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Preliminary Health Risk Assessment in Relation to Some Trace Elements in Ogunpa River, South-Western Nigeria

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Abstract

Ogunpa River receives municipal and industrial waste discharge from its catchments and these have depleted the quality of the water. Hence, this research examines the preliminary environmental impacts and health implications of some trace elements in the water using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) laboratory technique. Average values of Al, Ba, Fe, Mn, Ni and Pb are above the recommended limits of WHO. The CF showed that the trace elements varied from considerable contamination factor to very high contamination factor and the degree of contamination varied from 1023 to 11640. The hazard quotient computed for the adults is generally less than unity except Pb that has average value of 1.27. In children, the computed hazard quotient on the average ranges from 0.000572 to 4.04. Al, As, Ba, Cr, Cu, Ni, Zn and Cd have their average values less than unity respectively, while Fe, Mn and Pb has their average values greater than one. The Hazard Index (HI) in adults and children are greater than one. Carcinogenic risk assessment was computed for Cr, Pb and Cd which was greater than 10^{-6} in children and adult. Only Cd in adult was less than the prescribed limit of 10^{-6}. Effort should be made to checkmate indiscriminate dumping of refuse and sewages into the water body as these could serve as pollutants to other adjourning rivers and main water bodies. In conclusion, the water is not fit for domestic, agricultural and probably industrial uses because of its health implications on consumption.

Keywords: Ogunpa river, contamination factor, degree of contamination, Hazard quotient, hazard index, carcinogenic health risk

Introduction

Water is very essential for life, accounting for 70% of the human body. It is the basic essentials for human existence, survival and social development which is the indispensable materials for daily inventions and life. Safe and clean portable water is important to human health and also an important indicator to measure social development and human life quality (Chang, 2013; Li *et al.*, 2019). In recent years, due to development of the industrialized society, the environment has been deteriorated leading to water pollution catastrophes. It has been discovered that majority of the drinking water sources (surface water) have brought great threats to human health. As a result of lack of proper disinfection and treatment facilities, people have poor drinking water. Rivers generally are liable to indiscriminate dumping of municipal wastes. Although some of these rivers may not be directly consumed by people but they serve as tributaries to other rivers and main water bodies that other people consume. The effects of pollution are somehow reflected in the quality of the main water bodies. The Health Risk Assessment (HRA) of water emerged in the inception of 1980s (Chang, 2013; Li *et al.*, 2019). It adopted the concept of risk as an appraisal index to link environmental pollution with human health and quantitatively describing the risk of pollution to human health (Han, 2011; Li *et al.*, 2019). Interestingly, several researches related to HRA has been conducted

using the method prescribed by the USEPA around the world (Yuan *et al*, 2017; Li *et al*., 2019). Through the evaluation of the level of damage to human health, health risk assessment (HRA) can serve as a guide by administrative sector in water environment protection, pollution remediation and water environment risk management ((Khadam and Kaluarachchi, 2003; Kavcar *et al.* 2009; Li *et al*., 2019).

Ogunpa river is one of the main rivers at the center of Ibadan metropolis, south western Nigeria that receives effluents from various activities far and near within certain parts of Ibadan city. Consequently, this research surveys the environmental impacts and health implications of some selected trace elements in the river.

In general, Ibadan metropolis is situated South West of Nigeria. The study area lies between longitudes 7º21'15''N and 7º21'50''N and latitude 3º53'10''E and 3º53'50''E'. According to population census 1991, Ibadan has a population of 1,288,666 and slightly in excess of 1,338,659 in the year 2006 according to National Population Commission estimates. Ibadan is a commercial center and in recent times has witnessed an explosion in population, industrialization and an increased tempo of economic activities. The Geology of Ibadan and environs, including Ogunpa area, falls within the Pre-Cambrian rocks of Southwestern Nigeria. The main rock types are schist-quartzites, granite-gneiss, banded gneiss, augen-gneiss, and migmatites (Jones and Hockey, 1964), while minor rock types like pegmatite, aplites, quartz veins and dolerite dykes intruded the main rocks in Ibadan metropolis. Oladunjoye *et al* (2013) reported that Gneisses are migmatized in places and are characterized by predominantly medium-sized grains while schist quartzites occur as elongated ridges striking NW-SE. Moreover, the study area is typified by banded and migmatite gneisses which generally strike NW-SE and dip to the east. It was further reported that the joints on the outcrops in the area are mostly oriented perpendicular to the strike (NW-SE) of the rock foliation. In addition, some notable N-S and NW-SE plunging minor folds were mapped on the gneiss complex. Figure 1 present the location map of the area of study.

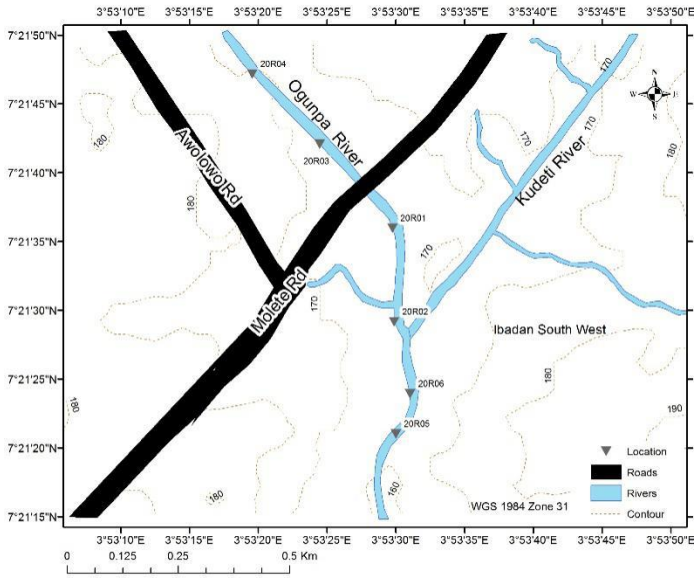

Figure. 1: Parts of Topographical Map of Ibadan, showing the Location of the study area and Sampling Points

Methodology

The sampling activities were carried out in January 2020. The study is just a preliminary study to further studies, hence, a total of six water samples were randomly sampled along the river channel with the aid of GPS. 60ml white plastic containers were used for the water sampling. The containers were rinsed severally by the water to be put in them and few drops of concentrated nitric acid were added to each of the water-filled bottles and corked immediately. The acid prevents the precipitations of the cations from solution. The samples were analyzed in ACME laboratory in Vancouver, Canada, North America. ICP-MS laboratory technique was used for the analysis of the cations. Only 11 trace elements were selected from the laboratory results for this study and the following were the selected trace elements: Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd.

Data Appraisal

Table 1 presents the World Health Organization (WHO) standard for drinking water quality and the mean composition of world rivers respectively.

Table 1: World Health Organization (2006) and Nigerian Standards for Drinking Water Quality for Potable Water (2007) and Mean Composition of World Rivers (2009).

Trace Elements	WHO Standard (ppm), 2006	NSDWQ, 2007 (ppm)	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

Contamination Factor: This is the single index usually determined by the following relation:

$$Cf = \frac{Cm}{Bm} \quad (1)$$

Cf is the contamination factor of the trace element of interest; Cm is the concentration of the trace element in the sample; Bm is the background concentration of the trace element in the sample. According to Atiemo *et al*., 2011, there are four categories of contamination factors which include the following:< 1= low contamination factor; 1-3=moderate contamination factor; 3-6=considerable contamination factor; > 6=very high contamination factor.

