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Assessing Human Health Risks in Asejire Lake: Implications for Water Resources in Industrialized Ibadan, Nigeria

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Abstract: Human health risk assessment of Asejire Lake in densely populated and industrialized Ibadan city has been examined using Average Daily Dose (ADD), Hazard Quotient (HQ), Hazard Index (HI), Chronic daily intake (CDI) and Carcinogenic Risk (CR) calculated from the hydrochemical analysis results of Aluminum, Barium, Chromium, Copper, Iron, Manganese, Nickel, Lead and Zinc. ICP-MS laboratory technique was used from which the results of the selected trace elements were extracted. The average values of Ba, Al, Cr, Fe, Cu, Mn, Pb, Ni and Zn are: 0.08ppm, 0.39ppm, 0.001ppm, 1.41ppm, 0.004ppm, 0.068ppm, 0.004ppm, 0.002ppm and 0.035ppm respectively which are all below prescribed standards except Al and Fe. The average values of TDS, EC and pH are: 51.73ppm, 100µS/cm and 7.4 respectively which show that the water is non-saline but slightly alkaline in nature. The average values of ADD, HQ, and HI for all age groups were generally <1 falling within low chronic risk for HI. However, Values computed for children are close to unity and caution must be taken for children's consumptions both in ingestion and derma absorption. Order of abundance of average CDI is: Fe>Al>Ba>Mn>Zn>Pb>Cu>Ni>Cr respectively. Average CR for Cr and Pb fall within 10^{-6} and 10^{-4} and above respectively and this gives a signal for cancer risk in consumption. Based on WHO background values, there are elevated values of average Contamination Factor (CF) above one for Al (2) and Fe (5) depicting some degrees of contamination in water phase and Degree of Contamination also ranged from 7 to 9 (average, 8) indicating low to moderate degree of contamination. Al and Fe sourced from the various anthropogenic and lithogenic activities contributed significantly to metal loading in the water which are of health significant.

Keywords: Asejire Lake, health risk assessment, contamination indexes, carcinogenic, non-carcinogenic, WHO, NSDWQ, ICP-MS

1. Introduction

It has been documented that more than one million individuals lack access to clean and potable water supply across the globe and out of this number, over 310 million people inhabiting the rural area of sub-Saharan Africa are being adversely affected [1], [2]. Furthermore, urbanization, industrialization and agricultural activities play a major role in the pollution of rivers and other surface water in urban settlements [3], [4], [5], [6], [7]. Several rivers have been dammed and most of these rivers are prone to pollutions due to various anthropogenic and geogenic activities. Some researchers reported that Lake Asejire collects metal loaded waste from the massive industries and urban areas situated in Ibadan City, Nigeria [8], [9], [10]. Urban sediments in Ibadan municipal are seriously contaminated by trace toxic metals which

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eventually runoff as effluent and enters the lake [11], [12], [10]. Hence, there is need for regular water quality assessments of these surface water so that relevant recommendations can be made to various governmental agencies to take adequate measures in controlling and monitoring various activities around the water bodies. Hence, this research aims at assessing the human health risk of Asejire Lake water, using human health risk parameters to reveal the extent of risk in the consumers

2. Study Area

Asejire Lake is an artificial reservoir (Fig. 1), constructed on Osun River, situated in Egbeda Local Government area of Oyo State, Southwest Nigeria. It has been slated that the river does not drain into River Niger but releases its constituents directly into coastal lagoons and creeks bordering the Atlantic Ocean. The Lake lies on 04°07′East and 07°21′North at an altitude of 137 m above sea level, covering a length of about 19.5 km. The lake has several tributaries. Utete and Fregene [10] established that the river was dammed at Asejire in the year 1972 for the supply of potable water to Asejire and Osegere water treatment plants in Ibadan megalopolis and localities. Asejire river catchment in Ibadan has a tropical wet and dry climate with an extensive wet season and a relative constant temperature throughout the year. Wet season commences in May through October while November to April forms the dry season. Asejire catchment falls within an area that receives a mean rainfall of 14.7mm and a mean temperature of 28.3°C [10]. Topographically, the area has a combination of high, low and undulating terrain. The main occupation of the people in the study area is fishing and trading because farming is completely prohibited in the catchment area.

The study area seats on parts of the western basement complex of Nigeria (Fig. 1) which is mainly of metamorphic rocks of Precambrian age with the intrusions of granites and porphyries of Jurrasic age. It constitutes mainly of pegmatites, quartzite, quartz muscovite schist granite gneiss and migmatite gneiss [13].

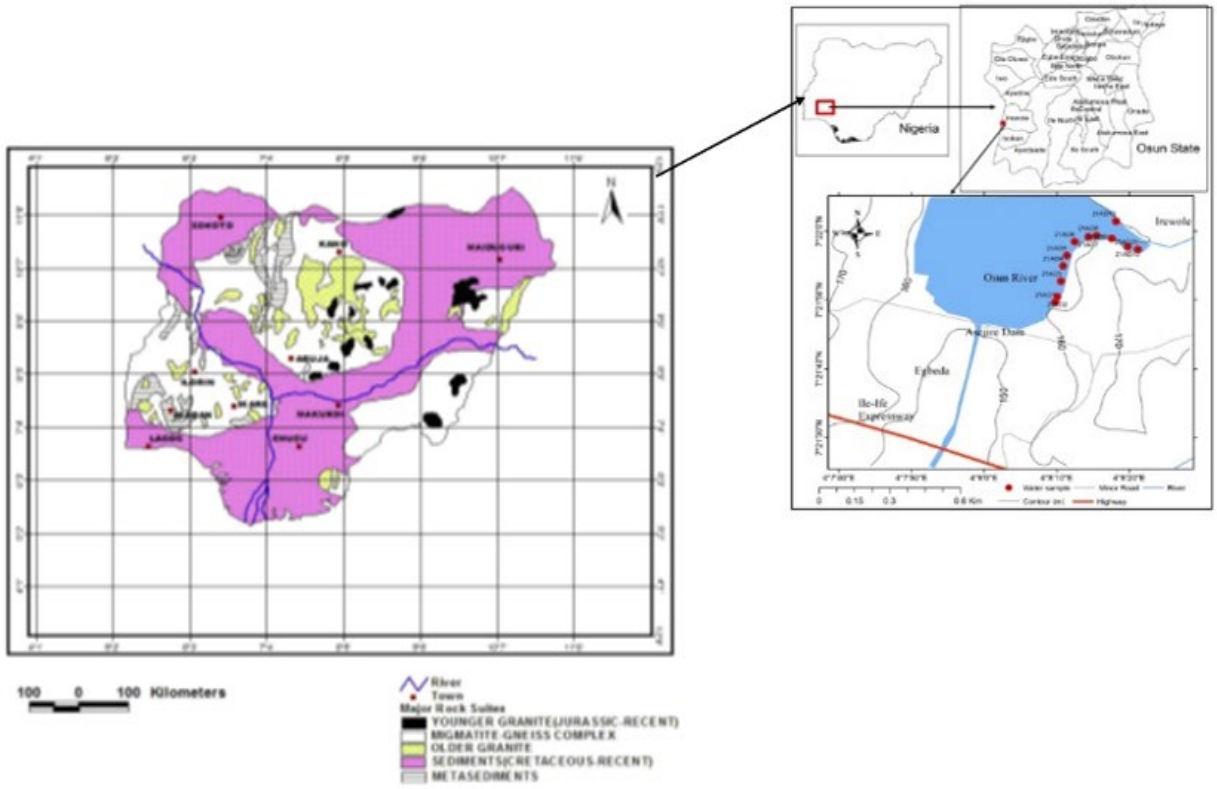

Fig. 1 - Generalized geological map of Nigeria showing the location of the study area and the sampling points [14]

3. Materials and Methods

Some parts of Asejire dam/river were sampled (water sampling) randomly with the aid of GPS as indicated in the sampling points (Fig.1) for the purpose of preliminary investigation of the health risk assessment of the dam/river. 12 water samples were taken. The respective sampled water in the 60ml white bottle containers was acidified by concentrated nitric acid in other to prevent the precipitation of the metals from the solution. Immediately after respective sampling, the bottles were covered tightly to prevent atmospheric interference with the bottled water. The water samples were then shipped to the laboratory (ACME, laboratory, Vancouver, North America, Canada for ICP-MS laboratory technique).

