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Assessment of pollution status and health risk in Nwangele local government area: case study of Onuezuze river

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Abstract

This study was carried out to assess the pollution status and health risk assessment in wet and dry season in Onuezuze River in Nwangele local government area of Imo State using some chemometric models to assess the pollution levels. The water samples were collected from the upstream, midstream and downstream of the river and were homogenized to form composite samples. The results obtained were compared with the World Health Organization (WHO) standards. The Do in wet season was 5.45±0.31 mg/L and 3.45±0.43 for dry season. The wet season has the electrical conductivity as 176.33±3.81 and 145.34±5.70 for dry. Though, the highest electrical conductivity from this present study were recorded for ON_1 (179.21) for the wet season and 147.27 for the dry season. In the current study, TDS for wet and dry seasons ranges from 104.71-±2.29 and 96.78±3.38 mg/L. Calcium in this study shows 4.37±0.40 in wet and 3.33±0.03 in dry. Sodium shows 5.59±0.31 in wet and 4.77±0.35 in dry season. Potassium was 5.28±0.14 for wet and 3.75±0.29 for dry. The phosphate showed 17.16±0.70 in wet and 16.25±1.45 in dry. Nitrate showed 20.81±0.77 in wet season and 19.54±0.87 in dry. Sulphate was 11.47±0.34 in wet and 10.23±1.48 in dry. The contamination factor in surface water was Pb (61.66) > Ni (31.00) > Fe (3.53) > Zn (1.49) > Cu (0.32) > Mn (0.09) > Cd (0.00) for wet season and Ni (71.5) > Pb (41.33) > Fe (8.28) > Zn (1.16) > Mn (0.08) > Cu (0.05) > Cd (0.00) in dry season. The HQin and HQderm diminished in the order of nickel > zinc > copper > lead > manganese > iron and zinc > nickel > manganese > iron > copper > lead for both children and adults in wet season, respectively. HQin and HQderm decreases in the order of nickel > zinc > iron > lead > manganese > copper and zinc > nickel > iron > lead > manganese > copper for both children and adults in dry season, the average levels of CRing for Pb ranged between 2.2E−3 – 1.58E−3 for adults in wet and dry season and 8.16E−3 – 6.07E−3 for children in wet and dry season. The surface water resources in this study area must have been contaminated with physiological tracer due to high pollution load index. There is every need for urgent and proper examination of this surface water sources in this area by the environmental agencies.

1. Introduction

Nature has blessed man with good environment but man on his daily activities has caused harm to the nature and environment through the mode of pollution. The environment fundamentally means the surroundings which comprises living existences like animals (birds, insects, man, micro-organisms) and non-living things which include air, water, soil that interact with each other to sustain a steady ecosystem, which makes the environment a supporting and satisfying system [1, 2]. Water is the second to importance after air and it forms a habitant to aquatic animals, therefore protecting our water is most paramount since it is used for day to day and metabolic processes. Water can be seen as the chemical substance which is essential to all known forms of life [3]. It is seen as colourless to the bare eye in small measurable amount, though it is really slightly blue in colour [4]. Generally, surface waters consist of streams, rivers, reservoirs, lakes, and wetlands. Stream is applied to exemplify other flowing surface waters, starting from brooks to the large rivers [5, 6].

Many researchers have assessed the surface water quality of from urban areas for their physiochemical, health risk and nutrients content in Imo state, Nigeria. Verla *et al.* [7] Worked on the water pollution scenario at river uramurukwa flowing through owerri metropolis, Imo state, Nigeria and discovered that the River is polluted with Cd and Pb, which are highly toxic metals which can cause serious health damages even at low concentration. Emmanuel and Chukwudi [8] Worked on water analysis on Nwaorie and Otamiri Rivers in Owerri and come to conclusion that River Nwaorie is more impacted than River Otamiri. They found out that the surface rivers contained high level of iron values. The high level of iron observed from the study could be harmful to human health if the river water is consumed without treatment. Anudike *et al.* [9] did a work on water quality assessment of Nwangele River in Imo State, Nigeria, they come to a conclusion that Nwangele River water is acidic, with high total suspended solid, phosphate and microbial loads.

There has not been any research work on Onuezuze River and this current study will form a base line for this subject. The major occupation in these areas are farming with few traders. The farming activities have important bearing on the ecology of the area. Daily activities in these rivers include; washing and fermentation of cassava, bathing, fishing etc. The inhabitants of these area depend on these rivers for their domestic and recreational purposes without proper knowledge of the river water quality and possible health implications. The aim of this work is to assess the pollution status and health risk assessment due to heavy in surface water sources in the study area.

2. Methodology

2.1 Study Area

Onuezuze is in Amaigbo and one of the major rivers in Nwangele local government area, Imo state Nigeria. Nwangele is in the tropical rainforest region and it has two different season which are the dry and wet the seasons and this research work were assessed during this two seasons. The wet season switches from April all the way through October yearly. Headquarter of Nwangele is in Amaigbo. It has an area of 63 km2 (24 sq mi) and a population of 128,472 as of the 2006 census according to Post offices. Being an Igbo community, the inhabitants of this communities are predominantly Igbos and they are Christians with very few traditionalists and other religion. Their major occupation is few traders with majorly farming as the key occupation for the inhabitants of these communities which have very important bearing on the ecology of the area.

2.2 Types and Sources of Data

The primary set of data were obtained from direct field survey which includes water samples from Okumpi River and some direct questions and interviews from the inhabitants of this community. The secondary data sources include all materials and facts from articles, textbook, journals and other publications. Standards from [10, 11] were utilized as part of the secondary sources. Table 1 and Figure 1 below show the coordinate of sampling points and Map showing Onuezuze River its environs.

