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Original Article

Physicochemical and Heavy Metal Distribution in Freshwater Column: Season- Location Interaction Effects and Public Health Risk

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ABSTRACT

Water samples from the Anambra River were taken from five distinct locations that displayed differential environmental stress to evaluate freshwater pollution. The physico-chemical characteristics of the river were conducted. The distribution and occurrence of heavy metals, which may affect human health and possibly induce aquatic damage, were investigated in the water column, adopting standard ecological and chemical techniques. The experimental approach was conducted under 2x5 factorial in a completely randomized block design using equal replicates to test the effects of season (rainy and dry) and location on the pollution parametric measurements, together with their interactions on heavy metal concentrations. Public survey on the use and treatment of water from the ecologically stressed river was investigated with questionnaire. Variations occurred between physico-chemical parameters and heavy metal concentrations of water samples from different locations in both rainy and dry seasons. Season by location interaction affected the heavy metal concentrations adversely, especially with regard to zinc. Likert scaling procedure further showed significant use and non-treatment of water from the river, posing a potential health threat to the dependent human population. Being obvious from the results that freshwater pollution could also be traceable to effluent/municipal wastewater discharged from industries and homes, there is need to respond appropriately to sustain the aquatic resources and avert possible human disease tragedies. In addition, Ackerman's principles of water management for people and environment should be followed.
Keywords: Anambra River, Zinc, Copper, Domestic Use, Water Treatment, Community Health

INTRODUCTION

Rivers are highly prone to material loadings that can result in pollution. Biodiversity-rich freshwater ecosystems are currently declining faster than marine or land ecosystems making them the world's most vulnerable habitats [1]; their sustainability being threatened by anthropocentrism [2-5]. Anthropogenic activities such as industrial, agricultural, domestic activities and urbanization processes give rise to pollutants, which are introduced into the surface waters through point and non-point sources and mechanisms [5] and much of the world still do not have access to clean, safe water [6,7].

Industrial effluents and domestic wastes have since been recognized as one of the most important sources of heavy metal and other pollutants in the Anambra River as well as similar water bodies all over the world [8-10]. Sewage sludge have been reported to contain considerable amounts of heavy metals [11] and therefore, considering the high volume of discharge of sewage materials in the freshwater of Anambra River placed at 18 years now, the contribution of these pollutants is very likely to be quite significant and urgently needs to be quantified and controlled. It is noteworthy that the dumping of untreated sewage into the Anambra River will pose environmental consequences that extend beyond the biological damage potential of heavy metals. This is so because, the dumping of sewage would tremendously increase the organic load in the water body with a corresponding reduction in dissolved oxygen [12] and nutrient enrichment [13], which may bring about eutrophication [14] with its attendant limiting problem to aerobic organisms. The combined effects of all these environmental pollutants may be reduction in population densities and species diversity, whereas, increases may be observed in a few opportunistic species that take advantage of the polluted environment, representing a change in prevailing conditions [15, 16].

However, apart from the adverse biodiversity effects imposed by the aquatic chemicals, changes are much more important from a human perspective, where human demands are placed on the aquatic system. Potable water in residential user communities around Anambra River is essential for human survival. Freshwater supply for human consumption should not only be safe but also wholesome [17], free from harmful chemical substances, pleasant in appearance, odour, taste and usable for drinking purposes [17]. Pathetically, in rural communities, potable water is collected from unprotected streams and rivers that are distant and prone to various material loadings that affect its quality, biota, and health of the dependent population. In view of the growing scarcity of water resources and it's recently acknowledged non-renewability, it is becoming important to plan its sustainability, safeguard and improve human conditions and enhance development.

Currently, the situation is perhaps far-fetched as the ignorant pollution and consumptions of freshwater resources are almost becoming acceptable trends, which potentially predispose human population to possible disease outbreak and ecological damage. Therefore, this study looks at the physicochemical characteristics and heavy metal concentrations of the Anambra River and susceptibility of the local population making use of the water to aquatic damage.

MATERIALS AND METHODS

Description of Study Area

The Anambra River spatially lies between latitudes 60 00'N and 60 30'N and between longitudes 60 45'E and 70 15'E. The river on the other hand is located in the South Central region of Nigeria, just close to the East of the Niger River into which it empties [18]. Anambra River is approximately 207.4km to 210km in length [19, 20], rising from the Ankpa Hills (ca. 305-610m above sea level) and discharging into River Niger at Onitsha [19]. The entire River basin draining an area of 14014km2 [18], see Figure 1.