ICP-MS used for the water samples gives detailed hydrochemical results of the major, trace and the rare earth elements which are all together 70 in number (that is, Ag, Al, As, Au, B, Ba, Be, Bi, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Hg, Ho, In, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, Re, Rh, Ru, S, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn and Zr) from which few toxic elements/metals (Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn)were selected for this study. However, detailed results of all the 70 elements were not presented in this work. Also, the reason for this selection was that there were no enough background values in literatures for more toxic elements in this work to calculate their health risk. In addition, physicochemical parameters like TDS, EC and pH were measured insitu using Total Dissolved Solid meter (DiST1 Waterproof TDS tester – 0 – 2000 ppm H198309), Electrical Conductivity meter (Ultra-Pure waterproof tester-0.000 – 1.999µS/cm- H198301) and pH meters respectively. The readings were recorded accordingly. The detection limits of the selected metals after the analysis are: Al (1 ppb), Ba (0.05 ppb), Cr (0.5 ppb), Cu (0.1 ppb), Fe (10ppb), Mn (0.05 ppb), Ni (0.2 ppb), Pb (0.2 ppb) and Zn (0.5 ppb).

3.1 Data Appraisals

The results of the selected metals were compared with WHO [15] and NSDWQ [16] standards for portable water to determine the quality of the water for drinking. The following are the WHO standard for drinking water as applied to the selected metals in this research: Al (0.1 ppm), Ba (0.7 ppm), Cr (0.7 ppm), Cu (2 ppm), Fe (0.1 ppm), Mn (0.07 ppm), Ni (0.07 ppm) and Pb (0.01 ppm). The World Health Organization Standards, Nigerian Standards for Drinking water Quality and the Mean Composition of world river are presented in Table 1. The selected metals were further subjected to metal contamination indexes to ascertain the extent of metal loading in the water. The following parameters were used for this: contamination factor and degree of contamination and they are expressed mathematically as follows:

$$\text{Contamination Factor} \quad (CF) = C_m/B_m \tag{1}$$

$$\text{Degree of Contamination } (C_{deg}) = \sum\left(\frac{Cm}{Bm}\right) \tag{2}$$

where: C_m= concentration of the metal in the sampled water; B_m= the background concentration of the metal in the sampled water [15],[17]. The interpretations of the contamination indexes were presented in Table 2. Furthermore, the data were as well subjected to health risk assessments using the following parameters: hazard quotient (HQ), hazard index (HI), average daily dose (ADD), chronic daily intake (CDI) and Carcinogenic risk (CR) and they were expressed mathematically as follows:

$$\text{Average Daily Dose (ADD), through ingestion} = \frac{\text{Cwater} * \text{IRd} * \text{EF} * \text{ED}}{BW * AT} \tag{3}$$

$$\text{Average Daily Dose } (ADD_{erm}), \text{ through skin absorption} = \frac{Cwater * SA * KP * ET * EF * ED * CF}{BW * AT} \tag{4}$$

ADD is the exposure dose through ingestion of water (µg/kg/day) and ADD_{erm} is the exposure dose through dermal absorption (mg/kg/day); C_{water} is the average concentration of metals in water sampled (µg/L); IRd is the ingestion rate in this project; EF is the exposure frequency; ED is the exposure duration; BW is the average body weight; AT is the averaging time; SA is the exposed skin area; Kp is the dermal permeability coefficient in water, (cm/h), Cu=0.001, Mn=0.001, Fe=0.001; Zn=0.0006; Cr=0.002 and Pb=0.004 (18); ET= exposure time (0.58 h/day for adults; 1 h/day for children) and CF= unit conversion factor which is equals to 0.001 L/cm^3 [19], [20], [21], [6], [22], [23], [24].

$$\text{Hazard Quotient (HQ)} = \frac{ADD}{RfD} \tag{5}$$

R_fD is the reference dose of specific metal. The reference dose for the selected metals are as follows: Al (1), Ba (0.2), Cr (1.5), Cu, (0.04), Fe (0.7), Mn (0.046), Ni (0.02), Pb (0.0035) and Zn (0.3) all in mg/kg/day respectively [25]. If the value of HQ is greater than unity, that is, 1, there is possibility of non-carcinogenic health risk, while HQ value less than 1 implies that the exposure to the water consumption would not likely have any practical effect on the consumers [25], [26], [27], [28].

$$\text{Hazard Index (HI)} = \sum (HI) \tag{6}$$

HI > 1 is an indication of a potential health risk on man [29], [18]

$$\text{Chronic daily intake (CDI)} = Cwater\frac{DI}{BW} \tag{7}$$

where C_{water}, DI and BW denote the concentration of metal in water in (mg/kg), average daily intake of water or the ingestion rate in this project (2.2 L/day for adults; 1.8 L/day for children) and body weight (70 kg for adults; 15 kg for children), respectively.

$$\text{Carcinogenic risk (CR)} = \frac{ADD}{SFing} \quad (8)$$

where, CR = carcinogenic risk via ingestion route and SF_{ing} = carcinogenic slope factor, where Pb is 8.5E and Cr is 5.0E+02 µg/kg/day [30],[18], [23], [7], [24]. The carcinogenic risks were not calculated for other metals because of unavailability of their values for SF_{ing} in literature. The interpretations of contamination indexes and health risk assessments parameters values for this research are presented in Table 2.

Table 1 - The standards adopted for water quality assessment in this research [15], [16], and background values for contamination indexes [15], [31]

Metals	WHO Standard(ppm), 2006	Mean Composition of world rivers in ppm (Viers *et al* ., 2009)	NSDWQ (ppm), 2007
Al	0.2	0.32	0.2
Ba	0.3	0.023	0.7
Cr	0.05	0.0007	0.05
Cu	2	0.00148	1
FE	0.3	0.066	0.3
Mn	0.5	0.00042	0.2
Ni	0.02	0.0008	0.001
Pb	0.01	0.00008	0.01
Zn	-	-	-

Table 2 - Interpretations of contamination indexes and health risk assessments parameters values for this research

Contamination Indexes Parameters and Interpretations (Atiemo *et al* ., 2011)	
CF (Contamination Factor)	
<1	low contamination factor
1 to 3	moderate contamination factor
3 to 6	considerable contamination factor
6>	very high contamination factor
Degree of Contamination	
<8	low degree of contamination
8 to 16	moderate degree of contamination
16 to 32	considerable degree of contamination
>32	very high degree of contamination
Health Risk Assessment Parameters (Edokpayi *et al* ., 2018)	
IRd (male adult)	2.72 L
IRd (female adult)	2.13L
IRd (children)	1.8L
EF	365days/year
ED (adult)	10 years
ED (children)	10 years
BW (male adult)	72 kg
BW (female adult)	68 kg
BW(children)	15 kg
AT (adult)	70*365
AT (children)	10*365
SA (adult)	5700cm^2
SA (children)	2800cm^2

Table 3 - The classification of non-carcinogenic health risk in human [19]

Risk Level	Hazard Index (HI)	Chronic Risk
1	<0.1	Negligible
2	≥0.1≤1	Low
3	≥ 1 > 4	Medium
4	≤ 4	High

4. Results and Discussions

4.1 Hydrochemistry

The hydrochemistry of Asejire river water was described in this research based on some physicochemical parameters (such as: TDS, EC and pH) and concentrations of selected trace metals. Table 4 and Fig. 2 illustrate further the descriptive summary and the average profiles of the analyzed water sample data. The results measured and recorded for TDS and pH ranged from 50 to 54 mg/l (average, 51.75) and 7.30 to 7.50 (average, 7.43) respectively. The results measured for EC is constant with the value 100 ppm. This showed that the water is fresh and slightly alkaline in nature, as indicated by TDS, Ec and pH respectively.

Basically, the following metals were extracted for this research: Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn. The results of the water analysis showed that Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn ranged from 0.359 to 0.434 ppm (mean, 0.395 pm), 0.071 to 0.082 ppm (mean,0.076 ppm), 0.0013 to 0.0018 ppm (mean, 0.0015 ppm), 0.0025 to 0.0078 ppm (mean, 0.00366 ppm), 1.278 to 1.574 ppm (mean, 1.41 ppm), 0.0575 to 0.091 ppm (mean, 0.068 ppm), 0.0015 to 0.0023 ppm (mean, 0.00178 ppm), 0.0016 to 0.0083 ppm (mean, 0.0039 ppm) and 0.0063 to 0.129 ppm (mean, 0.035 ppm) respectively. Comparing the average results of the metals with WHO 2006 and NSDWQ 2007, it was discovered that all the metals were below prescribed standard except Al and Fe that have higher mean values above 0.2 and 0.3 ppm respectively (Figure 2).