Table 1: Coordinates of Sampling Points

S/N	Sampling Points	Longitude	Latitude
1	ON_1	7.19802145879	5.6256987455
2	ON_2	7.19843824617	5.6267037246
3	ON_3	7.19896587455	5.6265987455

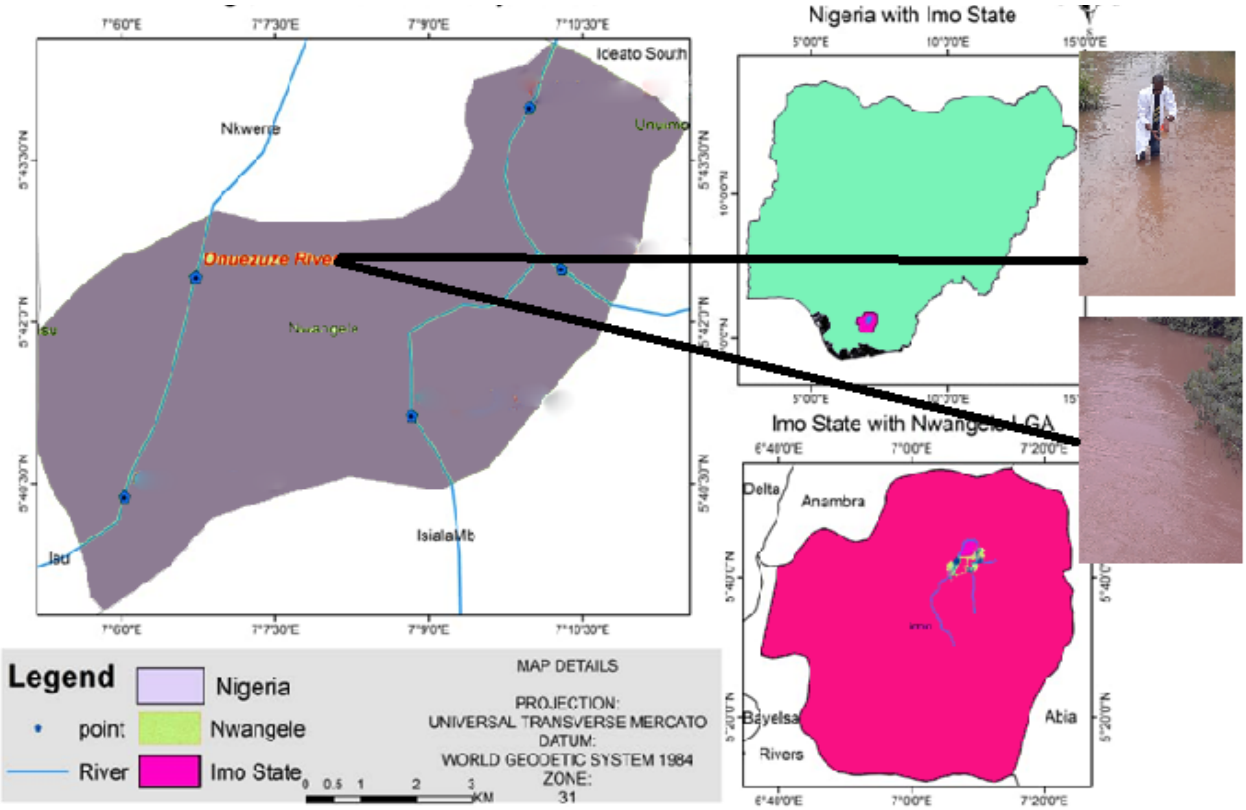

Figure 1: Map showing Onuezuze River its environs

2.3 Sample Collection

18 surface water samples were collected unsystematically within three locations in okumpi river (upstream, middle stream and downstream). Sampling were carried out for both dry and wet season and specified as ON_1, ON_2 and ON_3. The water samples were collected using cleaned plastic bottles from the different locations. Three samples were collected from each location. The plastic bottles that were used were appropriately marked and cleaned preceding to sample collection by soaking it in 10% HCl for 48 hours, washed and cleaned with deionized water and dried up [13]. Figure 2 below show the sampling process at the sampling sites.

Figure 2: Pictures of the sampling locations during sampling

2.4 Analytical Analysis

2.4.1 Laboratory Analysis of surface water samples

The surface water samples were examined for the following parameters: Temperature, Electrical conductivity (EC), Dissolved Oxygen (DO), Total dissolved solid (TDS), pH, Odour, Calcium (Ca), Sodium (Na), Phosphate (PO_4^{3-}), Potassium (K), Nitrate (NO_3^{2-}), Sulphate (SO_4^{2-}), Lead (Pb), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Zinc (Zn) and Cadmium (Cd).

2.4.2 Instrumentation

The electrical conductivity was measured using the HANNA HI8733 EC METER (µs/cm), the pH was measured using JENWAY 3510, the DO was measured using a Jen-way 9071 digital oxygen analyzer, colour and anion determination were done using Multiparameter bench photometer HI 82300 by HANNA Instruments. TDS were determined using Groline TDS meter by HANNA Instruments. Calcium, sodium, potassium, iron, copper, cadmium, Nikel, Manganese, Zinc, and lead, in the respective surface water samples will then be determined using Perkins Elmer AAnalyst 400 Atomic Absorption Spectrophotometer [10]. Cadmium reduction method was used to measure the nitrate within 48h using Hanna HI 83200 multi parameter bench photometer at 525nm. Hanna HI83200 multi parameter bench photometer at 466nm was used to determine for sulfate using turbidimetric method. Hanna HI8320 multi parameter bench photometer at 525nm was used to determine for phosphate on the samples by amino acid method, according to [13].

