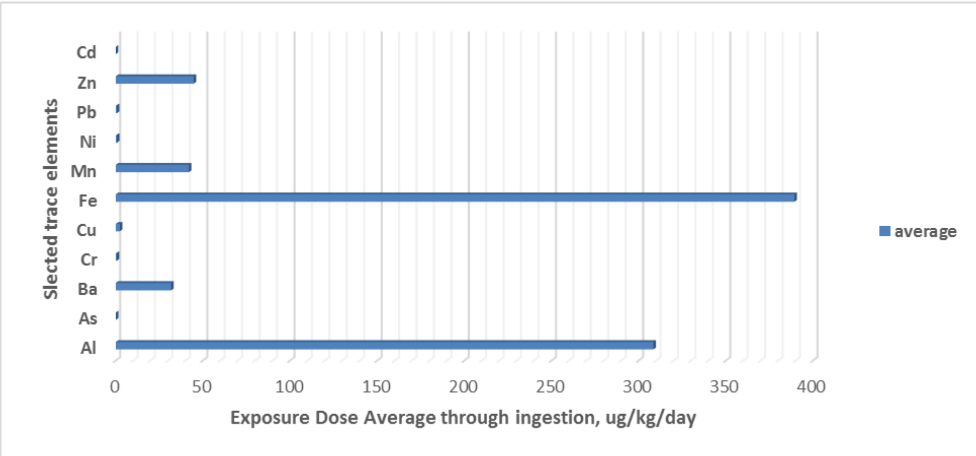

Fig. 7 - Profile of the average exposure dose through ingestion in children.

4.3.2 Hazard Quotient, and Index (HQ, and HI) In Adults

The Table 5 presents the statistical summary of the hazard quotient and its profiles respectively for adults, while the Fig. 8. Depicts the charts for this summary. From Fig. 8, Mn and Fe have the highest value of hazard quotient. Based on the computed average values, the trace elements are generally lower than unity. However, some locations have values higher than unity in Al, Fe and Mn; this could be a product of contributions from rocks weathering and aluminosilicates deposited in the soil/sediments as well as various agricultural activities (application of fertilizers, manures and composts) in the area of study. These elevated values could cause hazard health risk in the consumers. The hazard index values calculated ranged from 0.14 to 5.56 (average=0.75). Based on the average value, HI is lower than the recommended value of unity. However, some of the computed HI in the samples are more than unity which shows evidence of health risk in some of the locations and any adult consumer in such locations could be exposed to health risk.

Table 5 - Computed Hazard Quotient and Index (HQ, and HI) in adults.

Trace Elements	Hazard Quotient (HQ) in Adults											Hazard Index (HI)	
	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd		
Average	0.080793	0.002206	0.054034	0.000129	0.01521	0.210745	0.244741	0.01139	0.046477	0.08193	0.000845	Average	0.747656
Min	0.003017	0	0.019316	2.3E-05	0.0055	0.00422	0.007522	0.004243	0.017061	0.017799	0	Min	0.142705
Max	1.199031	0.008531	0.190443	0.001073	0.051779	2.304208	1.378204	0.060186	0.282857	0.416051	0.0044	Max	5.562238
Standard deviation	0.221697	0.002131	0.039907	0.000188	0.008231	0.465433	0.343736	0.01072	0.048803	0.09142	0.001368	Stdev	1.077751
Variance	0.04915	4.54E-06	0.001593	3.53E-08	6.77E-05	0.216628	0.118155	0.000115	0.002382	0.008358	1.87E-06	Var	1.161547
Median	0.025766	0.001571	0.044094	8.38E-05	0.012807	0.059624	0.088704	0.008171	0.033224	0.049594	0	Med	0.472235