The higher values of Fe in the samples also reflected in the values of contamination factor calculated for it. (average = 21.3- very high contamination factor or metal loading with respect to MCWR as background value and average of 4.69 using WHO as background value). It has been reported that excess iron in portable water and food materials constitute serious health hazard to the consumers. Consumption of water with high concentration results in gene mutation which could lead to a disease called haemochromatosis. The sign includes fatigue, joint pains, weight loss, liver problems, heart disease and diabetes [32]. Excess iron in water further causes serious allergic reactions like rash and itching, breathing difficulties, tightness in chest, swelling of the mouth, lips and face and severe vomiting or stomach pain [32]. Moreover, diabetes, darkening of the skin, abnormal heart rhythm or arthritis can also be as a result of excessive intake of Al [33]. The sources of elevated Fe concentrations are suggested to be from Coca Cola Bottling Industry situated close to the dam, aquacultural activities, agricultural industries and domestic settlements around the dam site [10].

Aluminum has average concentration value higher than the recommended value of WHO and NSDWQ (0.2 ppm). The contamination factor also is high (average contamination factor= 1.23 using MCWR and 1.97 adopting WHO standard as background value for computation). Based on the mean value of the contamination factor, the source of contamination is mainly anthropogenic [34]. This supports contributions from industrial, domestic and agricultural wastes. Although, it has been reported that Al is non-toxic, however, if large quantities of aluminum is administered orally, it can lead to irritation of the gastrointestinal tract and further lead to other health related problems as a result of high ingestion [35]. Excess Al can further lead to muscle weakness, seizures, brain disorders, lung problems and slow growth in children [33].

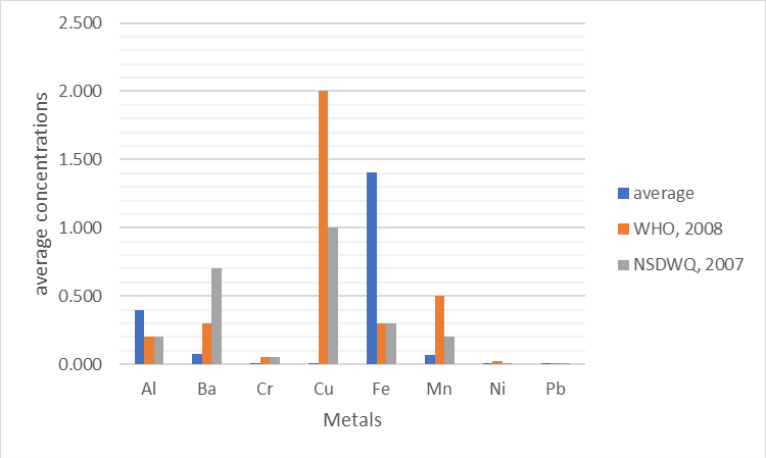

Fig. 2 - Trace elements profile in Asejire River water compared with WHO and NSDWQ [15], [16]

Table 4 - The hydrochemical, physicochemical parameters results and their descriptive summary in Asejire River water

Chemical Parameters			Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	TDS	EC	pH
Unit			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	mg/L	µS/cm	-
MDL			0.001	0.00005	0.0005	0.0001	0.01	0.00005	0.0002	0.0002	0.0005			
Sample ID	Coordinates													
21AD01	4°8′0.98″E	7°21′49.7″N	0.423	0.08123	0.0016	0.003	1.51	0.06169	0.0018	0.0028	0.0407	50	100	7.4
21AD02	4°8′10.1″E	7°21′50.5″N	0.425	0.07803	0.0016	0.0078	1.382	0.05753	0.0018	0.0054	0.0295	52	100	7.5
21AD03	4°8′10.6″E	7°21′52.8″N	0.434	0.07851	0.0018	0.0059	1.491	0.05934	0.0023	0.0075	0.1287	51	100	7.4
21AD04	4°8′10.9″E	7°21′55″N	0.423	0.07629	0.0016	0.0032	1.574	0.06524	0.0019	0.0045	0.0379	51	100	7.5
21AD05	4°8′11.4″E	7°21′56.5″N	0.359	0.08156	0.0013	0.0032	1.436	0.06884	0.0018	0.004	0.0316	51	100	7.5
21AD06	4°8′12.5″E	7°21′58.5″N	0.389	0.07602	0.0014	0.0027	1.376	0.06045	0.0017	0.002	0.0116	51	100	7.3
21AD07	4°8′14.4″E	7°21′59.2″N	0.382	0.07585	0.0013	0.0032	1.338	0.05812	0.0016	0.003	0.0126	53	100	7.4
21AD08	4°8′15.5″E	7°21′59.4″N	0.38	0.07698	0.0014	0.0039	1.363	0.06748	0.002	0.0083	0.0378	52	100	7.5
21AD09	4°8′17.6″E	7°21′59″N	0.372	0.07107	0.0015	0.0027	1.297	0.0765	0.0017	0.0026	0.0197	53	100	7.5
21A10	4°8′19.8″E	7°21′57.8″N	0.385	0.07421	0.0015	0.003	1.306	0.0862	0.0016	0.003	0.0557	52	100	7.5
21AD11	4°8′21.2″E	7°21′57.4″N	0.401	0.07429	0.0016	0.0028	1.516	0.09128	0.0017	0.0023	0.0082	54	100	7.3
21AD12	4°8′18.2″E	7°22′01.5″N	0.364	0.07203	0.0013	0.0025	1.278	0.06602	0.0015	0.0016	0.0063	51	100	7.4
average			0.39475	0.076339	0.001492	0.003658	1.405583	0.068224	0.001783	0.003917	0.035025	51.75	100	7.4
minimum			0.359	0.07107	0.0013	0.0025	1.278	0.05753	0.0015	0.0016	0.0063	50	100	7.3
maximum			0.434	0.08156	0.0018	0.0078	1.574	0.09128	0.0023	0.0083	0.1287	54	100	7.5
median			0.387	0.076155	0.0015	0.0031	1.379	0.06563	0.00175	0.003	0.03055	51.5	100	7.5
mode			0.423	-	0.0016	0.0032	-	-	0.0018	0.003	-	51	100	7.5
stdev			0.025832	0.003227	0.000156	0.001585	0.097922	0.011022	0.000212	0.002151	0.033199	1.13818	0	0.1
variance			0.000667	1.04E-05	2.45E-08	2.51E-06	0.009589	0.000121	4.52E-08	4.63E-06	0.001102	1.295455	0	0.01
WHO, 2006			0.200	0.300	0.050	2.000	0.300	0.500	0.020	0.010	-	-	-	-
NSDWQ, 2007			0.200	0.700	0.050	1.000	0.300	0.200	0.001	0.010	-	-	-	-

4.2 Contamination Indexes

The statistical summary and profiles of the contamination indexes were provided in Tables 5 to 6 and Figures 3 to 5. Using background values of Mean Composition of World River (MCWR), the results revealed that the Contamination Factor (CF) for Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn ranged from 1.12 to 1.36 (mean, 1.23), 3.09 to 3.55 (mean, 3.32), 1.86 to 2.57 (mean, 2.13), 1.69 to 5.27 (mean, 2.47), 19.36 to 23.85 (mean, 21.30), 136.98 to 217.33 (mean, 162.44), 1.88 to 2.88 (mean, 2.23), 20.00 to 103.75 (mean, 48.96) and 10.50 to 214.50 (mean, 58.38) respectively. This is an indication that the water has moderate contamination factor to very high contamination Factor [36], [37]. The Degree of Contamination (degC) ranged from 217 to 486 (mean, 302) which is an indication of very high degree of contamination (36, 37). The profile indicated that the water is heavily loaded with metals as also seen in the computed data.

Using WHO standard for drinking water quality as background values, the Contamination Factors and Degree of Contamination were also computed. The contamination factors ranged from 0.01 in copper to 5.25 in Iron. From the profile we could observe the elevated figure of Al and Fe over the rest of the metals. The Degree of Contamination ranged from 7 to 9 with an average of 8. This is an indication that the metal loading in the water with respect to research elements ranged from low degree of contamination to moderate degree of contamination.