2.5 Data analysis

The data were calculated for their mean and standard deviation. The statistical analysis were carried out using Microsoft excel 2013. Correlation analysis employed in order to establish relationship between physicochemical parameters whereas the test statistics was used to test for differences between means both at 5 % level of significance. The health risk analysis were calculated and expressed in tabular form.

Quality control

Ensuring standard quality control in analytical methodology is essential in request to create standard results. To guarantee the quality of our analytical results, standard methodology were kept with laboratory quality affirmation properly clung to with the samples analyzed in triplicates studies and the mean of all the results were taken. Great analytical grade reagents from Finlab Chemical Laboratories Nigeria Ltd, located in Owerri, were utilized for the analysis. Glassware and containers that were utilized for sampling were all well washed with detergents and deionized water. The glassware and containers were also doused for the time being with a 10% HNO_3 in 1% HCl solution, and were later washed with deionized water and desiccated using DHG 9023A (B. Brans Scientific and Instrument Company, England) according to [13]. The double-distilled deionized water utilized for the analysis was created using Eco-Still Mark, BSIC/ECO-4 (Bhanu Scientific Instruments Company, India) before it was utilized for subsequent metallic substance determination in the samples. All the reagents and chemicals utilized for the analysis of the concentration of anions with Hanna HI8320 were obtained from HANNA Instruments. The atomic absorption spectrophotometer (Perkins Elmer AAnalyst 400 Atomic Absorption Spectrophotometer), utilized for metallic substance determination has a high accuracy level of 99.776% and can accomplish higher affectability of more noteworthy than 0.9 absorbance and precision that is less than 0.5% relative to the standard deviation (RSD) arising ten-seconds after the expansion of 5 mg/L Cu standard.

3. Results and Discussion

3.1 Physicochemical analysis

The characteristics of the results obtained from the surface water is presented in Table 2. The table is showing some descriptive statistics which include mean, standard deviation, min and max for easy interpretation and comparison with standard of World Health Organization standards. The electrical conductivity and the pH from the study as seen in table 2 both in dry and wet season are below the acceptable range while other parameters are in line with the permissible range for drinking water quality except for dissolved oxygen for wet season which are above the permissible range for all the sampling locations. The Do in wet season was 5.45±0.31 mg/L and 3.45±0.43 for dry season. The wet season has the electrical conductivity as 176.33±3.81 and 145.34±5.70 for dry. Though, the highest electrical conductivity from this present study were recorded for ON1 (179.21) for the wet season and 147.27 for the dry season. This high levels of electrical conductivity and dissolved oxygen recorded in this study might be due to regular anthropogenic activities in the upstream, where most of the domestic activities are carried out. The slight increase in DO and pH during the wet season can be an indication that both parameters have and are affected by similar anthropogenic activities. Related results were noticed for Nworie River with dissolve oxygen been lower than WHO standard [14]. In the current study, TDS for wet and dry seasons ranges from 104.71-±2.29 and 96.78±3.38 mg/L. The colour of the water samples at all the sampling locations were lower than the permissible limit and they range from 8.18±2.00 - 8.6±2.0.

Table 2: Characteristics of Onuezuze River

	Wet				Dry						
Parameters	ON_1	ON_2	)N_3	Mean ± STD	ON_1	ON_2	ON_3	Mean ± STD	WHO	Min	max
Temp (^{O}C)	26.50	26.30	.6.90	26.56±0.34	28.72	26.03	27.19	27.13±0.52	20-30	26.30	28.72
DO (mg/l)	5.50	5.46	.33	5.45±0.31	3.64	3.48	3.52	3.45±0.43	4	3.48	5.50
EC	179.21	176.42	74.36	176.33±3.81	147.21	143.51	145.31	145.34±5.70	100	143.51	179.21
pH	6.09	6.21	.06	6.12±0.09	5.64	5.54	5.41	5.53±0.33	6.5-9.0	5.41	6.21
TDS	103.47	105.82	04.85	104.71±2.29	96.71	97.04	96.59	96.78±3.38	250	96.59	105.82
Colour	8.20	8.00	.36	8.18±2.00	8.25	8.55	9.0	8.6±2.0	15	8.00	9.0

Table 3: Mean Ionic composition of surface water from Onuezuze in the wet and dry season.

