



ENVIRONMENTAL IMPACT ASSESSMENT OF OLUYOLE INDUSTRIAL ESTATE ACTIVITIES ON RIVER ONA WATER, IBADAN, NIGERIA: IMPLICATIONS TO HUMAN HEALTH RISK

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Abstract

Environmental impact assessment of Oluyole Industrial Estate activities on river Ona water at Ibadan and its relation to human health risk have been investigated using carcinogenic and non-carcinogenic health parameters. Flame-photometry-technique was used to analysis some of the toxic metals from the water samples taken from the study area. Results shown that Fe, Mn, Ni, Pb and Cd had concentrations higher than WHO standard and their CF are >1 with very high Deg.C. The adults' Exp_{ing} (for Copper, Iron, Manganese, Nickel, Lead and Zinc) computed are >1 while < 1 for all other metals in children except for Co and Cd respectively. The Hazard Quotient calculated for Pb in adults are >1 and the corresponding Hazard Index are generally >1 (that is, of high chronic risk). The HQ of Fe, Mn, Ni and Pb calculated for children are generally >1 in the industrial areas compared to the upstream (except Pb that also has values >1) which are less than 1. The HI are >1 which also depicts high chronic risk. The CDII is >1. CR_{ing} values are greater than prescribed limits of 10⁻⁴ and 10⁻⁶ respectively. As the cause of elemental elevations for Fe, Mn, Ni, Pb and Cd in the water is being controlled mainly by the effluents being discharged by the industries, the rock weathering processes also controlled Cr, Cu, Zn and Cu in the water has illustrated by the value of CF. Hence, the water is both non-carcinogenic and carcinogenic toxic risks to human health.

Keywords: Oluyole, River Ona, non-carcinogenic and carcinogenic risks, contamination factor, degree of contamination

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ABBREVIATIONS:

AT:	This is the average time computed
B _m :	The contextual value of a specific element/metal
B _w :	This is the estimated average body weight (72kg and 15kg for adults and children respectively).
CDI:	Chronic Daily Intake.
CDII:	Chronic Daily Intake Index.
CF:	Contamination Factor
C _m :	Amount of trace element in a specific sample
CR _{ing} :	Carcinogenic Risk.
C _{water} :	This is the average value of metal (s)
Deg.C:	Degree of Contamination
DI:	This is the average litres of water consumed every day.
ED:	This is the number of years of exposure (70 and 6 years for adults and children respectively).
EF:	number of days of exposure per year (three hundred and sixty-five days per year).
Exp _{ing} / ADD:	Exposure Dose through Ingestion/ Average Daily Dose
HI:	Hazard Index.
HQ:	Hazard Quotient.
IR:	This is the average number of litres of water consumed per day (2.72 and 1.8 Litres for adults and children respectively).

R _f D:	This is the reference dose of a particular metal.
SF _{ing} :	This is the carcinogenic slope factor for respective metals.
USEPA:	United States Environmental Protection Agency.
WHO:	World Health Organization

INTRODUCTION

Most Rivers stand as dumping ground for wastes from various activities (agricultural, mining, urbanization, trading, etc.) of man most especially in the municipal areas of the developing world. The various sources of contaminations are very rampant in under developed and developing nations like Nigeria. Nigeria is suffering from series of water contaminations due to improper waste management and the failure of appropriate governmental agencies to curtail unscrupulous discharge of wastes into the environment. These activities of uncontrolled/unregulated waste discharges have caused serious pollution to the ecosystem thereby affecting the lives of aquatic organisms and man. Various carcinogenic and non-carcinogenic health risks have been recorded over the years as a result of these human activities (Adesina, 1986; Frontiers, 1996; Jhingan, 1997; Brown *et al.*, 2008; Olujimi *et al.*, 2015; Asare-Donkor *et al.*, 2016; Edokpayi *et al.*, 2018; Omotoso *et al.*, 2020; Osibanjo *et al.*, 2011; Omotoso *et al.*, 2023). River Ona in Ibadan, Nigeria has its course through Oluyole industrial estate in Ibadan and the industries continually discharge most of their untreated

wastes into this River which serves as tributary for other major Rivers in the Metropolis. Hence, there is the need to really assess the influence of these industrial activities on the river water so that meaningful recommendations could be made to combat the adverse effects of the contaminated water on the health of consumers, most especially man (children and adults).