Table 5 - Contamination Indexes of the sampled water in Asejire River, SW Nigeria using MCWR as background values

Elements, ppm	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	
MCWR, ppm	0.32	0.023	0.0007	0.00148	0.066	0.00042	0.0008	0.00008	
Sample ID	Contamination Factor								Degree of Contamination
21AD01	1.32	3.53	2.29	2.03	22.88	146.88	2.25	35.00	284
21AD02	1.33	3.39	2.29	5.27	20.94	136.98	2.25	67.50	289
21AD03	1.36	3.41	2.57	3.99	22.59	141.29	2.88	93.75	486
21AD04	1.32	3.32	2.29	2.16	23.85	155.33	2.38	56.25	310
21AD05	1.12	3.55	1.86	2.16	21.76	163.90	2.25	50.00	299
21AD06	1.22	3.31	2.00	1.82	20.85	143.93	2.13	25.00	220
21AD07	1.19	3.30	1.86	2.16	20.27	138.38	2.00	37.50	228
21AD08	1.19	3.35	2.00	2.64	20.65	160.67	2.50	103.75	360
21AD09	1.16	3.09	2.14	1.82	19.65	182.14	2.13	32.50	277
21A10	1.20	3.23	2.14	2.03	19.79	205.24	2.00	37.50	366
21AD11	1.25	3.23	2.29	1.89	22.97	217.33	2.13	28.75	294
21AD12	1.14	3.13	1.86	1.69	19.36	157.19	1.88	20.00	217
average	1.23	3.32	2.13	2.47	21.30	162.44	2.23	48.96	302
min.	1.12	3.09	1.86	1.69	19.36	136.98	1.88	20.00	217
max.	1.36	3.55	2.57	5.27	23.85	217.33	2.88	103.75	486
stdev.	0.08	0.14	0.22	1.07	1.48	26.24	0.27	26.89	75
var.	0.01	0.02	0.05	1.15	2.20	688.73	0.07	723.25	5657
med.	1.21	3.31	2.14	2.09	20.89	156.26	2.19	37.50	291

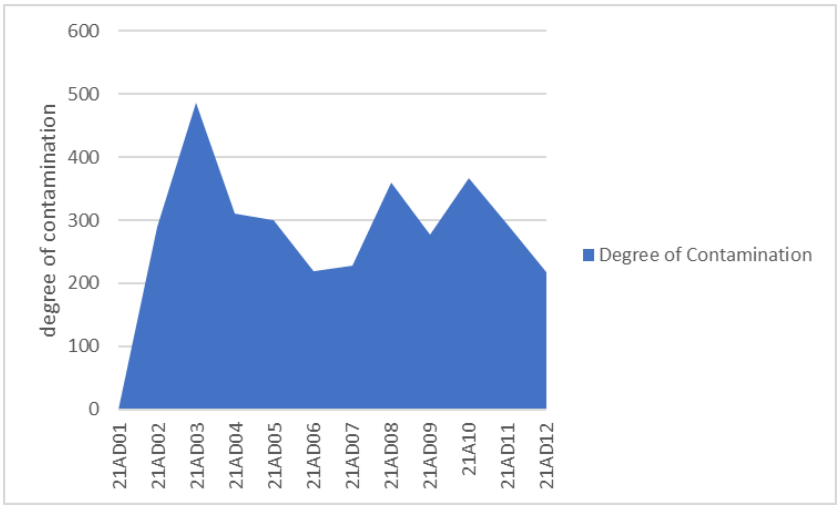

Fig. 3 - Contamination factor profile in Asejire River water

Table 6 - Contamination Indexes of the sampled water in Asejire River, SW Nigeria using WHO as background values

Elements, ppm	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	
WHO, ppm	0.2	0.3	0.05	2	0.3	0.5	0.02	0.01	
Sample ID	Contamination Factor								Degree of Contamination
21AD01	2.12	0.27	0.06	0.01	5.03	0.12	0.09	0.28	8
21AD02	2.13	0.26	0.16	0.03	4.61	0.12	0.09	0.54	8
21AD03	2.17	0.26	0.12	0.02	4.97	0.12	0.12	0.75	9
21AD04	2.12	0.25	0.06	0.01	5.25	0.13	0.10	0.45	8
21AD05	1.80	0.27	0.06	0.01	4.79	0.14	0.09	0.40	8
21AD06	1.95	0.25	0.05	0.01	4.59	0.12	0.09	0.20	7
21AD07	1.91	0.25	0.06	0.01	4.46	0.12	0.08	0.30	7
21AD08	1.90	0.26	0.08	0.01	4.54	0.13	0.10	0.83	8
21AD09	1.86	0.24	0.05	0.01	4.32	0.15	0.09	0.26	7
21A10	1.93	0.25	0.06	0.01	4.35	0.17	0.08	0.30	7
21AD11	2.01	0.25	0.06	0.01	5.05	0.18	0.09	0.23	8
21AD12	1.82	0.24	0.05	0.01	4.26	0.13	0.08	0.16	7
average	1.97	0.25	0.07	0.01	4.69	0.14	0.09	0.39	8
min.	1.80	0.24	0.05	0.01	4.26	0.12	0.08	0.16	7
max.	2.17	0.27	0.16	0.03	5.25	0.18	0.12	0.83	9
stdev.	0.13	0.01	0.03	0.01	0.33	0.02	0.01	0.22	1
var.	0.02	0.00	0.00	0.00	0.11	0.00	0.00	0.05	0
med.	1.94	0.25	0.06	0.01	4.60	0.13	0.09	0.30	8

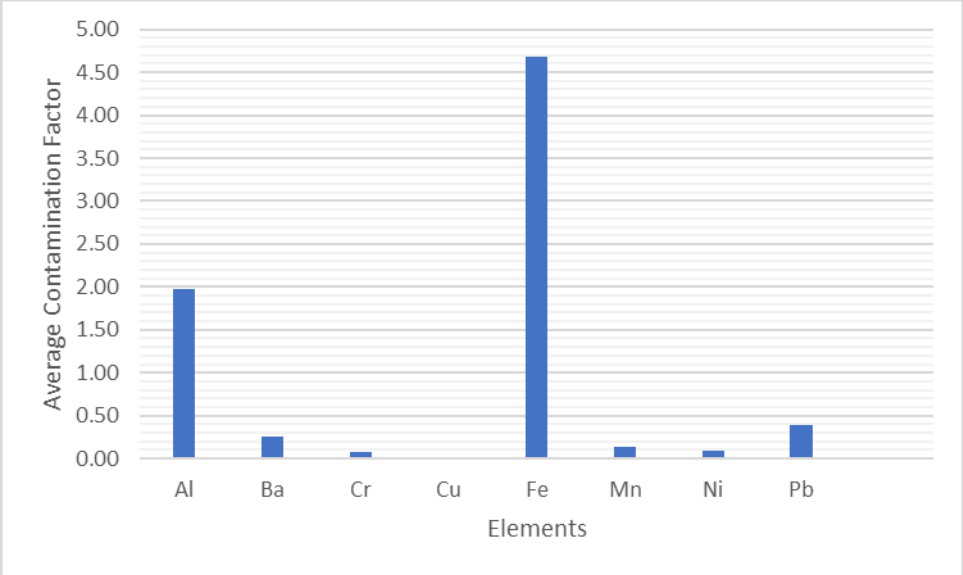

Fig. 4 - Profile of mean contamination factor of elements in Asejire Lake using WHO as background values