Experimental Design and Site

The experiment was conducted under 2x5 factorial in a completely randomized block design using equal replicates to test the effects of season and location on the pollution measuring parameters (heavy metals and physico-chemical properties) together with interactions on the concentration of heavy metals {[Chromium (Cr), Cadmium (Cd), Arsenic (As), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu)}. Seasons were tested at two levels viz: rainy season and dry season; location handled at five levels (Enugu Otu, Ezi Aguleri, Otuocha, Otu Nsugbe and Onono).

The model used is :

Yijk = ⍰ + Si + Lj + SLij + Єijk

Where;

Yijk = heavy metals (Cr, Cd, As, Zn, Pd, Ni and Cu) that were
Observed due to:
⍰ = the population mean;
Si = the effect of ith season
Lj = the effect of jth location from where the samples were collected
SLij = is the interaction between season and location.
Єijkl = is the error term associated with the experimentation.

Assumptions = error term is independently, identically and normally distributed with zero mean and constant variance. That is, iind (0, ⍰2).

The experimental site comprised of five distinct locations/stations established to cover possible impacted and unimpacted area along the river course based on an earlier field reconnaissance tour. The locations (LX) of the various sampled stations are:

L1 = Enugu Otu
L2 = Ezi Aguleri
L3 = Otuocha
L4 = Otu Nsugbe
L5 = Onono

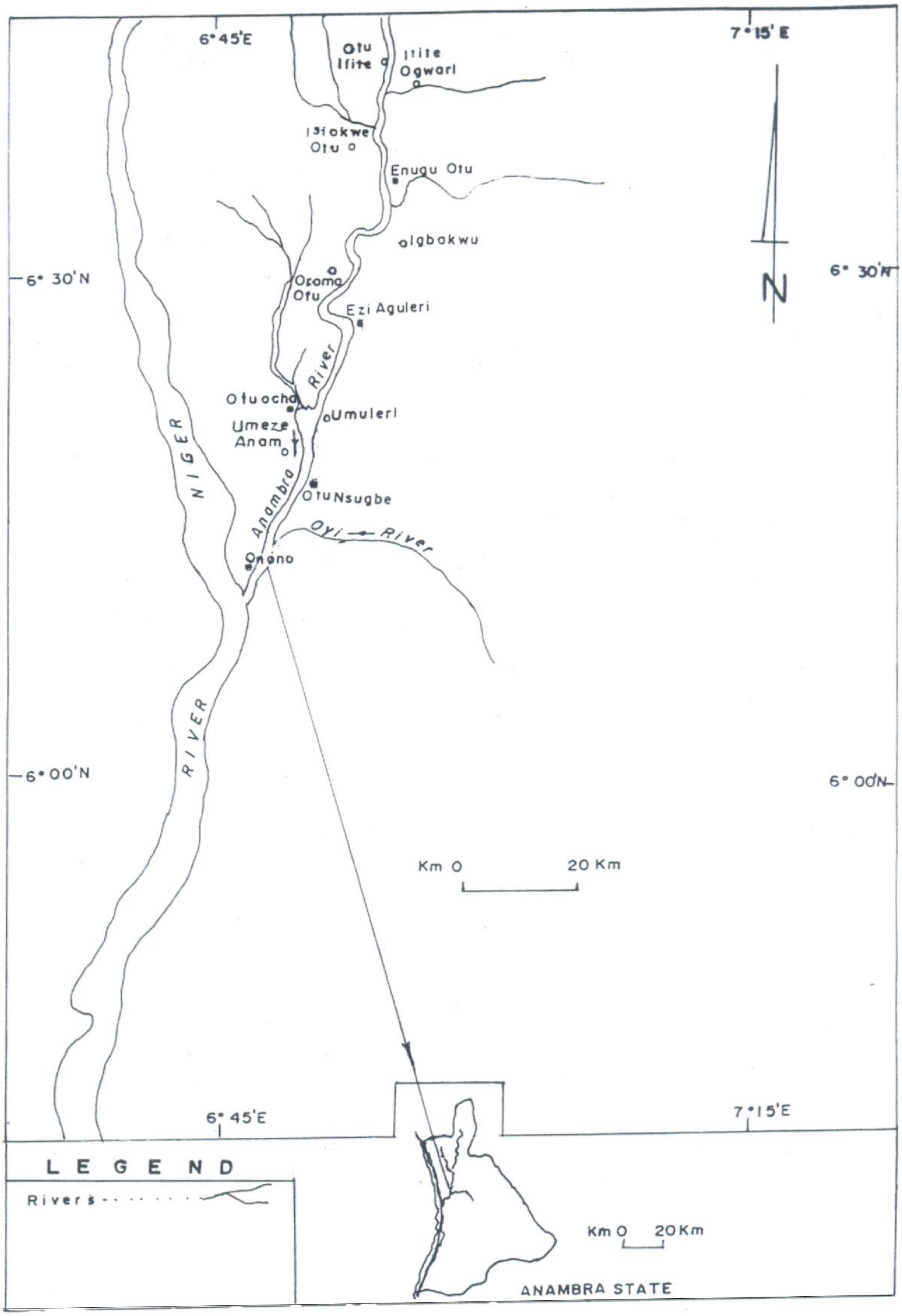

Figure 1. Map of the Anambra River showing localities interacting with it and sampled locations (■)