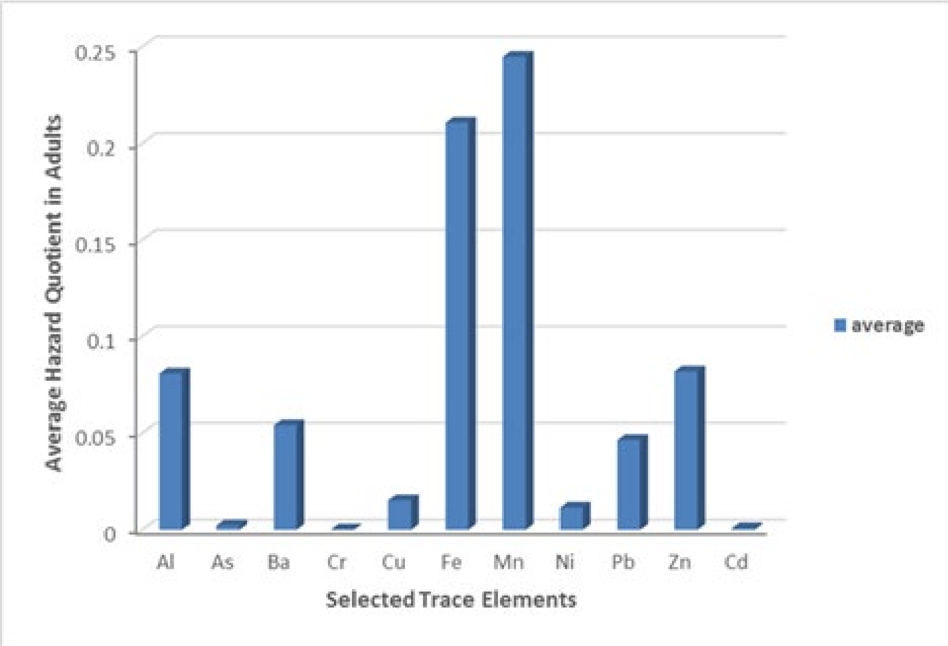

Fig. 8 - Profile of average hazard quotient in adults.

4.3.3 Hazard Quotient, and Index (HQ, and HI) for Children

The statistical summary presented in Table 6, and the graphical profiles, in Fig. 9 and 10, of the computed hazard quotient, and hazard index of the trace elements of interest in the water samples respectively. The average values of HQ computed for Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd are: 0.3, 0.008, 0.2, 0.00049, 0.058, 0.8, 0.9, 0.04, 0.18, 0.31 and 0.003 respectively. Although the computed average values are lower than unity, there are some locations where the values for Al, Fe, Mn, Pb and Zn are greater than unity which could result in potential health risk for children consuming the water in those areas. The index as given by the estimated HI ranges from 0.8 to 4.38 with a value of 2.19. The average value of 2.19 is higher than unity indicating that the water in the floodplain is not advisable to be recommended for consumption in children. The different reports had suggested that experts should not take for granted, reports for children that show estimated coefficient of HQ that is greater than unity, because are at high risk to pollutants [22, 33, 34, 35].

Table 6 - Computed Hazard Quotient and Hazard Index in children.

Trace Elements	Hazard Quotient (HQ) in Children											Hazard Index (HI)	
	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd		
Average	0.308483	0.008424	0.206312	0.000491	0.058076	0.804662	0.934466	0.04349	0.177458	0.312823	0.003228	Average	2.194561
Min	0.01152	0	0.073752	0.000088	0.021	0.016114	0.028722	0.0162	0.065143	0.06796	0	Min	0.799652
Max	4.57812	0.032571	0.727146	0.004096	0.1977	8.797886	5.262235	0.2298	1.08	1.58856	0.0168	Max	4.37586
Standard deviation	0.846481	0.008135	0.152374	0.000717	0.031426	1.777108	1.312447	0.040931	0.18634	0.349059	0.005222	Stdev	1.386424
Variance	0.71653	6.62E-05	0.023218	5.14E-07	0.000988	3.158114	1.722518	0.001675	0.034723	0.121842	2.73E-05	Var	1.92217
Median	0.09456	0.006	0.16836	0.00032	0.0489	0.227657	0.338687	0.0312	0.126857	0.18936	0	Med	1.814877