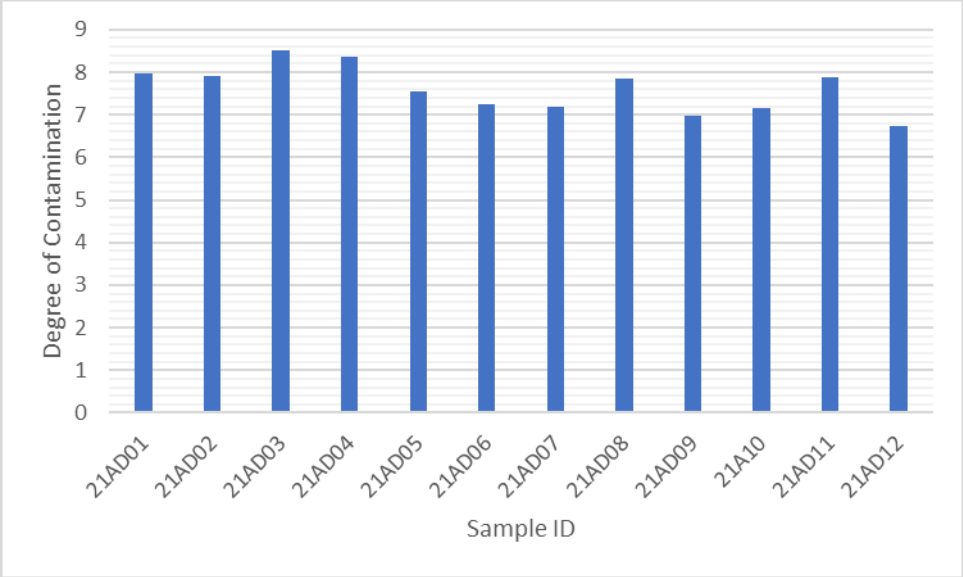

Fig. 5 - Profile of degree of contamination using WHO as background values

4.3 Assessment of Human Health Risk of Asejire Lake Water

4.3.1 Average Daily Dose for Male Adults (ADD)

The average daily dose for male adults is illustrated tabularly in Table 7. Statistically, ADD for male adults ranged from 13.56 to 16.40 µg kg^{-1} day^{-1} (average, 14.91 µg kg^{-1} day^{-1}), 2.68 to 3.08 µg kg^{-1} day^{-1} (average, 2.88 µg kg^{-1} day^{-1}), 0.05 to 0.07 µg kg^{-1} day^{-1} (average, 0,06 µg kg^{-1} day^{-1}), 0.09 to 0.29 µg kg^{-1} day^{-1} (average, 0.14 µg kg^{-1} day^{-1}), 48.28 to 59.46 µg kg^{-1} day^{-1} (average, 53.10 µg kg^{-1} day^{-1}), 2.17 to 3.45 µg kg^{-1} day^{-1} (average, 2.58 µg kg^{-1} day^{-1}), 0.06 to 0.09 µg kg^{-1} day^{-1} (average, 0.07 µg kg^{-1} day^{-1}), 0.06 to 0.31 µg kg^{-1} day^{-1} (average, 0.15 µg kg^{-1} day^{-1}) and 0.24 to 4.86 µg kg^{-1} day^{-1} (average, 1.32 µg kg^{-1} day^{-1}) in Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn respectively. Based on the mean values obtained, Cr, Cu, Ni and Pb have values less than unity while others have values greater than one. The high figures recorded for Al, Ba, Fe, Mn and Zn are as a result of contributions from various anthropogenic (municipal waste disposal system, leachates infiltrations and contributions probably from Nigerian Bottling Company) and geogenic (weathering of rock types in the study area) activities in the area [7].

Table 7 - Descriptive average daily dose (µg kg^{-1} day^{-1}) of water resources in Asejire River water for male adults via ingestion

Sample ID	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn
21AD01	15.98	3.07	0.06	0.11	57.04	2.33	0.07	0.11	1.54
21AD02	16.06	2.95	0.06	0.29	52.21	2.17	0.07	0.20	1.11
21AD03	16.40	2.97	0.07	0.22	56.33	2.24	0.09	0.28	4.86
21AD04	15.98	2.88	0.06	0.12	59.46	2.46	0.07	0.17	1.43
21AD05	13.56	3.08	0.05	0.12	54.25	2.60	0.07	0.15	1.19
21AD06	14.70	2.87	0.05	0.10	51.98	2.28	0.06	0.08	0.44
21AD07	14.43	2.87	0.05	0.12	50.55	2.20	0.06	0.11	0.48
21AD08	14.36	2.91	0.05	0.15	51.49	2.55	0.08	0.31	1.43
21AD09	14.05	2.68	0.06	0.10	49.00	2.89	0.06	0.10	0.74
21A10	14.54	2.80	0.06	0.11	49.34	3.26	0.06	0.11	2.10
21AD11	15.15	2.81	0.06	0.11	57.27	3.45	0.06	0.09	0.31
21AD12	13.75	2.72	0.05	0.09	48.28	2.49	0.06	0.06	0.24
average	14.91	2.88	0.06	0.14	53.10	2.58	0.07	0.15	1.32
min	13.56	2.68	0.05	0.09	48.28	2.17	0.06	0.06	0.24
max	16.40	3.08	0.07	0.29	59.46	3.45	0.09	0.31	4.86
stdev	0.98	0.12	0.01	0.06	3.70	0.42	0.01	0.08	1.25
var	0.95	0.01	0.00	0.00	13.68	0.17	0.00	0.01	1.57
med	14.62	2.88	0.06	0.12	52.10	2.48	0.07	0.11	1.15

4.3.2 Average Daily Dose for Female Adults (ADD)

The average daily dose for female adults is illustrated tabularly in Table 8. Statistically, ADD for female adults also ranged from 11.25 to 13.59 µg kg^{-1} day^{-1} (mean, 12.36 µg kg^{-1} day^{-1}), 2.23 to 2.55 µg kg^{-1} day^{-1} (mean, 2.39 µg kg^{-1} day^{-1}), 0.04 to 0.06 µg kg^{-1} day^{-1} (mean, 0.05 µg kg^{-1} day^{-1}), 0.08 to 0.24 µg kg^{-1} day^{-1} (mean, 0.11 µg kg^{-1} day^{-1}), 40.03 to 49.30 µg kg^{-1} day^{-1} (mean, 44,03 µg kg^{-1} day^{-1}), 1.80 to 2.86 µg kg^{-1} day^{-1} (mean, 2.14 µg kg^{-1} day^{-1}), 0.05 to 0.07 µg kg^{-1} day^{-1} (mean, 0.06 µg kg^{-1} day^{-1}), 0.05 to 0.26 µg kg^{-1} day^{-1} (mean, 0.12 µg kg^{-1} day^{-1}) and 0.20 to 4.03 µg kg^{-1} day^{-1} (mean, 1.10 µg kg^{-1} day^{-1}) in Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn respectively. Based on the mean values computed, it was discovered that the average values of Cr, Cu, Ni, and Pb were generally less than one while others have values of more than one.

Table 8 - Descriptive average daily dose (µg kg-1 day1) of water resources in Asejire River water for female adults via ingestion (ADD)

Sample ID	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn
21AD01	13.25	2.54	0.05	0.09	47.30	1.93	0.06	0.09	1.27
21AD02	13.31	2.44	0.05	0.24	43.29	1.80	0.06	0.17	0.92
21AD03	13.59	2.46	0.06	0.18	46.70	1.86	0.07	0.23	4.03
21AD04	13.25	2.39	0.05	0.10	49.30	2.04	0.06	0.14	1.19
21AD05	11.25	2.55	0.04	0.10	44.98	2.16	0.06	0.13	0.99
21AD06	12.18	2.38	0.04	0.08	43.10	1.89	0.05	0.06	0.36
21AD07	11.97	2.38	0.04	0.10	41.91	1.82	0.05	0.09	0.39
21AD08	11.90	2.41	0.04	0.12	42.69	2.11	0.06	0.26	1.18
21AD09	11.65	2.23	0.05	0.08	40.63	2.40	0.05	0.08	0.62
21A10	12.06	2.32	0.05	0.09	40.91	2.70	0.05	0.09	1.74
21AD11	12.56	2.33	0.05	0.09	47.49	2.86	0.05	0.07	0.26
21AD12	11.40	2.26	0.04	0.08	40.03	2.07	0.05	0.05	0.20
average	12.36	2.39	0.05	0.11	44.03	2.14	0.06	0.12	1.10
min	11.25	2.23	0.04	0.08	40.03	1.80	0.05	0.05	0.20
max	13.59	2.55	0.06	0.24	49.30	2.86	0.07	0.26	4.03
stdev	0.81	0.10	0.00	0.05	3.07	0.35	0.01	0.07	1.04
var	0.65	0.01	0.00	0.00	9.41	0.12	0.00	0.00	1.08
med	12.12	2.39	0.05	0.10	43.20	2.06	0.05	0.09	0.96

4.3.3 Average Daily Dose for Children (ADD)

The ADD for children is recorded in Table 9 This ranged from 29.37 to 35.51 µg kg^{-1} day^{-1} (mean, 32.3 µg kg^{-1} day^{-1}), 5.81 to 6.67 µg kg^{-1} day^{-1} (mean,, 6.25 µg kg^{-1} day^{-1}), 0.16 to 0.22 µg kg^{-1} day^{-1} (mean, 0.18 µg kg^{-1} day^{-1}), 0.20 to 0.64 µg kg^{-1} day^{-1} (mean, 0.30 µg kg^{-1} day^{-1}), 104.56 to 128.78 µg kg^{-1} day^{-1} (mean, 115 µg kg^{-1} day^{-1}), 4.71 to 7.47 µg kg^{-1} day^{-1} (mean,5,58 µg kg^{-1} day^{-1}), 0.12 to 0.19 µg kg^{-1} day^{-1} (mean, 0.15 µg kg^{-1} day^{-1}), 0.19 to 1.00 µg kg^{-1} day^{-1} (mean, 0.47 µg kg^{-1} day^{-1}) and 0 52 to 10.53 µg kg^{-1} day^{-1} (mean, 2.87 µg kg^{-1} day^{-1}) in Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn respectively. Cr, Cu and Ni have values less than unity while other trace elements have values higher than unity.