Degree of Contamination (C_{deg}): This is the addition of all the contamination factors in the sample and it is expressed as:

$$C_{deg} = \sum {}^{C_m}/_{B_m} \quad (2)$$

C_m is the concentration of the element m in the water; B_m is the local background concentration of trace element, m within the pristine area of catchment. Atiemo *et al*., 2011 also identified four categories namely: low degree of contamination (< 8); moderate degree of contamination (8 - 16); considerable degree of contamination (16 - 32); and very high degree of contamination (> 32).

The Average Daily Dose: The Average Daily Dose (ADD) was determined using equation 3 to estimate the health risk of the samples taken from Ogunpa River.

$$ADD = \frac{Cwater*IR*EF*ED}{BW*AT} \quad (3)$$

where, ADD is the average daily dose through ingestion of water (µg/kg/day); C_{water} is the average concentration of the estimated metals in water (µg/L); IR is the ingestion rate in this research (2.2 L/day for adults; 1.8 L/day for children); EF is the exposure frequency (365 days/year); ED is the exposure duration (70 years for adults; and 6 years for children); BW is the average body weight (70 kg for adults; 15 kg for children); AT is the average time (365 days/year × 70 years for an adult; 365 days/year × 6 years for a child)- **Edokpayi, *et al*. (2018)**.

Hazard Quotient (HQ): The non-carcinogenic risk as a result of the exposure to surface water resources consumption was computed as the hazard quotient (HQ). The formula below is used to calculate the HQ of the river water in Ogunpa, Ibadan:

$$HQ=ADD/R_fD \quad (4)$$

ADD is the average daily dose similar to the exposure dose through ingestion of water (µg/kg/day); R_fD is the reference dose of specific element. The reference dose for Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb and Zn are: 1, 0.0003, 0.2, 1.5, 0.04, 0.7, 0.046, 0.02, 0.0035 and 0.3 mg/kg/day, respectively (USEPA, 2001). If the value of HQ is greater than unity, that is, 1, there is possibility of non-carcinogenic negative effects on health while HQ value less than 1 implies that the exposure to the surface water consumption would not likely have any effect on the consumers (USEPA 2001, Yuan *et al.*, 2017; Maxwell *et al*., 2018; Joel *et al*., 2018).

Hazard Index (HI)*:* To assess the overall potential non-carcinogenic effects posed by more than one metal and pathway, the addition of the computed HQs across metals was expressed as hazard index (HI) using equation 5 after USEPA (1989):

$$HI = \sum_{i=1}^{n} HQ \quad (5)$$

HI > 1 is an indication of a potential adverse effect on human health (Li SY and Zhang, 2010; Naveedullah *et al*., 2014).

Chronic Daily Intake (CDI): Edokpayi *et al* (2018) calculated Chronic Daily Intake (CDI) of trace elements through ingestion using equation 6:

$$CDI = C_{water} * \frac{DI}{BW} \quad (6)$$

Carcinogenic Risk (CR): Edokpayi *et al (*2018) also used the equation 7 to estimate the carcinogenic risk (CR) through ingestion and this was also adopted in this research:

$$CR_{ing} = {Exp_{ing}}/{SF_{ing}} \quad (7)$$

where, CR_{ing} =carcinogenic risk via ingestion route and SF_{ing} = carcinogenic slope factor where Pb is 8.5E, Cd is 6.1E+03 and Cr is 5.0E+02 µg/kg/day (Iqbal and Shah, 2013; Naveedullah *et al*., 2014; Asare-Donkor *et al.*, 2016). The CR_{ing} values for other trace elements were not computed in this study because of unavailability of the SF_{ing} values.

Results and Discussion

Hydrochemical Analysis Results and Discussion

The hydrochemical analysis results of selected trace elements and their respective descriptive statistical summary were presented in Table 2. The profile of the concentrations of the selected trace elements and the profile of average concentrations of the selected trace elements were also presented in Figures 2 and 3 respectively.

Aluminum (Al): Al has a range between 0.23 and 3.49 ppm (average=1.25ppm; standard deviation=1.56; median=0.27ppm). All the values of Al in the water are greater than 0.2 ppm recommended by WHO (2006) and NSDWQ (2007). It has been reported that Al toxicity could results in neuro-degenerative disorders (NSDWQ, 2007). The elevated values of Al in the water is as a result of various anthropogenic activities around the study area (Motor mechanics activities, marketing, effluent from municipal waste disposals, leachate from households' materials and sewage disposals).

Arsenic (As): Arsenic ranges from 0.0015 to 0.0037ppm (average=0.0024ppm; standard deviation=0.001; median=0.002ppm). The value is lower than the recommended values of WHO, 2006 (0.01ppm) and NSDW, 2007 (0.01ppm). Since traces of Arsenic were observed, caution should be taken to prevent Arsenic toxicity in the water body because it can lead to various types of cancer infections when the water is ingested (NSDW, 2007). It has been reported that Arsenic enters the bodies of water via both natural and anthropogenic sources. Arsenic also is used in various agricultural insecticides, herbicides, animal diseases prevention and the stimulants for chickens as well as swine which could increase the concentration level in the water phase (Ekere *et al*., 2014).

Barium (Ba): The concentrations of Barium in the water body ranged from 0.1 to 1.29 ppm with an average of 0.4 ppm higher than the prescribed limit of 0.3ppm (WHO, 2006). Contributions from municipal waste disposal is more pronounced in the area leading to increase in the level of Ba. Barium causes hypertension in man. Hence, measures must be taken to stop indiscriminate dumping of refuse and channeling of sewage materials into the river channel.

Iron (Fe): The concentrations of Fe in the samples ranged from 1.23 to 17.78ppm with an average of 6.03ppm and median 1.37 ppm. Details could be seen in Table 2. It was observed that all the samples had elevated values of Fe greater than the recommendations of WHO and NSDWQ. It has been reported that excess iron in water and food constitutes health hazard to human being (Ekere *et al*., 2014). Chronic intake of water containing overloaded iron results in gene mutation leading to haemochromatosis whose symptoms include fatigue, weight loss, joint pains and ultimately heart disease, liver problems and diabetes (Ekere *et al*., 2014). It is suggested that the sources of the iron are chiefly from various anthropogenic activities in the study area and little contribution from the weathering of rock types in the area.

Manganese (Mn): The concentrations of Mn in the water samples ranged from 0.32 to 1.58ppm with an average of 0.65 ppm. All the values are greater than 0.2ppm prescribed by NSDW, 2007. Based on the average, the value obtained (average=0.65ppm) is higher than the value (0.5ppm) recommended by WHO (2006). The high concentrations may be as a result of landfill leachate leaching/flowing into the river (Edokpayi *et al*., 2018). It has been reported that concentrations between 0.1 and 0.15ppm could cause critical stain and taste problems (DWAF, 1996; WHO, 2006; Edokpayi *et al*., 2018).