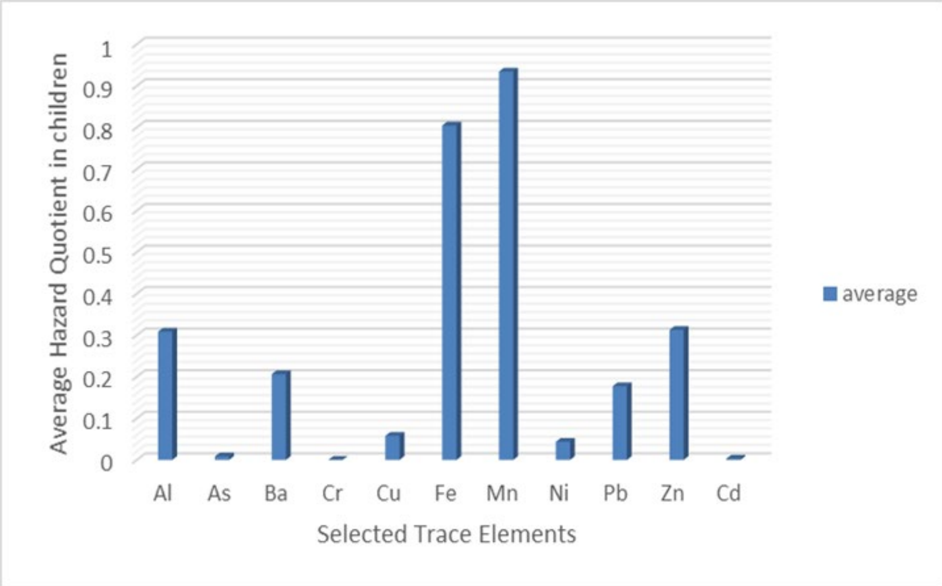

Fig. 9 - Profile of average hazard quotient in children.

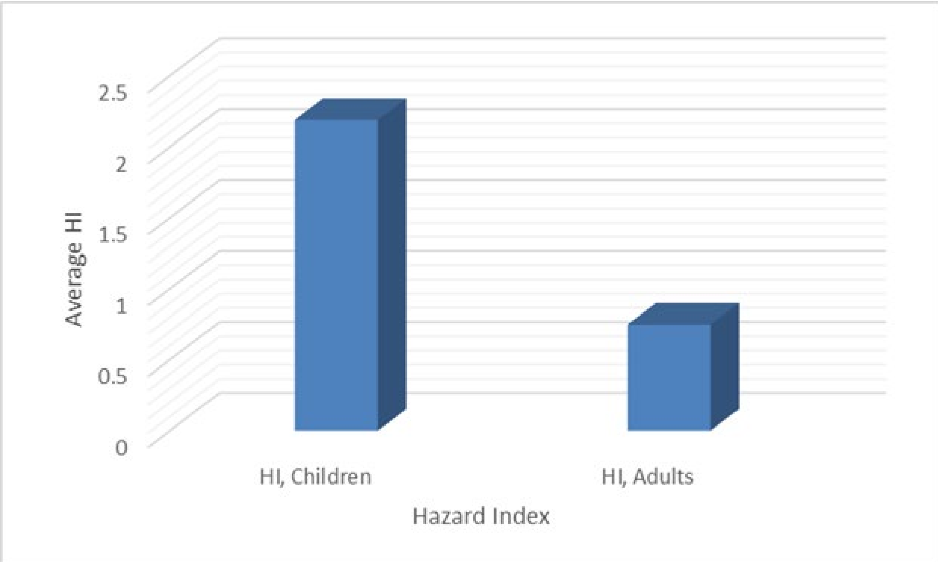

Fig. 10 - Profile of average hazard index of children and adults.