Table 9 - Descriptive average daily dose (µg kg^{-1} day^{-1}) of water resources in Asejire River water for children via ingestion (ADD)

Sample ID	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn
21AD01	34.61	6.65	0.19	0.25	123.55	5.05	0.15	0.34	3.33
21AD02	34.77	6.38	0.19	0.64	113.07	4.71	0.15	0.65	2.41
21AD03	35.51	6.42	0.22	0.48	121.99	4.86	0.19	0.90	10.53
21AD04	34.61	6.24	0.19	0.26	128.78	5.34	0.16	0.54	3.10
21AD05	29.37	6.67	0.16	0.26	117.49	5.63	0.15	0.48	2.59
21AD06	31.83	6.22	0.17	0.22	112.58	4.95	0.14	0.24	0.95
21AD07	31.25	6.21	0.16	0.26	109.47	4.76	0.13	0.36	1.03
21AD08	31.09	6.30	0.17	0.32	111.52	5.52	0.16	1.00	3.09
21AD09	30.44	5.81	0.18	0.22	106.12	6.26	0.14	0.31	1.61
21AD10	31.50	6.07	0.18	0.25	106.85	7.05	0.13	0.36	4.56
21AD11	32.81	6.08	0.19	0.23	124.04	7.47	0.14	0.28	0.67
21AD12	29.78	5.89	0.16	0.20	104.56	5.40	0.12	0.19	0.52
average	**32.30**	**6.25**	**0.18**	**0.30**	**115.00**	**5.58**	**0.15**	**0.47**	**2.87**
min	29.37	5.81	0.16	0.20	104.56	4.71	0.12	0.19	0.52
max	35.51	6.67	0.22	0.64	128.78	7.47	0.19	1.00	10.53
stdev	2.11	0.26	0.02	0.13	8.01	0.90	0.02	0.26	2.72
var	4.47	0.07	0.00	0.02	64.19	0.81	0.00	0.07	7.38
med	31.66	6.23	0.18	0.25	112.83	5.37	0.14	0.36	2.50

The average daily dose profiles for all the age groups via ingestion are presented in Fig.6. It can be observed the values of Fe and Al are higher than other elements. This indicates the influx of anthropogenic and geogenic contributions into the Lake via leaching and weathering respectively.

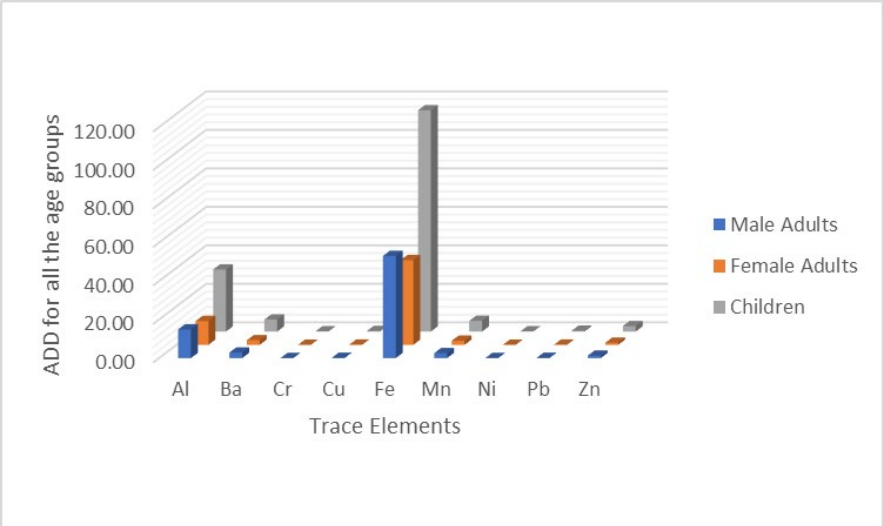

Fig. 6 - Average daily dose profile for all the age groups via ingestion

4.4 Average Daily Dose through Dermal Absorption

The exposure dose through dermal absorption for adults and children are presented in Table 10 and the profiles are presented in Fig. 7. For adults, it has mean values of 0.0004, 0.0005, 0.21, 0.01, 0.002, and 0.003 in Cr, Cu, Fe, Mn, b and Zn respectively. The mean values for children are 0.0013, 0.0061, 0.618, 0.03, 0.0069 and 0.0093 respectively. The values are generally lower than one (< 1). From the profile it can be observed that the average mean calculated for Iron is the highest compared to other metals in all the age groups followed by Mn. The other of increase of the average values in all age groups is as follows: Fe>Mn>Zn>Pb>Cu>Cr.

Table 10 - Descriptive average daily dose (mg kg^{-1} day $-^{1}$) of water resources in Asejire River water for adults and children via dermal ingestion

Trace metals	Cr	Cu	Fe	Mn	Pb	Zn
average for adults	0.0004	0.0005	0.2096	0.0102	0.0023	0.0031
average for children	0.0013	0.0016	0.6185	0.0300	0.0069	0.0092

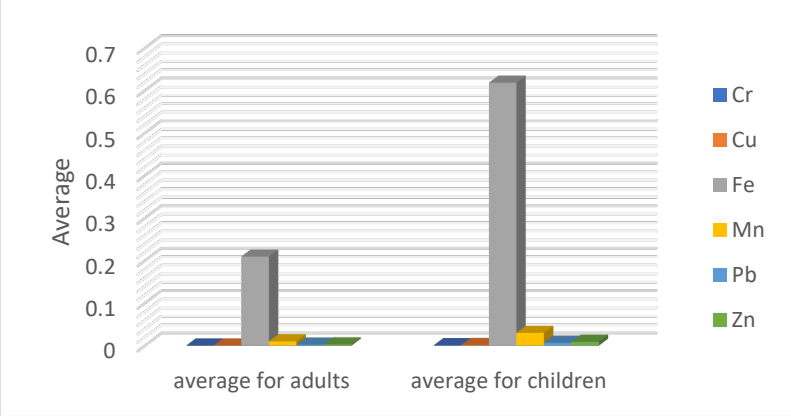

Fig. 7 - Profile of average daily dose for all the age groups via dermal ingestion

4.4.1 Hazard Quotient (HQ)

The hazard quotient which can be explained as the arithmetical estimate of the systemic toxicity potential caused by a single element within a single rout of exposure was computed. The statistical summaries of the calculated hazard quotients and hazard indexes for male adults, female adults and children are presented in Tables 11 to 13. Value of HQ >1 is considered as a potential health risk for human consumption and value < is recommended as safe for human consumption in water [19], [6], [7].

4.4.1.1 The Hazard Quotient (HQ) for Male Adults

The HQ for male adults is included in Table 11, where the statistical summary of the HQ is presented. The mean value for Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn is: 0.015, 0.014, 00004, 0.003, 0.076, 0.056, 0.003 and 0.042 respectively. The values are generally less than unity. The order of enrichment of the trace elements is: Fe>Mn>Pb>Al>Ba>Zn>Cu>Ni>Cr.

4.4.1.2 The Hazard Quotient (HQ) for Female Adults

The HQ for female adults is included in Table 12, where the statistical summary of the HQ is presented. The mean value for Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn is:0.0124, 0.012, 0.000031, 0.0029, 0.063, 0.046, 0.0028, 0.035 and 0.0037 respectively. The other of relative abundance with respect to HQ is similar to the hazard quotient of male adult.

4.4.1.3 The Hazard Quotient (HQ) for Children:

The mean value for HQ in children is 0.0323, 0.0312, 0.00012, 0.0075, 0.164, 0.121, 0.0073, 0.134 and 0.0096 for Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn respectively with corresponding median values of 0.032, 0.031, 0.00012, 0.00634, 0.161, 0.117, 0.0072, 0.103 and 0.00833 respectively. All the values are generally lower than unity.

4.4.2 The Hazard Index (HI):

The HI for male adults ranged from 0.17 in location 21AD12 and 0.27 in location 21AD03 (mean=0.215; standard deviation, 0.029). In female adults, the value ranged from 0.144 to 0 0.222 in locations 21AD12 and 21AD03 respectively with a mean and standard deviation values of 0.18 and 0.024 respectively. The average values for male and female adults falls within the range of low chronic risk. In children, the mean, standard deviation and range are: 0.51, 0.084 and 0.39 to 0.66 respectively. In fig. 8, it can be observed from the profile that there is a potential hazard most especially for children consuming this water resources and adequate measure must be put in place to suppress the escalation of the values for a long period of time.