Table 2: Concentrations and Descriptive Statistical Summary of the Selected Trace Elements (in ppm) in Ogunpa River

Sample ID	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
NSDW, 2007	0.2	0.01	0.7	0.05	1	0.3	0.2	0.001	0.01	3	0.003
20 RO1	3.48700	0.00360	1.29437	0.01540	0.85680	13.17300	1.58296	0.01170	0.39610	1.19780	0.00279
20 RO2	0.26700	0.00180	0.15152	0.00280	0.03620	1.22500	0.31627	0.00400	0.01110	0.04000	0.00016
20 RO3	3.03300	0.00370	0.64252	0.01520	0.44970	17.77200	0.76989	0.01760	0.28120	0.67560	0.00419
20 RO4	0.22700	0.00180	0.16277	0.00300	0.00890	1.46400	0.37182	0.00380	0.00710	0.02880	0.00010
20 RO5	0.27400	0.00150	0.15329	0.00280	0.00630	1.24600	0.45887	0.00330	0.00330	0.01500	0.00006
20 RO6	0.23100	0.00170	0.14969	0.00370	0.01020	1.28400	0.39476	0.00380	0.00740	0.06250	0.00009
average	1.25317	0.00235	0.42569	0.00715	0.22802	6.02733	0.64910	0.00737	0.11770	0.33662	0.00123
min	0.22700	0.00150	0.14969	0.00280	0.00630	1.22500	0.31627	0.00330	0.00330	0.01500	0.00006
max	3.48700	0.00370	1.29437	0.01540	0.85680	17.77200	1.58296	0.01760	0.39610	1.19780	0.00419
stdev	1.56121	0.00101	0.46825	0.00632	0.35381	7.45982	0.48481	0.00595	0.17498	0.49353	0.00180
var	2.43739	0.00000	0.21926	0.00004	0.12518	55.64890	0.23504	0.00004	0.03062	0.24357	0.00000
med	0.27050	0.00180	0.15803	0.00335	0.02320	1.37400	0.42682	0.00390	0.00925	0.05125	0.00013

Lead (Pb): The concentrations recorded for Lead also ranged from 0.003 to 0.396ppm with an average of 0.12ppm. Based on the average value computed, it is higher than the recommended values by WHO and NSDW (0.01ppm). It is reported that lead is stored in the skeleton with a half-life of 20 to 30 years (WHO, 1995; Edokpayi *et al*., 2018). The following are the acute symptoms of lead poisoning: headache, irritability, abdominal pains and symptoms related to nervous system (Ekere *et al*., 2014). Also, long term exposure in children may lead to diminished intellectual capability, encephalopathy, acute psychosis and reduces ability to understand (WHO, 1995; Ekere *et al*., 2014). Improper sewage and refuse disposal may result to leaching of Pb into the river thereby increasing the concentration.

Nickel (Ni): The concentrations of Ni ranged from 0.0033 to 0.018ppm (average=0.007ppm; median=0.004ppm). Based on the average, the concentration of Nickel is lower than 0.02ppm prescribed by WHO. However, concentrations are generally higher than the recommended values by NSDWQ. It is of interest to note that Nickel is necessary in many organism's diets. However, it can become carcinogenic and toxic in high doses. It has been observed that women are more commonly allergic to nickel exposure than men. Exposure to skin can cause dermatitis upon contact. The source could be from the electroplating waste discharge into the river bodies without treatment.

Chromium (Cr), Copper (Cu), Zinc (Zn) and Cadmium (Cd): The average concentrations of Cr, Cu, Zn and Cd are 0.0072, 0.23, 0.34 and 0.0012 ppm respectively. Detailed statistical summary is presented in Table 2. The values are generally below the recommended values of WHO and NSDWQ.

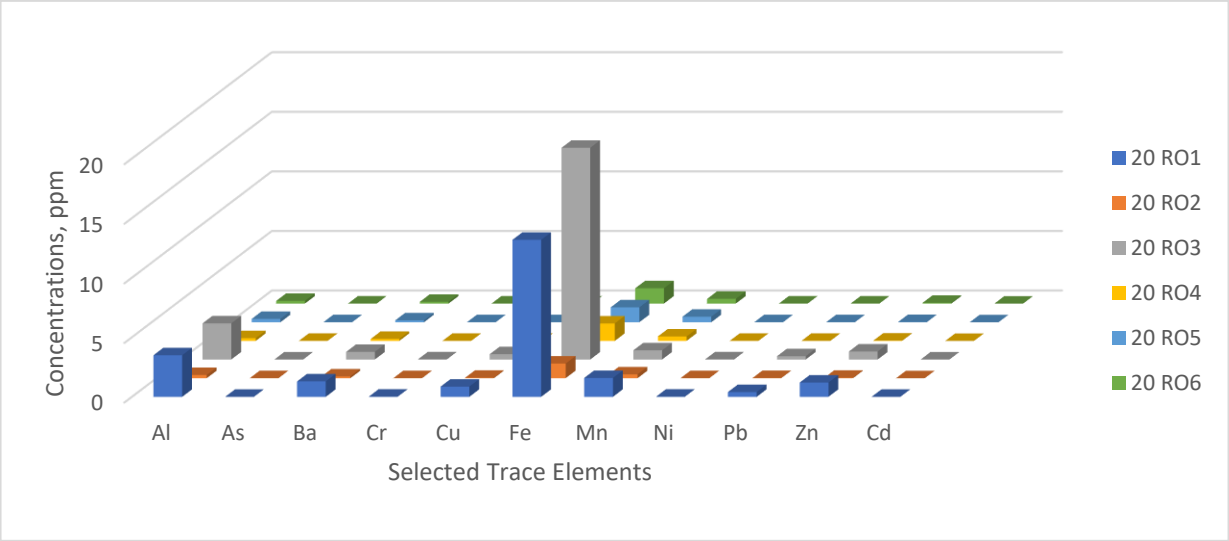

Figure 2: Profile of the Concentrations of the Selected trace Elements

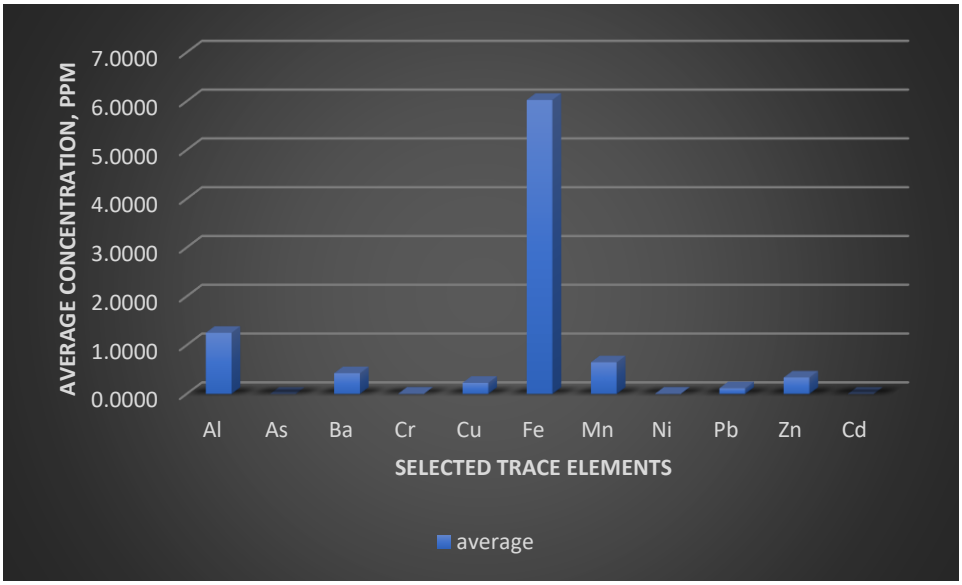

Figure 3: Profile of Average Concentrations of the Selected Trace Elements

Assessment of Contamination

Assessment of contamination of the water was carried out by computing the contamination factor and degree of contamination of the trace elements in the water samples.