4.3.4 Chronic Daily Intake (CDI) of Trace Elements

The descriptive summary of the chronic daily intake of the selected trace elements (CDI) for both adults and children is presented in Table 7 and their graphical profile is presented in Fig. 11. The average values computed for Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd in adults are: 8×10^{-2}, 3.1×10^{-5}, 1.1×10^{-2}, 1.9×10^{-4}, 6.2×10^{-4}, 1.5×10^{-2}, 1.1×10^{-2}, 2.3×10^{-4}, 1.6×10^{-4}, $2.5 \times 10^{-2}$and 8.5×10^{-7} respectively. The average values of CDI in children are as follows: 3.1×10^{-1}, 1.2×10^{-4}, 4.1×10^{-2}, 7.4×10^{-4}, 2.3×10^{-3}, 5.6×10^{-1}, 4.3×10^{-2}, 8.7×10^{-4}, 6.2×10^{-4}, 9.4×10^{-2} and 3.2×10^{-6} respectively. Based on the average values the order of abundance of CDI in both adults and children respectively is as follows: Fe>Al> Zn >Mn>Ba> Cu> Ni>Pb>Cr>As>Cd. Their graphical profile shows clearly the abundance of the values of children CDI over that of the adults. However, the values are less than unity which is an indication that the floodplain water practically portend a less significant threats to the health of both adults and children through the ingestion medium.

Table 7 - Statistical summary of daily chronic intake of trace elements for both adults and children.

Chronic Daily Intake (CDI) for Adults											
Trace Elements	**Al**	**As**	**Ba**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Cd**
Average	0.080793	3.09E-05	0.010807	0.000193015	0.000608414	0.1475214	0.011258	0.000228	0.000163	0.024579	8.45E-07
Min	0.003017	0	0.003863	3.45714E-05	0.00022	0.0029543	0.000346	8.49E-05	5.97E-05	0.00534	0
Max	1.199031	0.000119	0.038089	0.001609143	0.002071143	1.6129457	0.063397	0.001204	0.00099	0.124815	4.4E-06
Stdev	0.221697	2.98E-05	0.007981	0.000281742	0.000329221	0.3258032	0.015812	0.000214	0.000171	0.027426	1.37E-06
Variance	0.04915	8.9E-10	6.37E-05	7.93785E-08	1.08387E-07	0.1061477	0.00025	4.6E-08	2.92E-08	0.000752	1.87E-12
Median	0.024766	0.000022	0.008819	0.000125714	0.000512286	0.0417371	0.00408	0.000163	0.000116	0.014878	0
Chronic Daily Intake (CDI) for Children											
Trace Elements	**Al**	**As**	**Ba**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**	**Cd**
Average	0.308483	0.000118	0.041262	0.000736966	0.002323034	0.5632634	0.042985	0.00087	0.000621	0.093847	3.23E-06
Min	0.01152	0	0.01475	0.000132	0.00084	0.01128	0.001321	0.000324	0.000228	0.020388	0
Max	4.57812	0.000456	0.145429	0.006144	0.007908	6.15852	0.242063	0.004596	0.00378	0.476568	1.68E-05
Stdev	0.846481	0.000114	0.030475	0.001075742	0.001257027	1.2439759	0.060373	0.000819	0.000652	0.104718	5.22E-06
Variance	0.71653	1.3E-08	0.000929	1.15722E-06	1.58012E-06	1.547476	0.003645	6.7E-07	4.25E-07	0.010966	2.73E-11
Median	0.09456	0.000084	0.033672	0.00048	0.001956	0.15936	0.01558	0.000624	0.000444	0.056808	0