Table 11 - Descriptive statistics of hazard quotient and hazard index in the male adults via ingestion

Trace Elements	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn		HI, Male
21AD01	0.01598	0.01534	0.00004	0.00283	0.08149	0.05066	0.00340	0.03022	0.00513	**21AD01**	0.20510
21AD02	0.01606	0.01474	0.00004	0.00737	0.07458	0.04725	0.00340	0.05829	0.00371	**21AD02**	0.22543
21AD03	0.01640	0.01483	0.00005	0.00557	0.08047	0.04873	0.00434	0.08095	0.01621	**21AD03**	0.26755
21AD04	0.01598	0.01441	0.00004	0.00302	0.08495	0.05358	0.00359	0.04857	0.00477	**21AD04**	0.22891
21AD05	0.01356	0.01541	0.00003	0.00302	0.07750	0.05654	0.00340	0.04317	0.00398	**21AD05**	0.21661
21AD06	0.01470	0.01436	0.00004	0.00255	0.07426	0.04964	0.00321	0.02159	0.00146	**21AD06**	0.18180
21AD07	0.01443	0.01433	0.00003	0.00302	0.07221	0.04773	0.00302	0.03238	0.00159	**21AD07**	0.18874
21AD08	0.01436	0.01454	0.00004	0.00368	0.07356	0.05542	0.00378	0.08959	0.00476	**21AD08**	0.25972
21AD09	0.01405	0.01342	0.00004	0.00255	0.07000	0.06283	0.00321	0.02806	0.00248	**21AD09**	0.19664
21A10	0.01454	0.01402	0.00004	0.00283	0.07048	0.07079	0.00302	0.03238	0.00701	**21A10**	0.21513
21AD11	0.01515	0.01403	0.00004	0.00264	0.08182	0.07496	0.00321	0.02483	0.00103	**21AD11**	0.21772
21AD12	0.01375	0.01361	0.00003	0.00236	0.06897	0.05422	0.00283	0.01727	0.00079	**21AD12**	0.17384
average	0.01491	0.01442	0.00004	0.00346	0.07586	0.05603	0.00337	0.04228	0.00441	**average**	0.21477
min	0.01356	0.01342	0.00003	0.00236	0.06897	0.04725	0.00283	0.01727	0.00079	**min**	0.17384
max	0.01640	0.01541	0.00005	0.00737	0.08495	0.07496	0.00434	0.08959	0.01621	**max**	0.26755
stdev	0.00098	0.00061	0.00000	0.00150	0.00528	0.00905	0.00040	0.02322	0.00418	**stdev**	0.02859
var	0.00000	0.00000	0.00000	0.00000	0.00003	0.00008	0.00000	0.00054	0.00002	**var**	0.00082
med	0.01462	0.01438	0.00004	0.00293	0.07442	0.05390	0.00331	0.03238	0.00385	**med**	0.21587

Table 12 - Descriptive statistics of hazard quotient and hazard index in the female adults via ingestion

Sample ID	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn		HI, Female
21AD01	0.013250	0.012722	0.000033	0.002349	0.067569	0.042008	0.002819	0.025059	0.004250	**21AD01**	0.17
21AD02	0.013313	0.012221	0.000033	0.006108	0.061842	0.039175	0.002819	0.048328	0.003080	**21AD02**	0.19
21AD03	0.013594	0.012296	0.000038	0.004620	0.066719	0.040407	0.003602	0.067122	0.013438	**21AD03**	0.22
21AD04	0.013250	0.011948	0.000033	0.002506	0.070433	0.044425	0.002976	0.040273	0.003957	**21AD04**	0.19
21AD05	0.011245	0.012774	0.000027	0.002506	0.064258	0.046876	0.002819	0.035798	0.003299	**21AD05**	0.18
21AD06	0.012185	0.011906	0.000029	0.002114	0.061573	0.041163	0.002663	0.017899	0.001211	**21AD06**	0.15
21AD07	0.011966	0.011879	0.000027	0.002506	0.059873	0.039577	0.002506	0.026849	0.001316	**21AD07**	0.16
21AD08	0.011903	0.012056	0.000029	0.003054	0.060991	0.045950	0.003132	0.074282	0.003947	**21AD08**	0.22
21AD09	0.011652	0.011131	0.000031	0.002114	0.058038	0.052092	0.002663	0.023269	0.002057	**21AD09**	0.16
21A10	0.012060	0.011623	0.000031	0.002349	0.058441	0.058698	0.002506	0.026849	0.005816	**21A10**	0.18
21AD11	0.012561	0.011635	0.000033	0.002193	0.067838	0.062157	0.002663	0.020584	0.000856	**21AD11**	0.18
21AD12	0.011402	0.011281	0.000027	0.001958	0.057188	0.044956	0.002349	0.014319	0.000658	**21AD12**	0.14
average	0.012365	0.011956	0.000031	0.002865	0.062897	0.046457	0.002793	0.035053	0.003657	**average**	0.18
min	0.011245	0.011131	0.000027	0.001958	0.057188	0.039175	0.002349	0.014319	0.000658	**min**	0.14
max	0.013594	0.012774	0.000038	0.006108	0.070433	0.062157	0.003602	0.074282	0.013438	**max**	0.22
stdev	0.000809	0.000505	0.000003	0.001242	0.004382	0.007506	0.000333	0.019255	0.003466	**stdev**	0.02
var	0.000001	0.000000	0.000000	0.000002	0.000019	0.000056	0.000000	0.000371	0.000012	**var**	0.0006
med	0.012122	0.011927	0.000031	0.002428	0.061707	0.044691	0.002741	0.026849	0.003190	**med**	0.1790

Table 13 - Descriptive statistics of hazard quotient and hazard index in the children via ingestion

	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn		HI, children
21AD01	0.03461	0.03323	0.00013	0.00614	0.17649	0.10973	0.00736	0.09600	0.01110	**21AD01**	0.475
21AD02	0.03477	0.03192	0.00013	0.01595	0.16153	0.10233	0.00736	0.18514	0.00805	**21AD02**	0.547
21AD03	0.03551	0.03212	0.00014	0.01207	0.17427	0.10555	0.00941	0.25714	0.03510	**21AD03**	0.661
21AD04	0.03461	0.03121	0.00013	0.00655	0.18397	0.11604	0.00777	0.15429	0.01034	**21AD04**	0.545
21AD05	0.02937	0.03337	0.00010	0.00655	0.16784	0.12244	0.00736	0.13714	0.00862	**21AD05**	0.513
21AD06	0.03183	0.03110	0.00011	0.00552	0.16083	0.10752	0.00695	0.06857	0.00316	**21AD06**	0.416
21AD07	0.03125	0.03103	0.00010	0.00655	0.15639	0.10338	0.00655	0.10286	0.00344	**21AD07**	0.442
21AD08	0.03109	0.03149	0.00011	0.00798	0.15931	0.12002	0.00818	0.28457	0.01031	**21AD08**	0.653
21AD09	0.03044	0.02907	0.00012	0.00552	0.15160	0.13607	0.00695	0.08914	0.00537	**21AD09**	0.454
21AD10	0.03150	0.03036	0.00012	0.00614	0.15265	0.15332	0.00655	0.10286	0.01519	**21A10**	0.499
21AD11	0.03281	0.03039	0.00013	0.00573	0.17719	0.16236	0.00695	0.07886	0.00224	**21AD11**	0.497
21AD12	0.02978	0.02947	0.00010	0.00511	0.14938	0.11743	0.00614	0.05486	0.00172	**21AD12**	0.394
average	0.03230	0.03123	0.00012	0.00748	0.16429	0.12135	0.00730	0.13429	0.00955	**average**	0.508
min	0.02937	0.02907	0.00010	0.00511	0.14938	0.10233	0.00614	0.05486	0.00172	**min**	0.394
max	0.03551	0.03337	0.00014	0.01595	0.18397	0.16236	0.00941	0.28457	0.03510	**max**	0.661
stdev	0.00211	0.00132	0.00001	0.00324	0.01145	0.01960	0.00087	0.07376	0.00905	**stdev**	0.084
var	0.00000	0.00000	0.00000	0.00001	0.00013	0.00038	0.00000	0.00544	0.00008	**var**	0.007
med	0.03166	0.03115	0.00012	0.00634	0.16118	0.11673	0.00716	0.10286	0.00833	**med**	0.498