Contamination Factor (CF) and Degree of Contamination (D_{deg}): Table 3 presents the computed contamination factors and degree of contamination of the trace elements in the samples. The average contamination factors of Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd are: 3.92, 3.79, 18.51, 10.21, 154.07, 91.32, 1545.46, 9.21, 1471.25, 561.03 and 15.4 respectively. The CF < 1 is an indication that the sources of elements are generally from natural activities (weathering of rock types in the area) while CF >1 indicates sources from artificial or anthropogenic activities in the area of study (Tijani, 2007). The computed CF denotes contributions from various anthropogenic activities in the study area. The computed degree of contamination ranged from 1023 to 11640, indicating very high degree of contamination of these elements in the samples. Figure 4 presents the profile of the degree of contamination in the water samples.

Table 3: Computed Statistical Description Summary of Contamination Indexes

	Contamination Factor, CF										
	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd
20 RO1	10.90	5.81	56.28	22.00	578.92	199.59	3768.95	14.63	4951.25	1996.33	34.88
20 RO2	0.83	2.90	6.59	4.00	24.46	18.56	753.02	5.00	138.75	66.67	2.00
20 RO3	9.48	5.97	27.94	21.71	303.85	269.27	1833.07	22.00	3515.00	1126.00	52.38
20 RO4	0.71	2.90	7.08	4.29	6.01	22.18	885.29	4.75	88.75	48.00	1.25
20 RO5	0.86	2.42	6.66	4.00	4.26	18.88	1092.55	4.13	41.25	25.00	0.75
20 RO6	0.72	2.74	6.51	5.29	6.89	19.45	939.90	4.75	92.50	104.17	1.13
average	3.92	3.79	18.51	10.21	154.07	91.32	1545.46	9.21	1471.25	561.03	15.40
min	0.71	2.42	6.51	4.00	4.26	18.56	753.02	4.13	41.25	25.00	0.75
max	10.90	5.97	56.28	22.00	578.92	269.27	3768.95	22.00	4951.25	1996.33	52.38
stdev	4.88	1.63	20.36	9.03	239.06	113.03	1154.32	7.43	2187.24	822.55	22.56
var	23.80	2.67	414.48	81.57	57151.22	12775.23	1332450.14	55.25	4784005.63	676586.78	508.92
med	0.85	2.90	6.87	4.79	15.68	20.82	1016.23	4.88	115.63	85.42	1.63

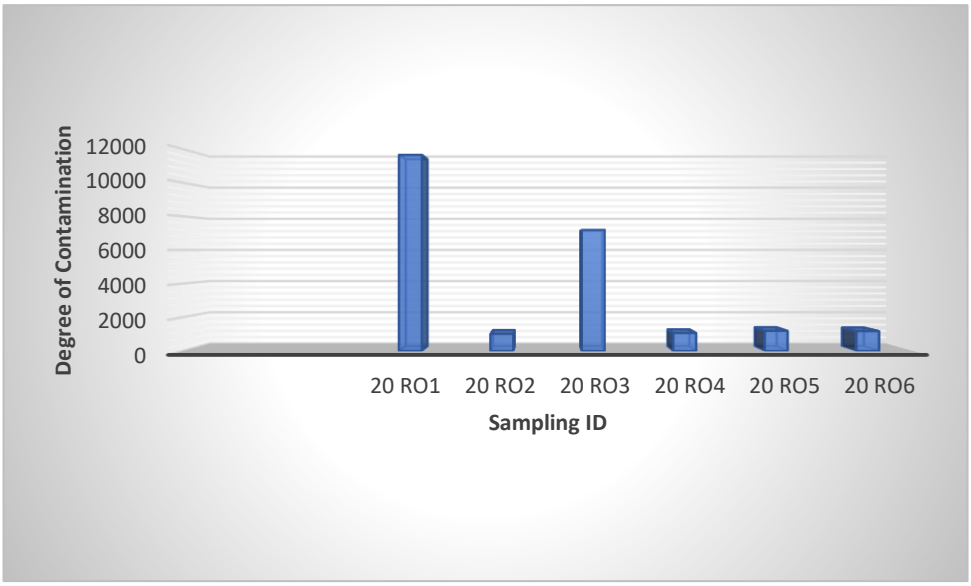

Figure 4: Profile of the Degree of Contamination in Ogunpa River

Health Risk Assessment:

The computed health risk assessment parameters are presented in Tables 4 and 5. The health risk assessment model introduced by the USEPA were adopted in this research to evaluate the health risks that trace elements could pose on human via direct ingestion of the water in Ogunpariver. The health-related risk associated with the exposure through ingestion is a factor of the weight, age and volume of water consumed by an individual which was determined using the measured minimum and maximum concentration of Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd.

The Average Daily Intake: The average daily intake for adults and children is presented in Tables 4 and 5. The average values computed for Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd are 47.34, 0.089, 16.08, 0.27, 8.61, 227.7, 24.52, 0.28, 4.45, 12.72 and 0.047 µg kg^{-1} day^{-1} respectively. The average values computed for As, Cr, Ni and Cd are < 1 while others are > 1. The average values of trace elements computed for Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd in children are: 150.38, 0.282, 51.083, 0.858, 27.36, 732.28, 77.89, 0.88, 14.12, 40.39 and 0.148 µg kg^{-1} day^{-1} respectively. The average values computed for As, Cr, Ni and Cd are also < 1 while others are > 1. Therefore, similar trend is observed in both adults and children. The average daily intake greater than unity is an indication of potential negative health hazard on people that consume the polluted water.

Table 4: Descriptive Average Daily Dose (μg kg^{-1} day^{-1}) of Ogunpa Water for Adults

	Exposure Dose through Ingestion in Adults (Exping)										
Sample ID	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd
20 RO1	131.731	0.136	48.898	0.582	32.368	497.647	59.801	0.442	14.964	45.250	0.105
20 RO2	10.087	0.068	5.724	0.106	1.368	46.278	11.948	0.151	0.419	1.511	0.006
20 RO3	114.580	0.140	24.273	0.574	16.989	671.387	29.085	0.665	10.623	25.523	0.158
20 RO4	8.576	0.068	6.149	0.113	0.336	55.307	14.047	0.144	0.268	1.088	0.004
20 RO5	10.351	0.057	5.791	0.106	0.238	47.071	17.335	0.125	0.125	0.567	0.002
20 RO6	8.727	0.064	5.655	0.140	0.385	48.507	14.913	0.144	0.280	2.361	0.003
average	47.342	0.089	16.082	0.270	8.614	227.699	24.521	0.278	4.446	12.717	0.047
min	8.576	0.057	5.655	0.106	0.238	46.278	11.948	0.125	0.125	0.567	0.002
max	131.731	0.140	48.898	0.582	32.368	671.387	59.801	0.665	14.964	45.250	0.158
stdev	58.979	0.038	17.689	0.239	13.366	281.815	18.315	0.225	6.610	18.644	0.068
var	3478.548	0.0015	312.918	0.057	178.658	79419.918	335.446	0.050	43.696	347.615	0.005
med	10.219	0.068	5.970	0.127	0.876	51.907	16.124	0.147	0.349	1.936	0.005