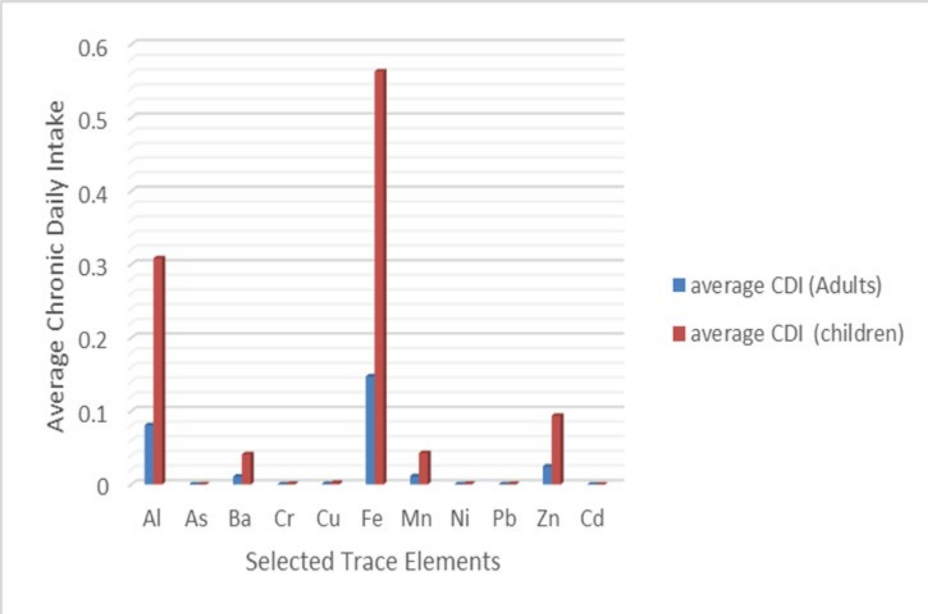

Fig. 11 - Profile of CDI for both adults and children.

4.3.5 Carcinogenic Risk (CR_{ing})

The carcinogenic risk as represented by the CR_{ing}, is defined as the tendency of a person to develop a cancerous cell during that person's lifetime as a result of exposure to certain elements under specific conditions. This was computed for the selected trace elements in this study adopting the works of [22, 24]. Only the carcinogenic risk of Cr, Cd and Pb for Jebba floodplain water were evaluated for both adults and children due to the fact that the values of carcinogenic slope factor for other elements could not be retrieved from literature.

The risk of exposure to carcinogenic elements by way of ingestion for adults and children were estimated and depicted in Table 8. Fig. 12 also presents the children and adults' profile risk of exposure to carcinogenic elements through ingestion pathway. The average carcinogenic values of Cr, Pb and Cd, for adults, are: 3.9×10^{-4}, 1.9×10^{-2} and 1.3×10^{-7} respectively. In children also, the average carcinogenic values of Cr, Pb and Cd are: 1.5×10^{-3}, 7.3×10^{-2} and 5×10^{-7} respectively. It has been reported that under most regulatory program [22] the risk of being exposed to carcinogenic elements exceeds the range of 10^{-6} and 10^{-4} for an individual which could signal a potential risk; therefore, the outcome of research analyses, which suggest high concentration of both Cr and Pb suggested Cr and Pb's level in the floodplain water is likely to lead to growth of cancer cells in adults and children alike. The average values computed for Cd in both adults and children are within the recommended limits [23].

Table 8 - Statistical summary of carcinogenic risk for adults and children in the floodplain water.

Carcinogenic Risk (CR_{ing}) for Adults			
	Cr	**Pb**	**Cd**
Average	3.9×10^{-4}	1.9×10^{-2}	1.4×10^{-7}
Minimum	6.9×10^{-5}	7×10^{-3}	0
Maximum	3.2×10^{-3}	1.2×10^{-1}	7.2×10^{-7}
Standard deviation	5.6×10^{-4}	2×10^{-2}	2.2×10^{-7}
Variance	3.2×10^{-7}	4×10^{-4}	5×10^{-14}
Median	2.5×10^{-4}	1.4×10^{-2}	0
Carcinogenic Risk (CR_{ing}) for Children			
	Cr	**Pb**	**Cd**
Average	1×10^{-3}	7×10^{-2}	5.3×10^{-7}
Minimum	2.6×10^{-4}	2.7×10^{-2}	0
Maximum	1.2×10^{-2}	4.4×10^{-1}	2.8×10^{-6}
Standard deviation	2.2×10^{-3}	7.7×10^{-2}	8.6×10^{-7}
Variance	4.6×10^{-6}	5.9×10^{-3}	7.3×10^{-13}
Median	1×10^{-3}	5.2×10^{-2}	0