In situ Measurements

In line with the experimental design, samples were collected in rainy and dry seasons. In each season, the samples were collected at five distinct locations. In situ measurements of some physico-chemical parameters were carried out before the samples were taken to laboratory for detailed or other analysis using appropriate digital read-out meters (Table1).

Table 1. Instrument for In situ Measurements

Parameter	Equipment used
pH	Horiba D- 51 pH meter
Electrical conductivity	Hanna Electrical Conductivity Meter
Turbidity	Aquafluor Fluorometer & Turbidimeter
Temperature	Mecury in Glass Thermometer
Total dissolved solids	Hanna Electrical Conductivity Meter
Dissolved oxygen	Jenway D.O meter

Collection of Water Samples

Two litres of water were collected at each location using grid technique with wide mouth polyethylene containers thoroughly cleaned. Surface water was collected at the depth of 0.5m and mixed with mid-point and bottom water samples at the same stations, obtained with the aid of Labcol Bottom Sampler. Total of six samples constituted routine collections at designated grids (points) to determine fluctuations of the parameters measured in situ. Samples of water were preserved by adding drops of nitric acid at pH < 2 [21] and stored below 40C in a refrigerator prior to analysis. The relative distance between each location was approximately 12km (Figure 1.(

Laboratory Analysis

Physico-chemical Parameters

Determination of Chloride and Salinity

Chloride in the water samples was determined using Morh's colorimetric method. To 25 mL of water sample, added 2 drops of potassium chromate indicator; titrated the mixture by using silver nitrate solution until the colour changed to a brick-red precipitate. Salinity was estimated by multiplying the chloride value by a factor of 1.805 [9]. Determination of Total Hardness and Biological Oxygen Demand

Total hardness (TH) was determined using ethylenediamine tetra-acetic acid titration method, and biological oxygen demand (BOD) using a dilution method. For TH determination, mix 20 ml of the sample with 2 drops of Erichrome Black T solution and 2 mL of ammonia buffer solution. Titrate the mixture with 0.01 M ethylenediamine tetra-acetic acid solution until the color changed from wine red to blue black. Biological Oxygen Demand (BOD) was carried out by measuring the amount of dissolved oxygen present in the samples before and after incubation in the dark at 20oC for five days. The samples were measured into the BOD bottles in duplicates. The Biological Oxygen Demand in mg/l of dissolved oxygen in incubated sample bottle from the dissolved oxygen in the initial bottles .

Determination of Total Solids and Total Suspended Solids

Total solids (TS) were determined by gravimetric method after evaporation. 100 ml of water sample was measured into an already weighted evaporating dish. It was weighted and then placed in an oven at 105OC for 24 h to dry after which it was weighted. The content was too dry after which it was weighted again. The amount of solids in mg/l was calculated and total suspended solids by subtracting the total dissolved solids from the total solids.

Heavy Metal Analysis of Water Samples

Water samples collected from the experimental locations were filtered and digested using standard digestion procedure as described by APHA (1995). The heavy metal concentrations in each digested samples was determined by comparing their absorbance with those of standards (solution of known metal concentration) using Aplha- 4 Cathodeon Atomic Absorption Spectrophotometer. The limit of detection for individual metal was 0.001.

Public Survey

The sample size for the opinion survey of the local population using the river was determined out of the two hundred and fifty one thousand-target population with the Yaro Yamen formula;

S=N

+ 1 N (e)2 where

S= sample size

N= population size;

=1theoretical constant;

e= error margin.

Four hundred (400) copies of questionnaire were randomly distributed to the people of various occupations in the sampled locations. The investigator and well-trained enumerators administered the questionnaire directly to the respondents at fair ground, which was completed and collected in situ. The population included all the residents of the five localities sampled (Enugu Otu, Ezi Aguleri, Otuocha, Otu Nsugbe and Onono). The Likert attitude scaling procedure was used. The instrument was rated on 5-point scale of Strongly Agree (5), Agree (4), Undecided (3), Disagree (2) and Strongly Disagree (1). The questionnaire was structured to reflect the domestic use of the river and whether the residents treat the water from the river before use.