	Wet				Dry						
Ions	ON_1	ON_2	ON_3	Mean ± STD	ON_1	ON_2	ON_3	Mean ± STD	WHO	Min	Max
Major cations											
Ca^{2+} (mg/l)	4.81	4.02	4.29	4.37±0.40	3.87	3.35	3.31	3.33±0.03	75	3.31	4.81
Na^{+} (mg/l)	5.94	5.35	5.47	5.59±0.31	5.02	4.91	4.37	4.77±0.35	200	4.37	5.94
K^{+} (mg/l)	5.45	5.19	5.21	5.28±0.14	3.94	3.90	3.42	3.75±0.29	20	3.42	5.45
Heavy metals											
Fe (mg/l)	1.12	1.03	1.03	1.06±0.05	2.69	2.39	2.40	2.49±0.17	0.3	1.03	2.69
Cu(mg/l)	0.19	0.15	0.13	0.16±0.03	0.02	0.02	0.01	0.01±0.01	0.3	0.01	0.19
Cd (mg/l)	0.00	0.00	0.00	0.00±0.00	0.00	0.00	0.00	0.00±0.00	0.003	0.00	0.00
Ni (mg/l)	0.64	0.63	0.59	0.62±0.03	1.50	1.41	1.38	1.43±0.06	0.02	0.59	1.50
Mn(mg/l	0.05	0.03	0.03	0.04±0.01	0.03	0.03	0.03	0.03±0.00	0.4	0.03	0.05
Zn(mg/l)	5.34	5.03	4.28	4.88±0.34	3.65	3.49	3.33	3.49±0.16	3.0	3.33	5.34
Pb (mg/l)	0.68	0.63	0.54	0.61±0.07	0.51	0.38	0.42	0.43±0.07	0.01	0.38	0.68
Major anions											
NO_3^- (mg/l)	21.09	21.41	19.94	20.81±0.77	20.55	19.03	19.04	19.54±0.87	50	19.03	21.41
PO_4^{3-}(mg/l)	17.93	16.98	16.57	17.16±0.70	17.87	15.84	15.05	16.25±1.45	1.0	15.05	19.93
SO_4^{2-} (mg/l)	11.87	11.30	11.24	11.47±0.34	11.92	9.65	9.12	10.23±1.48	250	9.12	77.87

From the results obtained from Table 3, calcium in this study shows 4.37±0.40 in wet and 3.33±0.03 in dry. Sodium shows 5.59±0.31 in wet and 4.77±0.35 in dry season. Potassium was 5.28±0.14 for wet and 3.75±0.29 for dry. From all the results obtained from the major cations showed that the wet season is higher in value and generally all results were below the threshold limit of 75, 200 and 20 as postulated by [15]. Of all the nutrients, the fundamental one responsible for fertility and potency of fish ponds is phosphate. Phosphate at reasonable amount is suitable for the growth of plankton [16]. The phosphate showed 17.16±0.70 in wet and 16.25±1.45 in dry. This research possibly will determine that phosphate grounded fertilizer might conceivably have been applied on farm lands close to the Rivers. Nitrate showed 20.81±0.77 in wet season and 19.54±0.87 in dry. Sulphate was 11.47±0.34 in wet and 10.23±1.48 in dry.

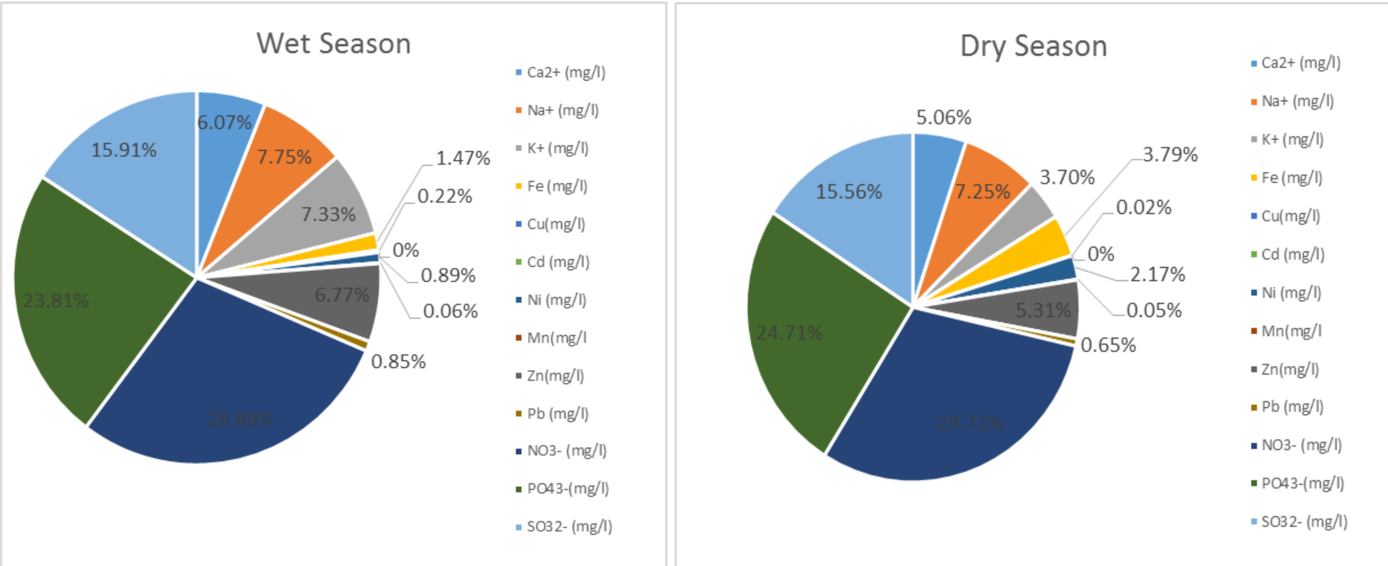

Figure 3: Ionic distribution in the Onuezuze River.