MATERIALS AND METHODS

The Study area

River Ona (Figure 1) passes through Oluyole Industrial Estate which is situated in Ibadan, Nigeria. The estate harbours several processing industries (e.g., food, beverage, organic chemical, basic steel production, pharmaceuticals, agrochemical processing, auto repair workshop processing industries, etc.). It has been reported that the city is the second largest and third most populated in Africa and Nigeria respectively with about 4 million population (Omoleke, 2004; Adedokun, 2008; Osibanjo *et al.*, 2011; Omotoso *et al.*, 2021). Figure 2 presents the location of the study area. Ibadan environs is positioned within South Western region of the Federal Republic of Nigeria. However, Ibadan is currently on the verge of population, industrialization and socio-economy explosions (Omotoso *et al.*, 2021). Observations from geological field mapping showed that the study area falls within the Pre-Cambrian rocks of South western part of Nigeria. The most common types of rocks in Ibadan environs are: quartzites schist, banded gneiss, augen-gneiss, granite-gneiss and migmatites (Omotoso *et al.*, 2021). Also, pegmatite, aplites, quartz veins and dolerite dykes were seen intruding their host rocks in the metropolis. The main rock type in the selected local area of this study is migmatite as seen in Figure 1.

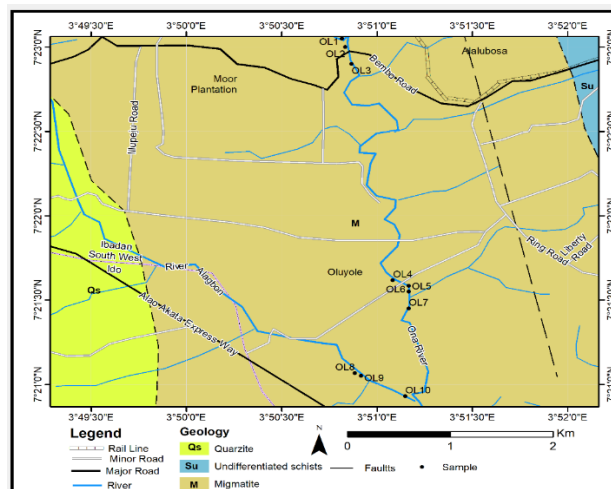


Figure 1: Geological map of the study area indicating the sampling points (NGSA, 2020-

<https://ngsa.gov.ng/geological-map/>)

Data collection

Water samples were collected along the river randomly with the aid of GPS during the dry season. Samples covered the upstream to the industrial areas to delineate any contributions from the industrial sectors. The samples were collected inside well rinsed white plastic bottles laboratory containers. The sampling points were recorded accordingly using the GPS. The collected samples were transported to the laboratory the same day. The following metals were analysed in the laboratory using flame photometry analytical technique: Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn with the model: BUCK Scientific ACCUSYS 211. The locations of the sampling points are shown in Figure 2.

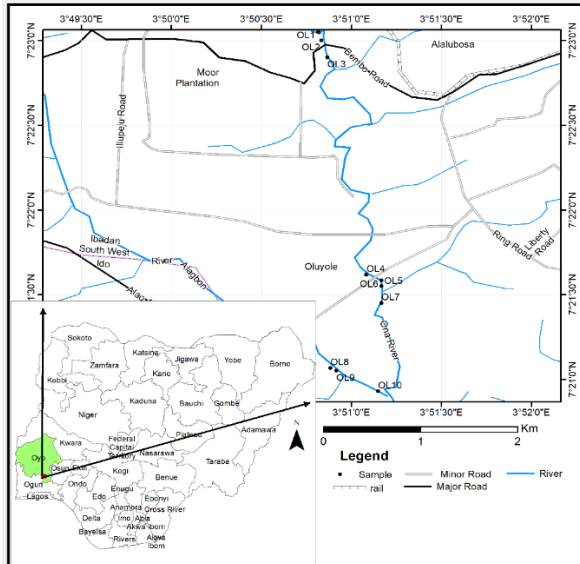


Figure 2: location map of the study area
(retrieve from World Map 2024:
<https://www.openstreetmap.org>)

Hydro-chemical Data Evaluations

The following hydro-chemical parameters were used to evaluate the quality of the river water in relation to health risk implications. They are: comparisons of the elements/metals' concentrations with World Health Organization (WHO) standards, extent of metal loading in the water (using Contamination Factor (CF), Degree of Contamination (Deg.C)), Non-carcinogenic and Carcinogenic Health Risk Parameters through Ingestion. Below are the formulas for computing the health risk parameters:

Contamination Factor:

$$Cf = \frac{Cm}{Bm} \dots\dots\dots \text{Equation 1}$$

Degree of Contamination:

$$Deg.C = \varepsilon \frac{Cm}{Bm} \dots\dots\dots \text{Equation 2}$$

Average Daily Exposure:

$$Exping = \frac{Cwater \cdot IR \cdot EF \cdot ED}{BW \cdot AT} \dots\dots\dots \text{Equation 3}$$

Hazard Quotient:

$$HQ = \frac{ADD}{Rfd} \dots\dots\dots \text{Equation 4}$$

Hazard Index:

$$HI = \sum_{i=1}^n HQ \quad (HI \text{ is the arithmetic sum of } HQ) \dots\dots\dots \text{Equation 5}$$