Table 5: Descriptive Average Daily Dose ((μg kg^{-1} day^{-1}) of Ogunpa Water for Children

	Exposure Dose through Ingestion in Children (Exping)										
Sample ID	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd
20 RO1	418.440	0.432	155.324	1.848	102.816	1580.760	189.955	1.404	47.532	143.736	0.335
20 RO2	32.040	0.216	18.182	0.336	4.344	147.000	37.952	0.480	1.332	4.800	0.019
20 RO3	363.960	0.444	77.102	1.824	53.964	2132.640	92.387	2.112	33.744	81.072	0.503
20 RO4	27.240	0.216	19.532	0.360	1.068	175.680	44.618	0.456	0.852	3.456	0.012
20 RO5	32.880	0.180	18.395	0.336	0.756	149.520	55.064	0.396	0.396	1.800	0.007
20 RO6	27.720	0.204	17.963	0.444	1.224	154.080	47.371	0.456	0.888	7.500	0.011
average	150.380	0.282	51.083	0.858	27.362	723.280	77.891	0.884	14.124	40.394	0.148
min	27.240	0.180	17.963	0.336	0.756	147.000	37.952	0.396	0.396	1.800	0.007
max	418.440	0.444	155.324	1.848	102.816	2132.640	189.955	2.112	47.532	143.736	0.503
stdev	187.346	0.122	56.190	0.759	42.458	895.178	58.178	0.714	20.997	59.224	0.217
var	35098.424	0.015	3157.327	0.576	1802.650	801344.227	3384.637	0.509	440.894	3507.426	0.047
med	32.460	0.216	18.964	0.402	2.784	164.880	51.218	0.468	1.110	6.150	0.016

Hazard Quotient (HQ) and Hazard Index (HI): The hazard quotient and hazard index computed for both adults and children are presented in Tables 6 and 7. For the adults, the average values computed is generally lower than unity except for Pb that has average value of 1.27. However, Mn in sample 20RO1 has a value of 1.3 above prescribed limit of 1. These indicate hazard effect of the water on the consumers. The order of abundance of the HQ for adults is: Pb> Mn >Fe >Cu >Ba >Al >Cd >Zn >Ni >As >Cr. The hazard index for adults ranges from 0.52 to 7.65 with an average of 2.53 above prescribed limit of one. This is an indication that the water has a high-risk health hazard to consumers. The profiles of hazard Index for adults and children are presented in Figures 5 and 6.

In children, the computed hazard quotient on the average ranges from 0.000572 in Cr to 4.04 in Pb. Al, As, Ba, Cr, Cu, Ni, Zn and Cd have their average values less than one respectively, while Fe, Mn and Pb have their average values > 1 respectively. This is an indication of negative health risk

in the water of the study area. It has been suggested that estimated HQ values for trace elements more than unity for children should not be overlooked because children are very much susceptible to pollutants (Olujimi, *et al*., 2015; Giandomenico, *et al*., 2016; Sudsandee *et al.*, 2017; Edokpayi, *et al*., 2018).

Table 6: Descriptive Statistics of Hazard Quotient and Hazard Index in the Adults

	Hazard Quotient (Adults)											Hazard Index	
	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd		
20 RO1	0.1317	0.0097	0.2445	0.0004	0.8092	0.7109	1.3000	0.0221	4.2754	0.1508	0.1054	20 RO1	7.65
20 RO2	0.0101	0.0049	0.0286	0.0001	0.0342	0.0661	0.2597	0.0076	0.1198	0.0050	0.0060	20 RO2	0.54
20 RO3	0.1146	0.0100	0.1214	0.0004	0.4247	0.9591	0.6323	0.0332	3.0352	0.0851	0.1583	20 RO3	5.42
20 RO4	0.0086	0.0049	0.0307	0.0001	0.0084	0.0790	0.3054	0.0072	0.0766	0.0036	0.0038	20 RO4	0.52
20 RO5	0.0104	0.0040	0.0290	0.0001	0.0060	0.0672	0.3768	0.0062	0.0356	0.0019	0.0023	20 RO5	0.54
20 RO6	0.0087	0.0046	0.0283	0.0001	0.0096	0.0693	0.3242	0.0072	0.0799	0.0079	0.0034	20 RO6	0.54
average	0.0473	0.0063	0.0804	0.0002	0.2153	0.3253	0.5331	0.0139	1.2704	0.0424	0.0465	average	2.53
min	0.0086	0.0040	0.0283	0.0001	0.0060	0.0661	0.2597	0.0062	0.0356	0.0019	0.0023	min	0.52
max	0.1317	0.0100	0.2445	0.0004	0.8092	0.9591	1.3000	0.0332	4.2754	0.1508	0.1583	max	7.65
stdev	0.0590	0.0027	0.0884	0.0002	0.3342	0.4026	0.3982	0.0112	1.8887	0.0621	0.0682	stdev	3.18
var	0.0035	0.0000	0.0078	0.0000	0.1117	0.1621	0.1585	0.0001	3.5670	0.0039	0.0046	var	10.1
med	0.0102	0.0049	0.0299	0.0001	0.0219	0.0742	0.3505	0.0074	0.0998	0.0065	0.0049	med	0.54

Table 7: Descriptive Statistics of Hazard Quotient and Hazard Index in Children

	Hazard Quotient (HQ) in Children											HI, children	
	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd		
20 RO1	0.418	0.031	0.777	0.001	2.570	2.258	4.130	0.070	13.581	0.479	0.335	20 RO1	24.65
20 RO2	0.032	0.015	0.091	0.000	0.109	0.210	0.825	0.024	0.381	0.016	0.019	20 RO2	1.72
20 RO3	0.364	0.032	0.386	0.001	1.349	3.047	2.008	0.106	9.641	0.270	0.503	20 RO3	17.71
20 RO4	0.027	0.015	0.098	0.000	0.027	0.251	0.970	0.023	0.243	0.012	0.012	20 RO4	1.68
20 RO5	0.033	0.013	0.092	0.000	0.019	0.214	1.197	0.020	0.113	0.006	0.007	20 RO5	1.71
20 RO6	0.028	0.015	0.090	0.000	0.031	0.220	1.030	0.023	0.254	0.025	0.011	20 RO6	1.73
average	0.150	0.020	0.255	0.001	0.684	1.033	1.693	0.044	4.035	0.135	0.148	average	8.199185
min	0.027	0.013	0.090	0.000	0.019	0.210	0.825	0.020	0.113	0.006	0.007	min	1.68
max	0.418	0.032	0.777	0.001	2.570	3.047	4.130	0.106	13.581	0.479	0.503	max	24.65
stdev	0.187	0.009	0.281	0.001	1.061	1.279	1.265	0.036	5.999	0.197	0.217	stdev	10.29
var	0.035	0.000	0.079	0.000	1.127	1.635	1.600	0.001	35.991	0.039	0.047	var	105.89
med	0.033	0.015	0.095	0.000	0.070	0.236	1.113	0.023	0.317	0.021	0.016	med	1.72

The main contributors for non-carcinogenic health risk in this study area for children is Fe, Mn and Pb. The computed cumulative HI across the trace elements served as a conservative assessment tool to estimate high-end risk rather than low-end risk in order to shield the public from possible health risk (Edokpayi, *et al*., 2018). The hazard index for children ranges from 1.68 to 24.65 with an average of 8.2. Based on these values computed for HI it is observed that exposure to these trace elements could pose adverse health risk to children.