Bar chart plots were formed in order to determine the graphical distribution of metal concentration in wet and dry season. From the result on Figure 3, Iron values observed in the current study shows 1.06±0.05 for wet and 2.49±0.17 for dry which is higher than WHO standards of 0.3 mg/L. The Iron level detected in all the samples in wet season may possibly be as a result of the use of iron coagulants [16]. Copper is an essential nutrient in water and in the same way a drinking water contaminant [17]. Cu showed 0.16±0.03 and 0.01±0.01 mg/L for wet and dry season respectively. Running river is prone to exhibit low level of copper [16]. Cu in this present study all below the WHO standard for drinking water quality and for domestic uses. Cadmium was not detected in any of the sampling locations and was not included in the plot for either season. Similar findings were also found in a study carried out on River Uramurukwa in Imo State [7]. Nickel was found to be 0.62±0.03 mg/L in wet and 1.43±0.06 mg/L in dry season. All concentration of Nickel were above the WHO and NSDWQ standards and were higher in dry season. Manganese ranges from 0.04±0.01 - 0.03±0.00 mg/L through the wet season and and dry season. At high concentration, Mn can constitute an exasperation with a characteristic metallic taste and discoloration properties [15]. Zinc observed both in wet and dry are 4.88±0.34 mg/L and 3.49±0.16 mg/L which is higher during the wet season, all the results on the Zn levels were higher than the standard. When the level of zinc is considerable in water, it gives a detrimental harsh taste to water [14]. Surface water contamination from lead in might possibly be as a result of the dissolution of lead from the soil [17]. Lead observed in this study showed 0.61±0.07 mg/L and 0.43±0.07 mg/l. the lead level observed in this study are all higher than the WHO standard and the higher level coming from the wet season. No quantity of Pb is considered safe in drinking water.

3.2 Chemometric Analysis

Contamination factor: The contamination factor was used in this study to determine the rate of individual metal contamination in the water samples. Contamination factors were calculated with (1) below.

$$Cf = \frac{cmetal}{c_{background}} \quad \textbf{(1)}$$

Where Cf represents contamination factor, C*metal* represents the concentration of heavy metal and $C_{background}$ represents the background value of metal. [10] Recommendations for safe drinking water are taken as the background values for water sample.

Table 4: Contamination factor ranking

Cf values	Contamination factor level
$C_f < 1$	Low contamination
$1 \leq C_f < 3$	Moderate contamination
$3 \leq C_f < 6$	Considerable contamination
$6 \leq C_f$	Very high contamination

Pollution load index (PLI): The suggested pollution load index through Tomlinson for classifying pollution levels in soil were applied to the water samples to identify the concentration of contamination of heavy metal in the diverse locations. Researchers have estimated the pollution load index using (2) below.

$$PLI = \sqrt[n]{C_{f1} \times C_{f2} \times C_{f3} \times \dots C_{fn}} \quad (2)$$

A PLI value > 1 point toward an instantaneous intervention to ameliorate pollution; a PLI value < 1 specifies that extreme rectification procedures are not needed.

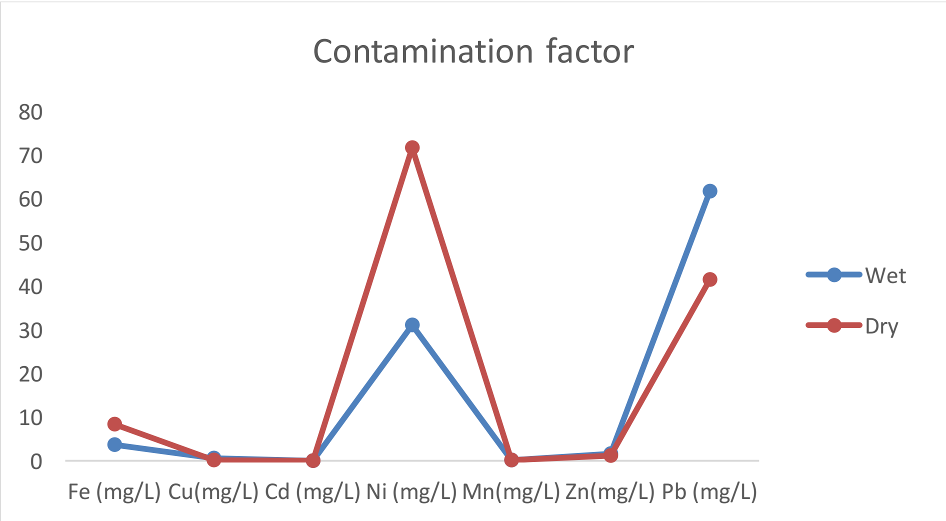

Figure 4: The Contamination factor for wet and dry season

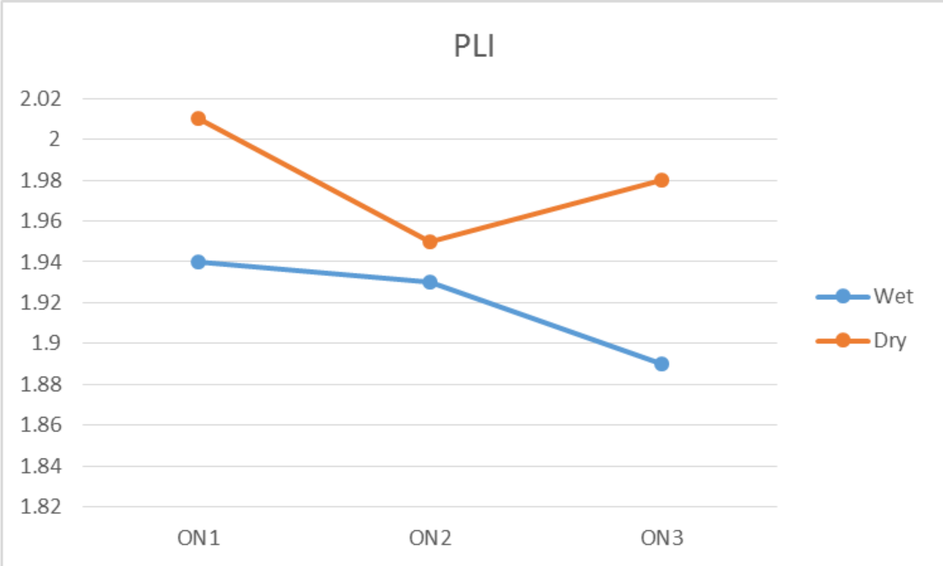

Figure 5: pollution load index of Onuezuze for wet and dry season.