Chronic Daily Intake:

$$CDI = Cwater * \frac{DI}{Bw} \dots\dots\dots \text{Equation 6}$$

Carcinogenic Risk:

$$CR_{ing} = \frac{Exping}{SFing} \dots\dots\dots \text{Equation 7}$$

RESULTS AND DISCUSSIONS

Hydro-chemical results and discussion:

The analytical results from the laboratory are presented in Table 1 together with their statistical results. *Chromium* in the samples water ranged from 0.011 to 0.069 mg/l. Only one of the samples exceeded the prescribed limit of 0.05 mg/l and the sample falls within the industrial estate where direct discharge of industrial wastes into the river takes place. *Copper* has its range from 0.2 to 0.28 and all fall below the prescribed standard of 2 mg/l. However, the concentrations are relatively more in the industrial area showing some influence of the discharge of waste products into the surrounding river. *Iron* has its range from 6.115 to 10.235 mg/l above the prescribed limit of 0.3 mg/l. The contribution of the industrial discharge into the river is evidence within the industrial area with higher values compared to areas before the industrial estates. *Manganese* ranged from 0.527 to 1.028 mg/l. all the values recorded are higher than the recommendation of 0.5 mg/l. Furthermore, the values are relatively higher in the industrial area than the upstream, before the industrial estates. *Nickel* also ranged from 0.114 to 0.807 mg/l. the values are also greater than the recommendation of 0.02 mg/l. In addition, the values are relatively higher in the industrial areas. The range of *Lead* in the

analyzed water samples is between 0.217 and 0.425 mg/l greater than the recommendation of 0.01 mg/l. The values are also greater in the industrial areas compared to the non-industrialized portion of the river. *Zinc* ranged from 0.111 to 0.154 mg/l with an average of 0.15 mg/l. The values are quite below the recommendations of 3 mg/l. *Cobalt* has a range between 0.003 and 0.034 mg/l which are generally below the recommendation of WHO. However, the values recorded at the industrial side are

relatively higher than that of the non - Industrialized wing of the river. *Cadmium* ranged from 0.004 to 0.018 mg/l which are generally greater than WHO recommendations. The values as well are higher in the industrial area than in the non-industrial areas. When Cd are ingested, it does not easily evacuated from the body, rather stored in the kidney. Cd has been reported to be cancerous. The sources are either geogenic or anthropogenic.

Table 1: Hydro-chemical analysis results of the trace metals in Ona River around Oluyole industrial estate, Ibadan, Nigeria with its descriptives statistical computations

Sample Codes	Coordinates	Metals, mg/l								
		Cr	Cu	Fe	Mn	Ni	Pb	Zn	Co	Cd
OL 1	7°23'03"N ; 3°50'49"E	0.014	0.205	6.735	0.837	0.114	0.274	0.153	0.003	0.004
OL 2	7°32'60"N ; 3°50'50"E	0.011	0.202	6.524	0.652	0.123	0.217	0.111	0.003	0.004
OL 3	7°22'54"N ; 3°50'52"E	0.018	0.201	6.115	0.619	0.123	0.225	0.116	0.003	0.004
OL 4	7°21'37"N ; 3°51'05"E	0.018	0.207	6.799	0.677	0.125	0.285	0.149	0.004	0.005
OL 5	7°21'35"N ; 3°51'10"E	0.016	0.209	6.117	0.527	0.124	0.225	0.113	0.003	0.006
OL 6	7°21'33"N ; 3°51'10"E	0.011	0.224	7.538	0.953	0.225	0.299	0.151	0.003	0.006
OL 7	7°21'27"N ; 3°51'10"E	0.069	0.272	10.221	1.019	0.807	0.425	0.154	0.034	0.017
OL 8	7°21'04"N ; 3°50'53"E	0.031	0.256	9.693	1.025	0.406	0.329	0.148	0.032	0.018
OL 9	7°21'03"N ; 3°50'55"E	0.028	0.277	9.792	1.014	0.405	0.324	0.146	0.031	0.016
OL 10	7°20'55"N ; 3°51'15"E	0.038	0.237	10.235	1.028	0.406	0.355	0.127	0.032	0.015
mean		0.025	0.229	7.977	0.835	0.286	0.296	0.137	0.015	0.010
minimum		0.011	0.201	6.115	0.527	0.114	0.217	0.111	0.003	0.004
maximum		0.069	0.277	10.235	1.028	0.807	0.425	0.154	0.034	0.018
median		0.018	0.217	7.169	0.895	0.175	0.292	0.147	0.004	0.006
standard deviation		0.018	0.030	1.781	0.198	0.224	0.066	0.018	0.015	0.006
variance		0.0003	0.0009	3.1704	0.0392	0.0503	0.0043	0.0003	0.0002	0.00004
WHO, ppm		0.05	2	0.3	0.5	0.02	0.01	3	0.1	0.003

Human health implications of the elevated metals' concentrations in the water of the study area:

The following elements in the river water have average values higher than the prescribed limits of WHO: Fe, Mn, Ni, Pb and Cd. Excess ***Iron*** in man causes haemochromatosis with the following health symptoms: fatigue, joint pains, weight loss, liver and diabetes issues. Water with excess iron leads to rashes, itching, problem in normal breathing, mouth swelling and stomach upsets (Wada, 2004; US-CDC,

2011; Utete and Fregene, 2020; Omotoso *et al.*, 2023). ***Manganese*** causes taste and stain issues which may be very critical (DWAf, 1996; WHO, 2006; Edokpayi *et al.*, 2018; Omotoso *et al.*, 2021). High level of ***Nickel*** in water causes neurological and gastrointestinal anomalies. It also causes allergic reaction. It causes stomach aches, multiplies red blood corpuscles and also elevates the level of protein in the urine. (ATSDR, 2005). ***Lead*** is a dangerous neurotoxin element which damages the human brain. It also damages kidneys and inhibits the production of red blood

corpuscles (Levallois *et al.*, 2018). Cadmium is stored in the kidney which can lead to kidney disease and can cause various kinds of cancers in the internal organs of man and animals (Genchi *et al.*, (2020).

Extent of Metal Loading in the Water Phase:

This was determined by the use of Contamination Factor and Degree of Contamination. The Contamination Factors of Cr, Cu, Zn and Co are generally less than

one (low contamination factor) except Cr in sample OL7 with CF of 1.38 (moderate contamination factor). This depicts the influence of geogenic factors above the anthropogenic factor (Tijani *et al.*, 2007; Omotoso *et al.*, 2023). Fe, Mn, Ni, Pb and Cd have values greater than one and this depicts the influence of anthropogenic activities in the area. The Degree of Contamination ranged from 58 to 167 (that is, very high degree of contamination), Atiemo, 2011. Table 2 gives a presentation of the statistical summaries of the contamination indexes.

Table 2: Statistical computations result of Contamination indexes of the water in the area of study

Contamination Factor												
S/Code	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Co	Cd	S/Code	Degree of Contamination	Interpretation, Atiemo et al., 2011
OL 1	0.28	0.10	22.45	1.67	11.40	27.40	0.05	0.03	1.33	OL 1	65	very high degree of contamination
OL 2	0.22	0.10	21.75	1.30	12.30	21.70	0.04	0.03	1.33	OL 2	59	very high degree of contamination
OL 3	0.36	0.10	20.38	1.24	12.30	22.50	0.04	0.03	1.33	OL 3	58	very high degree of contamination
OL 4	0.36	0.10	22.66	1.35	12.50	28.50	0.05	0.04	1.67	OL 4	67	very high degree of contamination
OL 5	0.32	0.10	20.39	1.05	12.40	22.50	0.04	0.03	2.00	OL 5	59	very high degree of contamination
OL 6	0.22	0.11	25.13	1.91	22.50	29.90	0.05	0.03	2.00	OL 6	82	very high degree of contamination
OL 7	1.38	0.14	34.07	2.04	80.70	42.50	0.05	0.34	5.67	OL 7	167	very high degree of contamination
OL 8	0.62	0.13	32.31	2.05	40.60	32.90	0.05	0.32	6.00	OL 8	115	very high degree of contamination
OL 9	0.56	0.14	32.64	2.03	40.50	32.40	0.05	0.31	5.33	OL 9	114	very high degree of contamination
OL 10	0.76	0.12	34.12	2.06	40.60	35.50	0.04	0.32	5.00	OL 10	119	very high degree of contamination
mean	0.51	0.11	26.59	1.67	28.58	29.58	0.05	0.15	3.17	mean	90	
minimum	0.22	0.10	20.38	1.05	11.40	21.70	0.04	0.03	1.33	minimum	58	
maximum	1.38	0.14	34.12	2.06	80.70	42.50	0.05	0.34	6.00	maximum	167	
median	0.36	0.11	23.90	1.79	17.50	29.20	0.05	0.04	2.00	median	75	
standard deviation	0.36	0.01	5.94	0.40	22.44	6.58	0.01	0.15	2.04	standard deviation	37	
variance	0.13	0.00	35.23	0.16	503.34	43.26	0.00	0.02	4.15	variance	1344	

Human health risk assessment of river Ona water at Oluyole industrial estate environs:

This is evaluated by adopting human health risk parameters such as: Exposed Dose (Average Daily Dose), Hazard Quotient, Hazard Index, Chronic Daily Intake and Carcinogenic Risk for both adults and children. Tables 3 to 6 give the statistical illustrations of these parameters. The adults' average values computed for Exposure Dose by ingestion (measured in $\mu\text{g/kg/day}$) are significantly greater than one in Cu (8.65), Fe (301.35), Mn (31.55), Ni (10.80), Pb (11.17) and Zn (5.17) but less than one in Cr (0.96), Co (0.56) and Cd (0.35). In children, the values are also significantly >1 for Cr (3), Cu (19), Fe (653), Mn (68), Ni (23), Pb (35) and Zn (11) but less than one in Co (0.47) and Cd