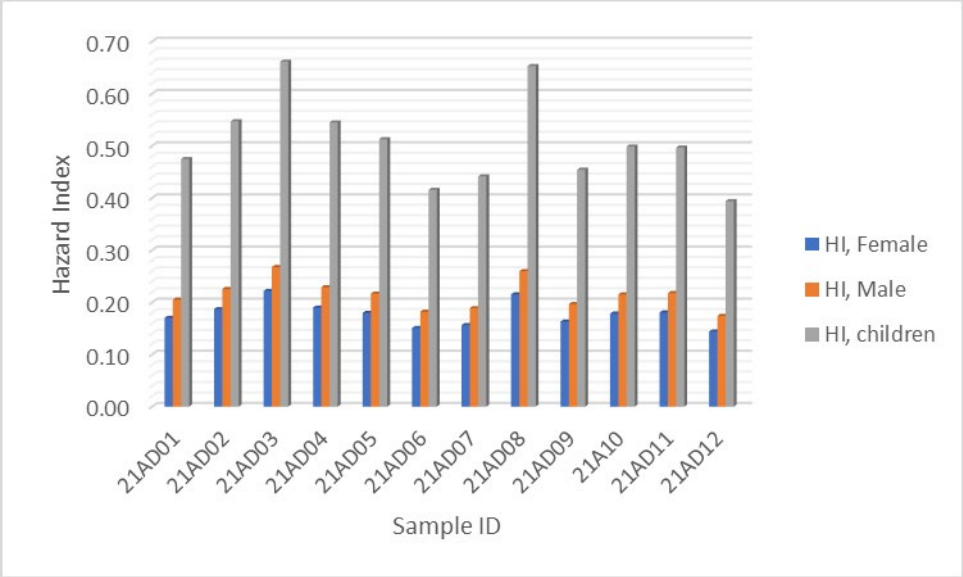

Fig. 8 - Profile of the hazard index for all the age groups via ingestion

4.5 The Chronic Daily Intake (CDI) of Heavy Metals / Trace Elements:

The descriptive statistics of the Chronic Daily Intake (CDI) of the selected trace elements for both adults and children are included in Table 14. In the adults, the respective mean value of the trace elements, (Al, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn) is as follows: 0.0124, 0.0024, 0.000047, 0.000115, 0.0442, 0.00214, 0.000056, 0.000123 and 0.0011 respectively. The values for children are as follows: 0.047, 0.0092, 0.000179, 0.000439, 0.169, 0.00819, 0.000214, 0.00047 and 0.0042 respectively. Based on the values of the mean, the order of abundance of CDI in both adults and children is as follows: Fe>Al>Ba>Mn>Zn>Pb>Cu>Ni>Cr respectively. All the values calculated are quite below the value of unity (< 1). This may be a pointer that the water sampled practically poses less significant health threats to both adults and children through ingestion medium.

Table 14 - Descriptive statistical summary of chronic daily intake of trace elements through ingestion for all the age groups

Adults	Al	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn
average	0.012406	0.002399	0.000047	0.000115	0.044175	0.002144	0.000056	0.000123	0.001101
min	0.011283	0.002234	0.000041	0.000079	0.040166	0.001808	0.000047	0.000050	0.000198
max	0.013640	0.002563	0.000057	0.000245	0.049469	0.002869	0.000072	0.000261	0.004045
stdev	0.000812	0.000101	0.000005	0.000050	0.003078	0.000346	0.000007	0.000068	0.001043
var	0.00000066	0.00000001	0.00000000	0.00000000	0.00000947	0.00000012	0.00000000	0.00000000	0.00000109
med	0.012163	0.002393	0.000047	0.000097	0.043340	0.002063	0.000055	0.000094	0.000960
Children	**Al**	**Ba**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
average	0.04737	0.0091607	0.000179	0.000439	0.16867	0.0081869	0.000214	0.00047	0.004203
min	0.04308	0.0085284	0.000156	0.0003	0.15336	0.0069036	0.00018	0.000192	0.000756
max	0.05208	0.0097872	0.000216	0.000936	0.18888	0.0109536	0.000276	0.000996	0.015444
stdev	0.00309985	0.00038727	1.8771E-05	0.00019025	0.0117507	0.00132268	2.5499E-05	0.00025818	0.00398391
var	9.6091E-06	1.4998E-07	3.5236E-10	3.6195E-08	0.00013808	1.7495E-06	6.5018E-10	6.6655E-08	1.5872E-05
med	0.04644	0.0091386	0.00018	0.000372	0.16548	0.0078756	0.00021	0.00036	0.003666

4.6 The Carcinogenic Risk (CR)

The carcinogenic risk (CR) can be well-defined as the tendency that a patient will develop cancer during his/her lifetime as a result of acquaintance under specific conditions [20], [6], [7]. This was calculated for some selected metals (Cr and Pb) in this study. Table 15 presents the carcinogenic risk for all the age groups and Fig. 9 illustrates the profiles. The Cr average values for male adults, female adults and children are: 0.000113, 0.000093 and 0.000358 respectively. The values for Pb are: 0.0174, 0.0144 and 0.0553 respectively. The mean values of Cr for all the age groups fall within 10^{-6} and 10^{-4} which is an indication of a potential carcinogenic health risk for consumption having values between 10^{-6} and 10^{-4} [6],[7]. This can lead to Nausea, vomiting, peptic ulcer, liver problem, kidney dysfunction and growth retardation [33]

Table 15 - Carcinogenic Risk for all the age groups via ingestion

carcinogenic	adult male		adult female		children	
risk	Cr	Pb	Cr	Pb	Cr	Pb
average	0.000113	0.017407	0.000093	0.014433	0.000358	0.055294
min	0.000098	0.007111	0.000081	0.005896	0.000312	0.022588
max	0.000136	0.036889	0.000113	0.030587	0.000432	0.117176
stdev	0.000012	0.009562	0.000010	0.007928	0.000038	0.030374
med	0.000113	0.013333	0.000094	0.011055	0.000360	0.042353

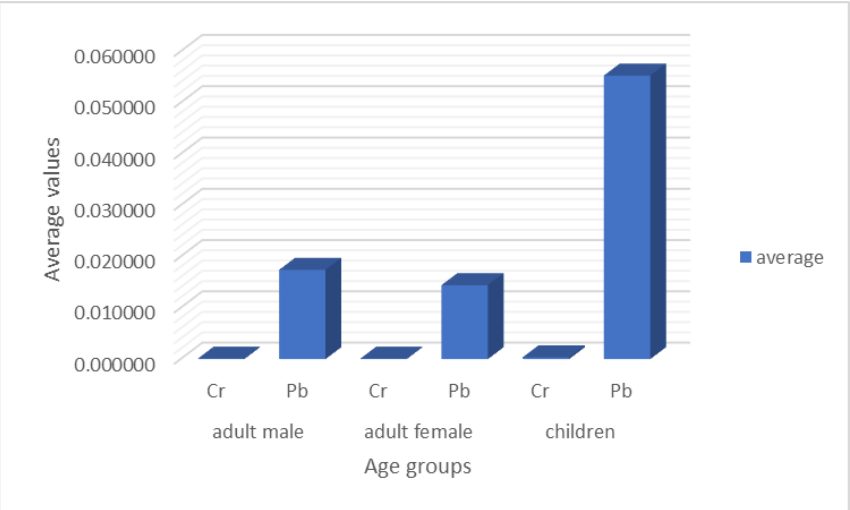

Fig. 9 - The profile of male adults, female adults and children carcinogenic risk via ingestion route (average values)

5. Conclusion and Recommendations

The preliminary human health risk assessment of Asejire Lake water has been established through the analysis of the sampled water. concentrations of few selected trace metals and computed values of contamination indexes and health risk assessment parameters. The mean values of TDS, EC and pH indicated that the water is fresh and slightly alkaline in nature respectively. The mean values calculated for Al (0.39 ppm) and Fe (1.41 ppm) are higher than the prescribed standard of WHO and NSDWQ Standards which make the water potentially hazardous for domestic consumptions. The contamination factors values gave a signal of slight contaminations to very high contamination and the source is concluded to be more of anthropogenic in nature as recorded by the values of contamination factors greater than one. The values calculated for degree of contamination show that the water is heavily loaded with these trace metals which might be detrimental to human health. High values of average daily dose through ingestion were recorded for Al, Ba, Fe, Mn and Zn in all the age groups which might give a signal for potential hazard. The average daily dose through derma ingestion is generally lower than one. The hazard quotient and the hazard index are generally lower than one for all the age groups, however, the values fall within low chronic risk category for HI in all the age groups. Average hazard index computed for children is very close to one. Hence, caution must be taken while utilizing the water for children's consumption. The values computed for chronic daily intake is generally less than one which depict practically low non-carcinogenic health threat to the consumers. The average values of carcinogenic risk calculated for Cr and Pb fall within carcinogenic range of 10^{-6} and 10^{-4} and above respectively. This gives a signal for carcinogenic health risk to the consumers, especially the children. Farming and fishing activities must be strictly and legally regulated if not totally prohibited in the area to prevent leaching of agrochemicals into the water body. The Nigerian Bottling Company situated close to the river must be cautioned on how they discharge their wastes into the river and its catchmen.

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