The contamination factors (Figure 4) and pollution load index (Figure 5) for heavy metals of surface water samples is shown above. Following classifications for contamination factors described previously [12], the contamination factors for the individual heavy metals showed low contamination (Cf < 1) for Cu, Cd, Mn and Zn in all samples, also Cd were generally low because it was not detected in any of the sampling points in the both seasons.

The arrangement of contamination factor in surface water was Pb (61.66) > Ni (31.00) > Fe (3.53) > Zn (1.49) > Cu (0.32) > Mn (0.09) > Cd (0.00) for wet season and Ni (71.5) > Pb (41.33) > Fe (8.28) > Zn (1.16) > Mn (0.08) > Cu (0.05) > Cd (0.00) in dry season. Low contamination was exhibited by Cd, Cu and Mn for both we and dry. Pb was paramount during the wet season while Ni was the highest during the dry season. Little children are mostly in danger to lead poisoning for the reason that they ingest more lead as adults from a given source [18]. From this study, all sampling points showed high pollution load and in order of On_1 (1.94) > On_2 (1.93) > On_3 (1.89) for wet and On_1 (2.01) > On_3 (1.98) > On_2 (1.95) in dry. The results obtained during the dry season showed higher pollution load index especially in On_1. Pollution Load Index (PLI) is a suitable tool in assessing the metal pollution load and uncovers the intensity of metal pollution in a sample. If the pollution load index calculated is greater than one, it simply means that the sample is highly loaded with metals and hence polluted [19].

Water quality index (WQI)

WQI is an arithmetic expression that researchers use to convert large number of adjustable data into a single number, which shows the water quality level. The WQI is developed from the following formula [13].

$$Wi = \frac{w_i}{\sum_{i=1}^{n} wi} \quad (3)$$

Where: Wi = comparative weight, wi = weight of every single parameter and n = number of parameters. Water quality evaluation may be developed further using (4)

$$qi = \frac{C_I}{S_I} \times 100 \quad (4)$$

Where: qi = quality ranking, Ci = concentration of each chemical parameter in every single water sample in mg/L, and Si = WHO drinking water quality standard. To work out the WQI, the SI was established for each chemical parameter, which is then used to determine the WQI using Equation 5 and 6. The overhead equation becomes:

$$SI_i = W_i \times q_i \quad (5)$$

$$WQI = \sum SI \quad (6)$$

SIi = sub-index of ith parameter, qi = rating based on concentration of ith parameter and n = number of parameters. The benchmark values were acquired from [18]. The following point out the arrangement of (WQI) and the quality of water WQI

Table 5: Water Quality Index Values

Cf Value	Water Quality
WQI < 50	Excellent water quality
50 < WQI ≤ 100	Good water quality
100 < WQI ≤ 200	Poor water quality
200 < WQI ≤ 300	Very poor water quality
WQI > 300	Unsuitable for drinking

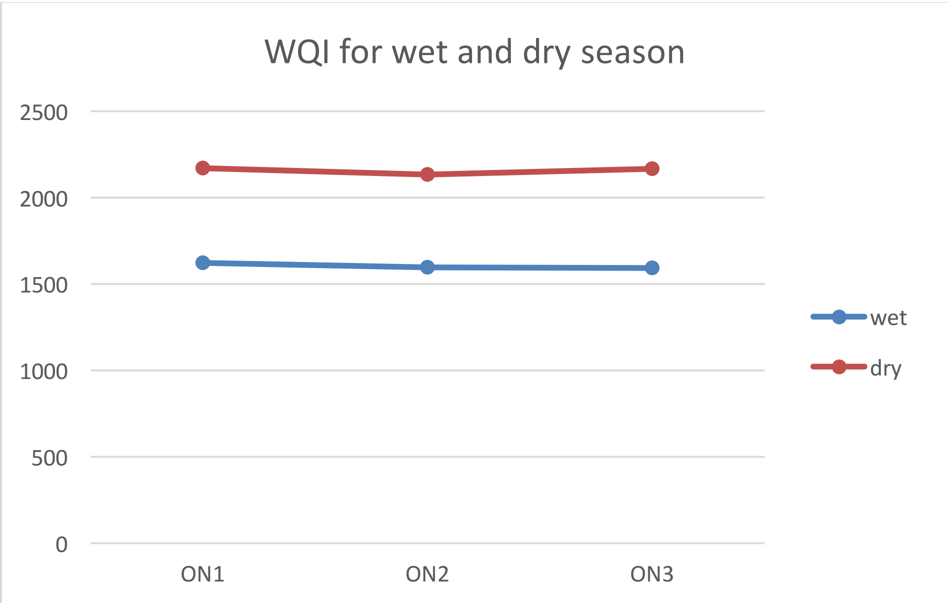

Figure 6: water quality index for Onuezuze for wet and dry season

From the calculation of water pollution index (WPI) in Figure 6, the PLI for wet season follows the order of On_1 (1622.73) > On_2 (1598.32) > On_3 (1593.64) and for the dry season On_1 (2171.95) > On_3 (2169.65) > On_2 (2133.54). The surface water samples in both season are all above the estimated level for good drinking water quality and domestic use and these results obtained showed that the water resources of this area are severally polluted with physiochemical tracers. Many anthropogenic activities have been going on this river and these activities must have contaminated this river.