(0.30). This is an indication of contributions from the industrial discharges because values are higher in the industrial areas than in the upstream where there is little or no industries. The adults HQ for Cr, Cu, Fe, Mn, Ni, Zn, Co and Cd are relatively less than one except Ni in sample OL7 (that is, 1.52). Only Pb has HQ greater than 1 and the value ranged from 2.3 to 4.587 above the prescribed limit of 1 (USEPA 1989). Consequently, the HI in adults ranged from 4 to 8 depicting high chronic risk. Similarly, the HQ computed for children is lower than 1 in Cr, Cu, Zn, Co and Cd and greater than 1 in Mn (except in sample OL5, 0.937), Pb and part of Fe and Ni. The HI for children ranged from 10.44 to 22.05 and this gives an indication of high chronic risk in ingestion by children. The CDI for

adults is generally below unity and the index ranged from 0.285 to 0.516 (Table 5). This posed a threat to the consumers. The CDI for children is generally lower than 1 for all the elements except in the downstream around the industrial areas for Fe. The chronic Daily Index ranged from 0.8 to 1.56. Hence, 50% of the samples (downstream, around the industrial areas) are above 1 which indicates a risk hazard for children. The Carcinogenic

Risk (measured) was computed using Cr, Pb and Cd for both the adults and the children (Table 6). In adults, it ranged from 0.000831 to 0.005213, 0.96 to 1.88 and 2×10^{-5} to 10^{-4} , 11×10^{-5} respectively for Cr, Pb and Cd which actually exceeded the prescribed limit of 10^{-4} and 10^{-6} respectively. In children, CR ranged from 0.00264 to 0.01656, 3.06 to 6 and 2×10^{-5} to 9.27×10^{-5} which exceeded the prescribed limit as well.

Table 3: Statistical computations of the exposure dose for all the age groups (in $\mu\text{g/kg/day}$)

Average Daily Dose for Adults									
Sample Code	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Co	Cd
OL 1	0.53	7.74	254.43	31.62	4.31	10.35	5.78	0.11	0.15
OL 2	0.42	7.63	246.46	24.63	4.65	8.20	4.19	0.11	0.15
OL 3	0.68	7.59	231.01	23.38	4.65	8.50	4.38	0.11	0.15
OL 4	0.68	7.82	256.85	25.58	4.72	10.77	5.63	0.15	0.19
OL 5	0.60	7.90	231.09	19.91	4.68	8.50	4.27	0.11	0.23
OL 6	0.42	8.46	284.77	36.00	8.50	11.30	5.70	0.11	0.23
OL 7	2.61	10.28	386.13	38.50	30.49	16.06	5.82	1.28	0.64
OL 8	1.17	9.67	366.18	38.72	15.34	12.43	5.59	1.21	0.68
OL 9	1.06	10.46	369.92	38.31	15.30	12.24	5.52	1.17	0.60
OL 10	1.44	8.95	386.66	38.84	15.34	13.41	4.80	1.21	0.57
average	0.96	8.65	301.35	31.55	10.80	11.17	5.17	0.56	0.36
minimum	0.42	7.59	231.01	19.91	4.31	8.20	4.19	0.11	0.15
maximum	2.61	10.46	386.66	38.84	30.49	16.06	5.82	1.28	0.68
standard deviation	0.67	1.12	67.27	7.48	8.48	2.48	0.68	0.57	0.23
variance	0.45	1.26	4524.70	56.00	71.84	6.17	0.46	0.32	0.05
median	0.68	8.18	270.81	33.81	6.61	11.03	5.55	0.13	0.23
Average Daily Dose for Children									
Sample Code	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Co	Cd
OL 1	1.68	16.77	551.05	68.48	9.33	32.88	12.52	0.09	0.13
OL 2	1.32	16.53	533.78	53.35	10.06	26.04	9.08	0.09	0.13
OL 3	2.16	16.45	500.32	50.65	10.06	27.00	9.49	0.09	0.13
OL 4	2.16	16.94	556.28	55.39	10.23	34.20	12.19	0.13	0.16
OL 5	1.92	17.10	500.48	43.12	10.15	27.00	9.25	0.09	0.19
OL 6	1.32	18.33	616.75	77.97	18.41	35.88	12.35	0.09	0.19
OL 7	8.28	22.25	836.26	83.37	66.03	51.00	12.60	1.07	0.53
OL 8	3.72	20.95	793.06	83.86	33.22	39.48	12.11	1.01	0.57
OL 9	3.36	22.66	801.16	82.96	33.14	38.88	11.95	0.97	0.50
OL 10	4.56	19.39	837.41	84.11	33.22	42.60	10.39	1.01	0.47
average	3.05	18.74	652.66	68.33	23.38	35.50	11.19	0.47	0.30
minimum	1.32	16.45	500.32	43.12	9.33	26.04	9.08	0.09	0.13
maximum	8.28	22.66	837.41	84.11	66.03	51.00	12.60	1.07	0.57
standard deviation	2.13	2.43	145.68	16.21	18.36	7.89	1.46	0.47	0.19
variance	4.54	5.91	21223.49	262.67	336.95	62.29	2.14	0.22	0.04
median	2.16	17.71	586.51	73.23	14.32	35.04	12.03	0.11	0.19