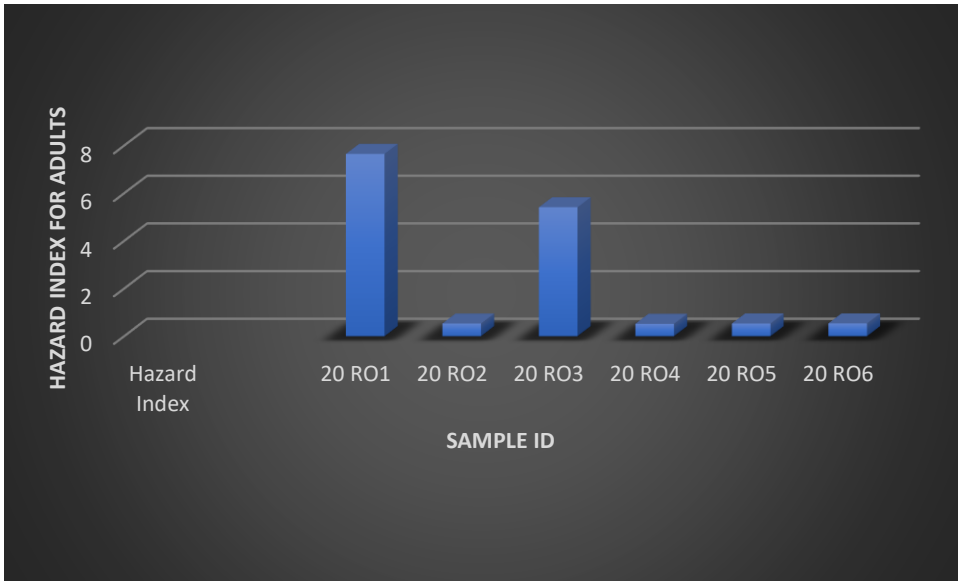

Figure 5: Profile of Hazard Index for Adults

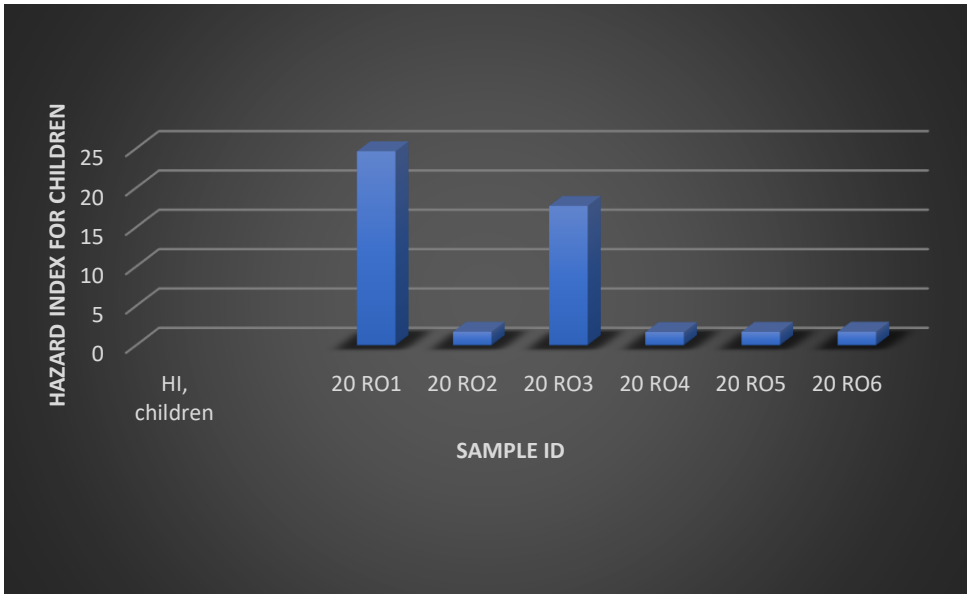

Figure 6: Profile of Hazard Index for Children

Chronic Daily Intake of Trace Elements (CDI): The average CDI values computed for Al, As, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Cd in adults are: 0.039, 7.39E-05, 0.0134, 2.2E-04, 0.0072, 0.189, 0.02, 2.3 E-04, 3.7E-03, 0.01 and 3.87E-05 respectively while that of the children are: 0.15, 0.00028, 0.051, 0.000858, 0.027, 0.723, 0.077, 0.000884, 0.014, 0.04 and 0.000148 respectively (Tables 8 and 9). The following is the order of abundance of the average CDI for adults and children: Fe> Al> Mn> Ba>Zn>Cu>Pb>Ni>Cu>As>Cd respectively. Although, most of the computed values are less than one which show no evidence of non-carcinogenic hazard risk, there are evidence of hazard in values computed for Fe in samples 20R01 (1.58) and 20R03 (2.13). Figures 7 and 8 show CDI profiles for adults and children, respectively.