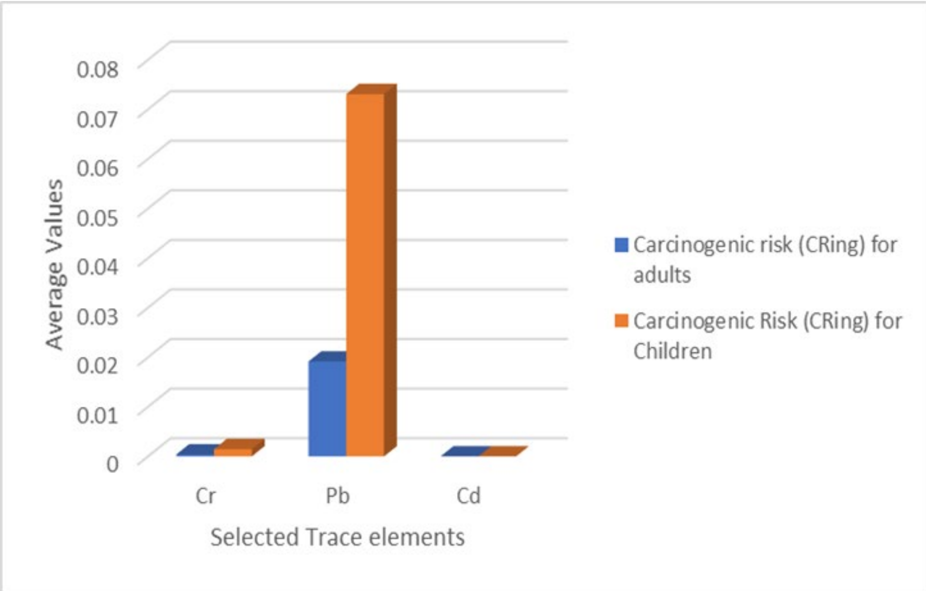

Fig. 12 - Profile of average carcinogenic risks for adults and children.

5. Summary

The human health risk assessment of floodplain water in Jebba central Nigeria has been established using the following criteria: contamination indexes and quantitative health risk parameters. The average concentrations of Al, Fe and Mn are higher than the prescribed limits and these could pose a serious health hazard to both adults and children that consume the water. The contamination factors of the selected trace elements range from low contamination in Cd (0) to very high contamination factor in Mn (4802.8). This also depicts the main source of the elements from various anthropogenic activities in the area over the weathering of aluminosilicate minerals in the rock types in the study area. The degree of contamination depicts very high degree of contamination (average = 2348). In adults, the value computed for average daily dose (exposed dose through ingestion) for Al, Ba, Fe, Mn and Zn are > 1 and in children Al, Ba, Cu, Fe, Mn and Zn are likewise greater than unity which is an indication of non-carcinogenic health risk in both adults and children consumers. The computed HQ for adults indicates some traces of values in Al, Ba, Fe and Zn that are greater than unity against the prescribed limit of < 1. Likewise, the HI of some samples are also greater than unity. In children, Al, Fe, Mn and Zn also show some HQ values greater than unity and the average HI computed (2.19) is greater than unity which is an indication of potential health risk in children. The computed values for daily chronic intakes are generally lower than unity for both adults and children. The average carcinogenic risk for both adults and children in Cr and Pb is higher than prescribed limit of 10^{-6} and 10^{-4}.

6. Conclusion and Recommendations

In general, it can be concluded that the floodplain water is not fit for human consumptions due to the influence of various anthropogenic activities (e.g. irrigation practices, application of manure and fertilizers, herbicides, influx of industrial and municipal waste, etc.) in the area. The practice of mechanized farming should be checked and properly monitored because of leaching of agrochemical and manure into the water bodies. There should be regulatory agency to always monitor the usage of fertilizers in the farmlands in the area. Further studies are also recommended to assess the point sources of contaminations in the area.

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