3.3 Assessment of health risk

Dermal and ingestion exposure, Hazard quotient (HQ), Hazard Indices (HI)

Dermal ingestion, inhalation and absorption are the major pathways through which heavy metals can enter into the body from water causing health risk to human. However, the River studied in this research are constantly used by the inhabitants of the community for most of their domestic activities as well as recreational activities. The health risk was calculated using equation 7 and 8 according to the USEPA risk estimation method [20-23].

$$Exp_{ing} = \frac{C_{WATER} \times IR \times EF \times ED}{BW \times AT} \quad (7)$$

$$Exp_{derm} = \frac{C_{water} \times SA \times KP \times ET \times EF \times ED \times CF}{BW \times AT} \quad (8)$$

where, Exp_{ing} = the exposure dose via ingestion of water (mg/kg/day); Exp_{derm} = the exposure dose via dermal absorption (mg/kg/day); C_{water} = average level of the estimated metals in water (μg/L); IR = the ingestion level in this study (2.2 L/day for adults; 1.8 L/day for children); EF = exposure frequency (365 days/year); ED = exposure duration (70 years for adults; and 6 years for children); BW = average body weight (70 kg for adults; 15 kg for children); AT = averaging time (365 days/year × 70 years for an adult; 365 days/year × 6 years for a child); SA = exposed skin area (18,000 cm^2 for adults; 6600 cm^2 for children); Kp = dermal permeability coefficient in water, (cm/h), 0.001 for Cu, Mn, Fe and Cd, whereas 0.0006 for Zn; 0.0001 for Ni; and 0.004 for Pb [22]; ET = exposure time (0.58 h/day for adults; 1 h/day for children) and CF = unit conversion factor (0.001 L/cm^3) [24]. Potential non-carcinogenic risks in line for exposure of heavy metals were established by evaluating the calculated contaminant exposures from each exposure path (ingestion and dermal) with the proposal dose [21] using equation 9 below adequate to obtain hazard quotient (HQ) toxicity potential of an average daily intake to reference dose for an individual via the two fold pathways using the equation 13 below.

$$HQ_{ing/derm} = \frac{Exp_{ing/derm}}{RfD_{ing/derm}} \quad (9)$$

Where RfDing/derm = ingestion and dermal toxicity recommendation dose (mg/kg/day). The RfD_{derm} and RfD_{ing} values were gotten from literature according to [25, 26]. An HQ under 1 is presumed to be safe and taken as substantial non-carcinogenic (USEPA, 2019).

$$HI = \sum_{i=1}^{n} HQ_{ing/derm} \quad (10)$$

Where $HI_{ing/derm}$ = hazard index through dermal contact or ingestion.

The result obtained from the dermal and ingestion exposure on Table 6 was used to calculate the hazard quotient (HQ) in Table 7. Calculation for both HQderm and HQing in wet and dry season for all the trace metals examined in the study were less than one (1) except for HQing for adult in wet season which shows 1.8E0. This indicates there is little adverse health effect are expected to be stimulated by all these metals when the surface water is used. The HQin and HQderm diminished in the order of nickel > zinc > copper > lead > manganese > iron and zinc > nickel > manganese > iron > copper > lead for both children and adults in wet season, respectively. HQin and HQderm decreases in the order of nickel >

zinc > iron > lead > manganese > copper and zinc > nickel > iron **> lead > manganese > copper for both children and adults in dry season, respectively.**

Table 6: Dermal and ingestion exposure (mg/kg/day) for adults and children both in wet and dry season.

			wet				dry			
Metals	RfD_{derm}	RfD_{ing}	EXP_{derm} (Adult)	EXP_{derm} (Children)	D_{ing} (Adult)	D_{ing} (Children)	EXP_{derm} (Adult)	EXP_{derm} (Children)	D_{ing} (Adult)	D_{ing} (Children)
Fe	140	700	1.58E-4	4.66E-5	3.3E-2	1.27E-2	3.72E-4	1.09E-4	7.84E-2	2.98E-2
Cu	8	40	2.39E-5	7.04E-6	5.03E-3	1.92E-3	1.49E-6	4.4E-7	3.14E-4	1.2E-4
Ni	0.5	0.025	9.26E-6	2.72E-6	1.95E-2	7.44E-3	2.13E-5	6.29E-6	4.5E-2	1.71E-2
Mn	5.4	20	5.97E-6	1.76E-6	1.25E-3	4.8E-4	4.48E-6	1.32E-6	9.44E-4	3.6E-4
Zn	0.96	24	4.37E-4	1.28E-4	1.53E-1	5.85E-2	3.12E-4	9.21E-5	1.09E-1	4.18E-2
Pb	120	300	3.64E-4	1.07E-4	1.92E-2	7.32E-3	2.57E-4	7.56E-5	1.35E-2	5.16E-3
Cd	0.42	1.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 7: Hazard quotient for potential non-carcinogenic risk (HQ) and cumulative hazard