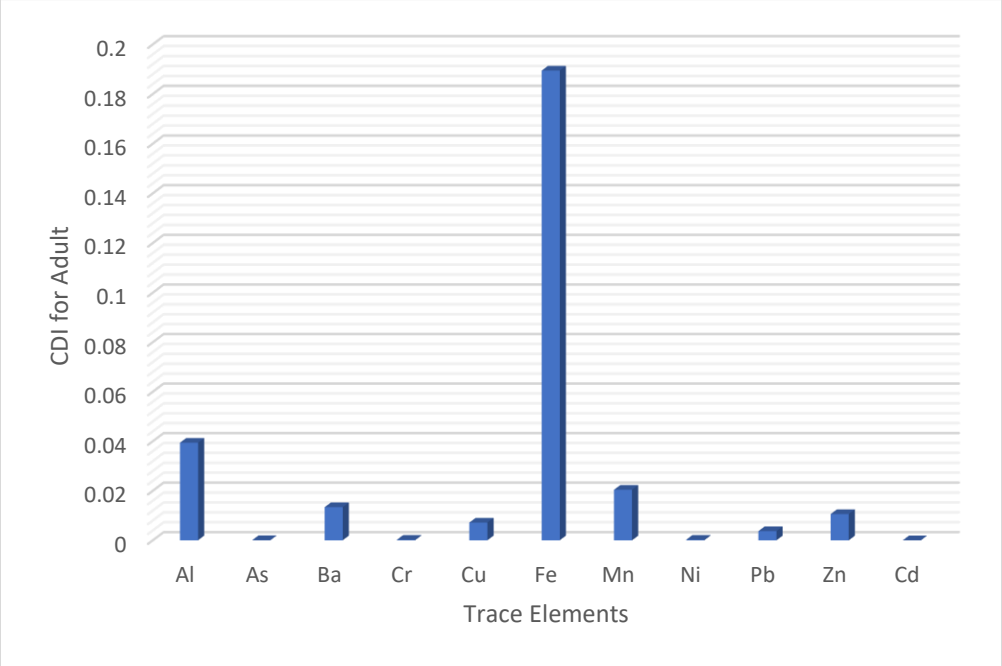

Figure 7: Profile of CDI Average Values for Adults

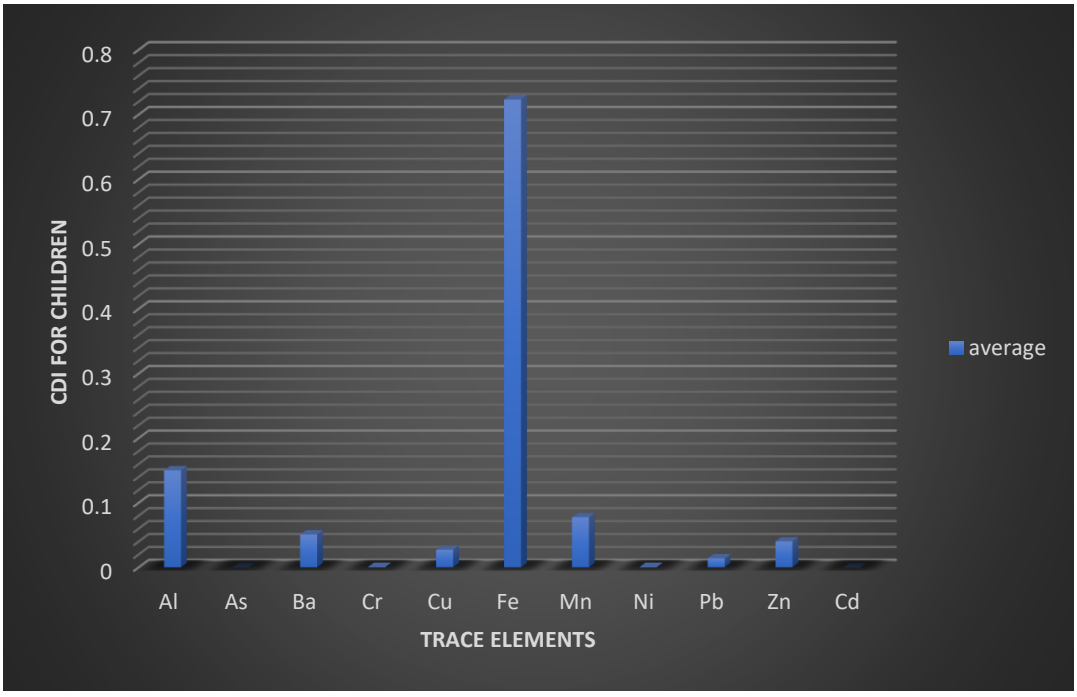

Figure 8: Profile CDI Average Values for Children

Table 8: Statistical Summary of Chronic Daily Intake for Adults

Chronic Daily Intake (CDI) for Adults

Sample ID	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd
20 RO1	0.109591	0.000113143	0.04068	0.000484	0.026928	0.41400857	0.04975	0.000367714	0.012448857	0.037645	8.76857E-05
20 RO2	0.008391	5.65714E-05	0.004762	0.000088	0.001138	0.0385	0.00994	0.000125714	0.000348857	0.001257	5.02857E-06
20 RO3	0.095323	0.000116286	0.020193	0.000477714	0.014133	0.55854857	0.024197	0.000553143	0.008837714	0.021233	0.000131686
20 RO4	0.007134	5.65714E-05	0.005116	9.42857E-05	0.00028	0.04601143	0.011686	0.000119429	0.000223143	0.000905	3.14286E-06
20 RO5	0.008611	4.71429E-05	0.004818	0.000088	0.000198	0.03916	0.014422	0.000103714	0.000103714	0.000471	1.88571E-06
20 RO6	0.00726	5.34286E-05	0.004705	0.000116286	0.000321	0.04035429	0.012407	0.000119429	0.000232571	0.001964	2.82857E-06
average	0.039385	7.38571E-05	0.013379	0.000224714	0.007166	0.18943048	0.0204	0.000231524	0.003699143	0.010579	3.87095E-05
min	0.007134	4.71429E-05	0.004705	0.000088	0.000198	0.0385	0.00994	0.000103714	0.000103714	0.000471	1.88571E-06
max	0.109591	0.000116286	0.04068	0.000484	0.026928	0.55854857	0.04975	0.000553143	0.012448857	0.037645	0.000131686
stdev	0.049067	3.185E-05	0.014716	0.00019869	0.01112	0.23445147	0.015237	0.000186895	0.005499339	0.015511	5.67205E-05
var	0.002408	1.01442E-09	0.000217	3.94776E-08	0.000124	0.05496749	0.000232	3.49297E-08	3.02427E-05	0.000241	3.21721E-09
med	0.008501	5.65714E-05	0.004967	0.000105286	0.000729	0.04318286	0.013414	0.000122571	0.000290714	0.001611	4.08571E-06

Table 9: Statistical Summary of Chronic Daily Intake for Children

	Chronic Daily Intake for children (CDI)										
	Al	As	Ba	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Cd
20 RO1	0.418440	0.000432	0.155324	0.001848	0.102816	1.580760	0.189955	0.001404	0.047532	0.143736	0.000335
20 RO2	0.032040	0.000216	0.018182	0.000336	0.004344	0.147000	0.037952	0.000480	0.001332	0.004800	0.000019
20 RO3	0.363960	0.000444	0.077102	0.001824	0.053964	2.132640	0.092387	0.002112	0.033744	0.081072	0.000503
20 RO4	0.027240	0.000216	0.019532	0.000360	0.001068	0.175680	0.044618	0.000456	0.000852	0.003456	0.000012
20 RO5	0.032880	0.000180	0.018395	0.000336	0.000756	0.149520	0.055064	0.000396	0.000396	0.001800	0.000007
20 RO6	0.027720	0.000204	0.017963	0.000444	0.001224	0.154080	0.047371	0.000456	0.000888	0.007500	0.000011
average	0.150380	0.000282	0.051083	0.000858	0.027362	0.723280	0.077891	0.000884	0.014124	0.040394	0.000148
min	0.027240	0.000180	0.017963	0.000336	0.000756	0.147000	0.037952	0.000396	0.000396	0.001800	0.000007
max	0.418440	0.000444	0.155324	0.001848	0.102816	2.132640	0.189955	0.002112	0.047532	0.143736	0.000503
stdev	0.187346	0.000122	0.056190	0.000759	0.042458	0.895178	0.058178	0.000714	0.020997	0.059224	0.000217
var	0.035098	0.000000	0.003157	0.000001	0.001803	0.801344	0.003385	0.000001	0.000441	0.003507	0.000000
med	0.032460	0.000216	0.018964	0.000402	0.002784	0.164880	0.051218	0.000468	0.001110	0.006150	0.000016

Carcinogenic Risk Assessment (CRing): Carcinogenic risk assessment, defined as the incremental probability that a consumer will develop cancer during his or her lifetime as a result of exposure, was calculated for both adult and children. Table 10 presents the calculated CRing for Ogunpa river water and Figures 10 and 11 present the carcinogenic profiles. The average values of Cr, Cd and Pb for adults are: 0.00054, 7.63E-06 and 0.523 respectively. The average value computed for Cr and Pb are higher than 10^{-6}, which is an indication that the water could pose serious health issue to an individual consuming the water. The average values computed for children are: 0.0017, 2.422E-05 and 1.66 respectively. All the values computed for children are higher than the recommended limits of 10^{-6} which could pose serious carcinogenic health problems for children. The profiles of Carcinogenic Risk for Adults and Children are presented in Figures 9 and 10.