Table 4: statistical computations and results of all the age groups Hazard Quotient and Hazard Indexes with interpretations

HQ, Male Adults												HI, Adult	Interpretation, USEPA 1989
S/Code	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Co	Cd	S/Code			
OL 1	0.0004	0.1936	0.3635	0.6874	0.2153	2.9575	0.0193	0.0038	0.1511	OL 1		5	High Chronic Risk
OL 2	0.0003	0.1908	0.3521	0.5355	0.2323	2.3422	0.0140	0.0038	0.1511	OL 2		4	High Chronic Risk
OL 3	0.0005	0.1898	0.3300	0.5084	0.2323	2.4286	0.0146	0.0038	0.1511	OL 3		4	High Chronic Risk
OL 4	0.0005	0.1955	0.3669	0.5560	0.2361	3.0762	0.0188	0.0050	0.1889	OL 4		5	High Chronic Risk
OL 5	0.0004	0.1974	0.3301	0.4328	0.2342	2.4286	0.0142	0.0038	0.2267	OL 5		4	High Chronic Risk
OL 6	0.0003	0.2116	0.4068	0.7827	0.4250	3.2273	0.0190	0.0038	0.2267	OL 6		5	High Chronic Risk
OL 7	0.0017	0.2569	0.5516	0.8369	1.5243	4.5873	0.0194	0.0428	0.6422	OL 7		8	High Chronic Risk
OL 8	0.0008	0.2418	0.5231	0.8418	0.7669	3.5511	0.0186	0.0403	0.6800	OL 8		7	High Chronic Risk
OL 9	0.0007	0.2616	0.5285	0.8328	0.7650	3.4971	0.0184	0.0390	0.6044	OL 9		7	High Chronic Risk
OL 10	0.0010	0.2238	0.5524	0.8443	0.7669	3.8317	0.0160	0.0403	0.5667	OL 10		7	High Chronic Risk
mean	0.0006	0.2163	0.4305	0.6858	0.5398	3.1928	0.0172	0.0186	0.3589	mean		5	
minimum	0.0003	0.1898	0.3300	0.4328	0.2153	2.3422	0.0140	0.0038	0.1511	minimum		4	
maximum	0.0017	0.2616	0.5524	0.8443	1.5243	4.5873	0.0194	0.0428	0.6800	maximum		8	
standard deviation	0.0004	0.0281	0.0961	0.1627	0.4238	0.7099	0.0023	0.0189	0.2310	standard deviation		2	
variance	0.0000	0.0008	0.0092	0.0265	0.1796	0.5040	0.0000	0.0004	0.0534	variance		3	
median	0.0005	0.2045	0.3869	0.7350	0.3306	3.1517	0.0185	0.0044	0.2267	median		5	

HQ in children, through ingestion												HI, children	Interpretation, USEPA 1989
S/Code	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Co	Cd	S/Code			
OL 1	0.001	0.419	0.787	1.489	0.466	9.394	0.042	0.003	0.126	OL 1		12.73	High Chronic Risk
OL 2	0.001	0.413	0.763	1.160	0.503	7.440	0.030	0.003	0.126	OL 2		10.44	High Chronic Risk
OL 3	0.001	0.411	0.715	1.101	0.503	7.714	0.032	0.003	0.126	OL 3		10.61	High Chronic Risk
OL 4	0.001	0.423	0.795	1.204	0.511	9.771	0.041	0.004	0.157	OL 4		12.91	High Chronic Risk
OL 5	0.001	0.428	0.715	0.937	0.507	7.714	0.031	0.003	0.189	OL 5		10.53	High Chronic Risk
OL 6	0.001	0.458	0.881	1.695	0.920	10.251	0.041	0.003	0.189	OL 6		14.44	High Chronic Risk
OL 7	0.006	0.556	1.195	1.812	3.301	14.571	0.042	0.036	0.534	OL 7		22.05	High Chronic Risk
OL 8	0.002	0.524	1.133	1.823	1.661	11.280	0.040	0.034	0.566	OL 8		17.06	High Chronic Risk
OL 9	0.002	0.567	1.145	1.804	1.657	11.109	0.040	0.032	0.503	OL 9		16.86	High Chronic Risk
OL 10	0.003	0.485	1.196	1.828	1.661	12.171	0.035	0.034	0.471	OL 10		17.88	High Chronic Risk
mean	0.002	0.468	0.932	1.485	1.169	10.142	0.037	0.016	0.299	mean		14.55	
minimum	0.001	0.411	0.715	0.937	0.466	7.440	0.030	0.003	0.126	minimum		10.44	
maximum	0.006	0.567	1.196	1.828	3.301	14.571	0.042	0.036	0.566	maximum		22.05	
standard deviation	0.001	0.061	0.208	0.352	0.918	2.255	0.005	0.016	0.192	standard deviation		3.85	
variance	0.000	0.004	0.043	0.124	0.842	5.085	0.000	0.000	0.037	variance		14.86	
median	0.001	0.443	0.838	1.592	0.716	10.011	0.040	0.004	0.189	median		13.67	