	Wet				Dry			
Metals	HQ_{derm} (Adult)	HQ_{derm} (children)	HQ_{ing} (Adult)	HQ_{ing} (children)	HQ_{derm} (Adult)	HQ_{derm} (children)	HQ_{ing} (Adult)	HQ_{ing} (children)
Fe	1.12E-6	3.32E-7	4.71E-5	1.81E-5	2.65E-6	7.78E-7	1.12E-4	4.25E-5
Cu	2.98E-6	8.8E-7	1.25E-4	4.8E-5	1.86E-7	5.5E-8	7.85E-6	3.0E-6
Ni	1.85E-5	5.44E-6	7.8E-1	2.97E-1	4.26E-5	1.25E-5	1.8E0	6.84E-1
Mn	1.1E-6	3.26E-7	6.25E-5	2.4E-5	8.29E-7	2.44E-7	4.72E-5	1.8E-5
Zn	4.55E-4	1.33E-4	6.37E-3	2.43E-3	3.25E-4	9.59E-5	4.54E-3	1.74E-3
Pb	3.03E-7	8.92E-7	6.4E-5	2.44E-5	2.14E-6	6.3E-7	4.5E-5	1.17E-5
Cd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HI	4.79E-4	1.41E-4	7.8E-1	2.99E-1	3.73E-4	1.1E-4	**1.8E0**	6.85E-1

Nevertheless, it has been recommended that estimated HQ values for metals > 1 for adult should not be disregarded. The estimated total HQ values were less than one as seen in table 7 except for Ni in HQing for adult, hence, discovery to these elements all the way through mouth ingestion.

Chronic daily intake (CDI) and Carcinogenic risk (CR)

The carcinogenic risk (CRing) simply shows the rise in the possibility of a person, to develop cancer during his lifetime owing to disclosure to heavy metals [25]. The chronic daily consumption of heavy metals through ingestion was computed using the equation below.

$$CDI = C_{water} \times \frac{DI}{BW} \quad (11)$$

Whereas C_{water} = concentration of trace metal in water in (mg/L), DI = average daily intake of water (2.2 L per day for adults; 1.8 L per day for children) and BW = whole body weight (70 kg for adults; 15 kg for children), correspondingly [27]. The cancer risk (CR) was calculated using the formula in equation below:

$$CR_{ing} = \frac{D_{ing}}{SF_{ing}} \quad (12)$$

whereas SF_{ing} = cancer slop factor. The SF_{ing} for Pb is 8.5 mg/kg/day [21, 28].

		wet		dry	
Metals	**Statistical parameter**	**CDI (Adult)**	**CDI (children)**	**CDI (Adult)**	**CDI (children)**
Fe	Minimum maximum	3.32E-2	1.27E-1	7.81E-2	2.98E-1
Cu	Minimum maximum	5.02E-3	1.92E-2	3.14E-4	1.2E-3
Cd	Minimum maximum	0.00	0.00	0.00	0.00
Ni	Minimum maximum	1.94E-2	7.44E-2	4.49E-2	1.7E-1
Mn	Minimum maximum	1.26E-3	4.8E-3	9.42E-4	3.6E-3
Zn	Minimum maximum	1.53E-1	5.85E-1	1.09E-1	4.18E-1
Pb	Minimum maximum	1.91E-2	7.32E-2	1.35E-2	5.16E-2

Table 8: Chronic risk assessment (CDIing) of heavy metals for both seasons in adults and children

The maximum Chronic risk values for the selected metals in wet and dry seasons ranged between 1.53E−1 – 5.02E−3 and 1.09E−1 – 9.42E-4 in adults, while children index was 1.27E−1 – 4.8E-3 and 1.7E−1 – 3.6E−3, respectively. The CDI indices for heavy metals during the study period for both ages were found to be in the order of Zn > Fe > Ni > Cu > Pb > Mg in wet season; and Zn > Ni > Fe > Pb > Cu > Mn in dry season as shown in Table 8. This is an indication that surface water from this area possess health risk for adults and less effect for children through the both pathways [22], however procedures should be made to evade accumulation of heavy metals that will pose any health problems especially in adult. The carcinogenic risk of Pb for Onuezuze surface water was calculated for both adults and children for both season because the value of carcinogenic slope factor for other metals were not traced in the sources. The maximum calculated values for CRing are shown in Table 9 and from the result obtained, the average levels of CRing for Pb ranged between 2.2E−3 – 1.58E−3 for adults in wet and dry season and 8.16E−3 – 6.07E−3 for children in wet and dry season.

Table 9: Carcinogenic risk assessment (CRing) of Pb for wet and dry season for both adults and children

Metal	wet		dry	
	Adult	Children	Adult	Children
Pb	2.24E-3	8.61E-3	1.58E-3	6.07E-3

Under extreme regulatory program, the carcinogenic risk values between 10^{-6} and 10^{-4} for an individual suggest potential risk, therefore the results in this current study showed that the level of Pb in the surface water could pose carcinogenic risk to both adults and children in the study area. For that reason, it is good for constant regulation and preventive actions to protect the health of humans in his study area.

Conclusion

The present study has effectively characterized the surface water in Onuezuze River in Nwangele Local Government area during the wet and dry season using various quality assessment models and health risk assessment models. The information from models is regarded as shortened concepts of environmental concerns. By this means making for easy perception of these environmental concerns by policy makers, this way evaluations on environmental issues are urgently arrived at. This current study has shown extensively that the surface water in this area is highly contaminated / polluted with heavy metals, due to the relatively high concentrations of the metals, the river water appears not to be proper for drinking purposes as shown by the high water quality index (> 300). The Hazard quotients and the total non-carcinogenic health hazard indices through the dermal adsorption and ingestion of the surface water were less than one. Nevertheless, the results have shown the potential risk of some of the selected metals on human, especially adults. The surface water resources in this study area must have been contaminated with physiological tracer due to high pollution load index. There is every need for urgent and proper examination of this surface water sources in this area by the environnemental agencies.

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Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects.

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