Table 10: Carcinogenic Risk Assessment (CR_{ing}) of Cr, Cd and Pb for Adults and Children

	Carcinogenic risk (CRing) for adults			Carcinogenic Risk (CRing) for children		
Sample ID	Cr	Cd	Pb	Cr	Cd	Pb
20 RO1	0.001163556	1.72787E-05	1.7604444	0.003696	5.48852E-05	5.592
20 RO2	0.000211556	9.90893E-07	0.0493333	0.000672	3.14754E-06	0.156705882
20 RO3	0.001148444	2.5949E-05	1.2497778	0.003648	8.24262E-05	3.969882353
20 RO4	0.000226667	6.19308E-07	0.0315556	0.00072	1.96721E-06	0.100235294
20 RO5	0.000211556	3.71585E-07	0.0146667	0.000672	1.18033E-06	0.046588235
20 RO6	0.000279556	5.57377E-07	0.0328889	0.000888	1.77049E-06	0.104470588
average	0.000540222	7.62781E-06	0.5231111	0.001716	2.42295E-05	1.661647059
min	0.000211556	3.71585E-07	0.0146667	0.000672	1.18033E-06	0.046588235
max	0.001163556	2.5949E-05	1.7604444	0.003696	8.24262E-05	5.592
stdev	0.000477658	1.11769E-05	0.7776843	0.00151727	3.55031E-05	2.470291182
var	2.28157E-07	1.24923E-10	0.6047928	2.3021E-06	1.26047E-09	6.102338525
med	0.000253111	8.051E-07	0.0411111	0.000804	2.55738E-06	0.130588235

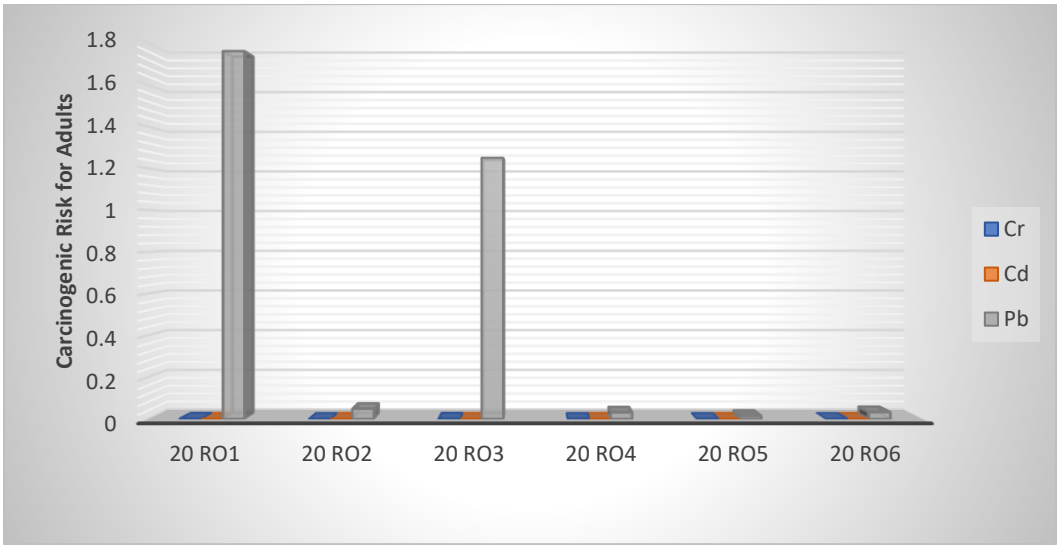

Figure 9: Profile of the Carcinogenic Risk for Adults

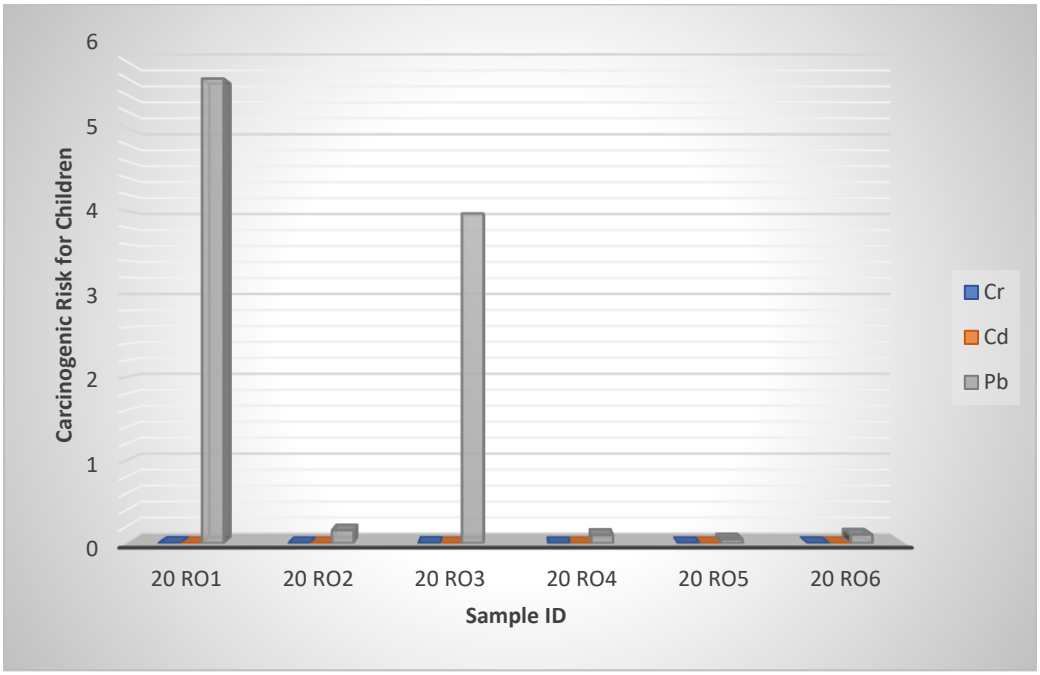

Figure 10: Profile of the Carcinogenic Risk for Children

Conclusion

This study examines the health risk that indiscriminate dumping and discharging of municipal and industrial wastes into Ogunpa River could pose to the consumers. This was carried out empirically using computed contamination Indexes, Average Daily Dose, Hazard Quotient, Hazard Index, Chronic Daily Intake and Carcinogenic Risk. It was concluded based on the results that the water could pose various life-threatening diseases in Adults and Children consumers. Hence, effort should be made to checkmate indiscriminate dumping of refuse and sewages into the body of the water system.

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