Table 5: Statistical computations for daily chronic intake and daily chronic intake index for all the age groups

CDI for Children											
Sample Code	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Co	Cd	Sample Code	CDI Index
OL 1	0.0017	0.0246	0.8082	0.1004	0.0137	0.0329	0.0184	0.0004	0.0005	OL 1	1.00
OL 2	0.0013	0.0242	0.7829	0.0782	0.0148	0.0260	0.0133	0.0004	0.0005	OL 2	0.94
OL 3	0.0022	0.0241	0.7338	0.0743	0.0148	0.0270	0.0139	0.0004	0.0005	OL 3	0.89
OL 4	0.0022	0.0248	0.8159	0.0812	0.0150	0.0342	0.0179	0.0005	0.0006	OL 4	0.99
OL 5	0.0019	0.0251	0.7340	0.0632	0.0149	0.0270	0.0136	0.0004	0.0007	OL 5	0.88
OL 6	0.0013	0.0269	0.9046	0.1144	0.0270	0.0359	0.0181	0.0004	0.0007	OL 6	1.13
OL 7	0.0083	0.0326	1.2265	0.1223	0.0968	0.0510	0.0185	0.0041	0.0020	OL 7	1.56
OL 8	0.0037	0.0307	1.1632	0.1230	0.0487	0.0395	0.0178	0.0038	0.0022	OL 8	1.43
OL 9	0.0034	0.0332	1.1750	0.1217	0.0486	0.0389	0.0175	0.0037	0.0019	OL 9	1.44
OL 10	0.0046	0.0284	1.2282	0.1234	0.0487	0.0426	0.0152	0.0038	0.0018	OL 10	1.50
average	0.0030	0.0275	0.9572	0.1002	0.0343	0.0355	0.0164	0.0018	0.0011	average	1.18
minimum	0.0013	0.0241	0.7338	0.0632	0.0137	0.0260	0.0133	0.0004	0.0005	minimum	0.88
maximum	0.0083	0.0332	1.2282	0.1234	0.0968	0.0510	0.0185	0.0041	0.0022	maximum	1.56
standard deviation	0.0021	0.0036	0.2137	0.0238	0.0269	0.0079	0.0021	0.0018	0.0007	standard deviation	0.27
variance	0.0000	0.0000	0.0457	0.0006	0.0007	0.0001	0.0000	0.0000	0.0000	variance	0.08
median	0.0022	0.0260	0.8602	0.1074	0.0210	0.0350	0.0176	0.0004	0.0007	median	1.06

CDI for Adults											
Sample Code	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Co	Cd	Sample Code	CDI Index
OL 1	0.0005	0.0080	0.2617	0.0325	0.0044	0.0106	0.0059	0.0001	0.0002	OL 1	0.32
OL 2	0.0004	0.0078	0.2535	0.0253	0.0048	0.0084	0.0043	0.0001	0.0002	OL 2	0.30
OL 3	0.0007	0.0078	0.2376	0.0241	0.0048	0.0087	0.0045	0.0001	0.0002	OL 3	0.29
OL 4	0.0007	0.0080	0.2642	0.0263	0.0049	0.0111	0.0058	0.0002	0.0002	OL 4	0.32
OL 5	0.0006	0.0081	0.2377	0.0205	0.0048	0.0087	0.0044	0.0001	0.0002	OL 5	0.29
OL 6	0.0004	0.0087	0.2929	0.0370	0.0087	0.0116	0.0059	0.0001	0.0002	OL 6	0.37
OL 7	0.0027	0.0106	0.3972	0.0396	0.0314	0.0165	0.0060	0.0013	0.0007	OL 7	0.51
OL 8	0.0012	0.0099	0.3766	0.0398	0.0158	0.0128	0.0058	0.0012	0.0007	OL 8	0.46
OL 9	0.0011	0.0108	0.3805	0.0394	0.0157	0.0126	0.0057	0.0012	0.0006	OL 9	0.47
OL 10	0.0015	0.0092	0.3977	0.0399	0.0158	0.0138	0.0049	0.0012	0.0006	OL 10	0.48
average	0.0010	0.0089	0.3100	0.0324	0.0111	0.0115	0.0053	0.0006	0.0004	average	0.38
minimum	0.0004	0.0078	0.2376	0.0205	0.0044	0.0084	0.0043	0.0001	0.0002	minimum	0.29
maximum	0.0027	0.0108	0.3977	0.0399	0.0314	0.0165	0.0060	0.0013	0.0007	maximum	0.51
standard deviation	0.0007	0.0012	0.0692	0.0077	0.0087	0.0026	0.0007	0.0006	0.0002	standard deviation	0.09
variance	0.0000	0.0000	0.0048	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000	variance	0.01
median	0.0007	0.0084	0.2785	0.0348	0.0068	0.0113	0.0057	0.0001	0.0002	median	0.34

Table 6: Statistical computations of Carcinogenic Risk for all the age groups

Carcinogenic Risk for Adults			
S/Code	Cr	Pb	Cd
OL 1	0.00106	1.21778	0.00002
OL 2	0.00083	0.96444	0.00002
OL 3	0.00136	1.00000	0.00002
OL 4	0.00136	1.26667	0.00003
OL 5	0.00121	1.00000	0.00004
OL 6	0.00083	1.32889	0.00004
OL 7	0.00521	1.88889	0.00011
OL 8	0.00234	1.46222	0.00011
OL 9	0.00212	1.44000	0.00010
OL 10	0.00287	1.57778	0.00009
average	0.00192	1.31467	0.00006
minimum	0.00083	0.96444	0.00002
maximum	0.00521	1.88889	0.00011
standard deviation	0.00134	0.29231	0.00004
variance	0.00000	0.08545	0.00000
median	0.00136	1.29778	0.00004
Carcinogenic Risk for Children			
S/Code	Cr	Pb	Cd
OL 1	0.00336	3.86824	0.00002
OL 2	0.00264	3.06353	0.00002
OL 3	0.00432	3.17647	0.00002
OL 4	0.00432	4.02353	0.00003
OL 5	0.00384	3.17647	0.00003
OL 6	0.00264	4.22118	0.00003
OL 7	0.01656	6.00000	0.00009
OL 8	0.00744	4.64471	0.00009
OL 9	0.00672	4.57412	0.00008
OL 10	0.00912	5.01176	0.00008
average	0.00610	4.17600	0.00005
minimum	0.00264	3.06353	0.00002
maximum	0.01656	6.00000	0.00009
standard deviation	0.00426	0.92852	0.00003
variance	0.00002	0.86215	0.00000
median	0.00432	4.12235	0.00003

CONCLUSION

The environmental impact assessments of Oluyole Industrial estate activities on River Ona, Ibadan metropolitan have been partly established using the various carcinogenic and non-carcinogenic risk parameters. The laboratory analysis results have shown that the concentrations of Fe (range, 6 to 10 mg/l), Mn (range, 0.5 to 1.0 mg/l), Ni (range, 0.11 to 0.81 mg/l), Pb (range, 0.22 to 0.43 mg/l), and Cd (range, 0.004 to 0.018 mg/l) in the river water are above the recommendations of World Health Organization for portable water

consumption. Some of these elements do cause liver, kidney, lungs and gastrointestinal disorders which may ultimately lead to death. The metal loading computations indicated that Fe, Mn, Ni, Pb and Cd have CF greater than 1 which depicts influences or contributions from anthropogenic activities in the area. The other elements (Cr, Cu, Zn and Co) are being controlled by the weathering of the rock type in the area with values of CF < 1. The Deg.C computed also falls within very high degree of contamination (range, 58 to 167).

Furthermore, the non-carcinogenic health risk parameters have shown that:

- the average values of Daily Exposure Dose ($\mu\text{g/kg/day}$) through ingestion ranged from 0.36 (Cd) to 301 (Fe) in adults and 0.3 (Cd) to 653 (Fe) in children above the recommendation of unity;
- the average HQ ranged between 0.00064 (in Cr) and 3.19 (in Pb) for adults and 0.002 (in Cr) and 10.14 (in Pb) for children;
- HI from adults ranged from 4 to 8 and from 10.44 to 22.05 in children which made the water of high chronic risk;
- the chronic daily intake index (sum of the chronic daily intake in each sample) ranged from 0.89 to 1.56. Hence, 50% of the chronic daily intake index is greater than 1 in children while in adult the index ranged from 0.285 to 0.516.

The CR_{ing} for Cr, Pb and Cd ranged from 0.000831 to 0.0052, 0.96 to 1.89 and 0.000025 to 0.000111 respectively (in adults) and from 0.00264 to 0.017, 3.06 to 6.0 and 2E-05 to 9.27E-05 (in children) above the prescribed limits of 10^{-4} and 10^{-6} respectively. The CR computed for both adults and children indicated that the water is of carcinogenic health risk to the consumers. The sources of river water contamination are

mainly from the industrial and municipal waste discharges above a little contribution from the weathering of the migmatitic rock type in the area.

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