Statistical Analysis

Data obtained were analyzed using SPSS (version 17) and Microsoft Excel (2007 version). Significance and interaction effects on heavy metal concentrations detected in the water sampled were subjected to two-way analysis of variance (ANOVA). The differences between treatments means were separated using Duncan's New Multiple Range Test (DNMRT). The coefficient of variation (CV %) and Student's t test were used to determine the variability and seasonal differences of the physical parameters. Descriptive statistical tools like frequency distribution and percentages and Likert Scaling technique were used to determine the degree and variation of agreement or disagreement with each of the statements in the questionnaire. The Likert scale was obtained as described by Idoko and Iyadi [22].

RESULTS

Results of the physico-chemical characteristics of the Anambra River in mid rainy and dry seasons are presented in Tables 2 and 3.

The temperature of the water column in this tropical freshwater was typically warm. There was no significant ($p>0.05$) thermal stratification observed in any of the sampling stations but values obtained in dry season were significantly higher ($p<0.05$) than those of the rainy season with percentage coefficient of variation (CV) of 4.31% and 2.40%, respectively.

Dissolved oxygen quotient was significantly different ($p<0.05$) in both seasons, with %CV of 8.2% and 4.91% for rainy and dry seasons, respectively.

Salinity is consistently numerically lower (37.4+2.20mg/l) in wet season than the dry season, with average value of 40.3+1.42mg/l and corresponding value of 0.71% coefficient of variation within the locations sampled. Enugu Otu, Ezi Aguleri, Otuocha, Otu Nsugbe and Onono salinities, for dry season are relatively more uniform, that is, displayed less variation than the salinities in wet season with no significant difference ($p>0.05$) in both seasons.

In terms of hydrogen ion concentration of the river, significant difference ($p<0.05$) was observed in mid rainy and dry seasons. Of all the locations studied, Otu Nsugbe gave an equilibrium reading of 7.00 in dry season. PH recorded 1.8% and 3.55% for %CV for rainy and dry seasons, respectively.

There was no difference ($p>0.05$) between the seasons studied in the water hardness of the river but %CV for wet (5.10%) was higher than dry season (4.07%).

Table 2. Physico-chemical Characteristics of Anambra River in Mid Rainy Season- July, 2009

S/No	Parameters	N_{obs}	L_1	L_2	L_3	L_4	L_5	Mean ($\pm$S.D)
1	Temperature (^{0}C)	6	27.40	26.30	26.00	25.80	25.60	26.22$\pm$0.71
2	pH	6	6.33	6.48	6.43	6.67	6.38	6.46$\pm$0.13
3	Conductivity (μScm^{-1})	6	19.80	20.70	27.00	27.00	63.00	31.50$\pm$17.93
4	Turbidity (FTU)	6	6.03	5.06	8.08	10.00	10.05	7.84$\pm$2.27
5	Total solids (Mg/L)	3	18.00	20.00	22.00	19.00	43.00	24.40$\pm$10.50
6	Total Dissolve solids (Mg/L)	6	13.00	16.00	17.00	12.00	36.83	18.97$\pm$10.20
7	Total suspended solid(Mg/L)	-	5.0	4.00	5.00	7.00	6.17	5.43$\pm$1.16
8	Dissolved oxygen (Mg/L)	6	4.80	4.60	3.90	4.00	3.60	4.18$\pm$0.50
9	Total hardness (Mg/L)	3	10.00	10.00	10.00	9.00	9.01	9.60$\pm$0.54
10	Salinity (Mg/L)	3	35.00	35.00	37.00	39.80	40.02	37.40$\pm$2.51
11	Chloride (Mg/L)	3	2.00	4.010	2.00	2.00	8.05	3.61$\pm$2.63
12	Biological Oxygen Demand (Mg/L)	3	13.60	13.90	17.80	14.20	18.40	15.58$\pm$2.32

N_{obs}.Number of Observations; L1: Enugu Otu; L2: Ezi Aguleri, L3: Otuocha; L4: Otu Nsugbe; L5: Onono

Table 3. Physico-chemical Characteristics of Anambra River in Mid Dry Season- February, 2010

S/No	Parameters	N_{obs}	L_1	L_2	L_3	L_4	L_5	Mean (±S.D)
1	Temperature	6	30.40	30.10	28.60	27.90	27.20	28.84±1.38
2	pH	6	6.82	6.36	6.65	7.00	6.97	6.76±0.26
3	Conductivity (μScm^{-1})	6	24.02	19.91	31.01	30.02	69.03	34.80±19.66
4	Turbidity (FTU)	6	6.04	6.01	6.20	5.02	11.10	6.87±2.41
5	Total solids (Mg/L)	3	20.00	19.00	26.00	21.00	45.00	26.20±10.85
6	Total Dissolve solids (Mg/L)	6	14.00	12.00	19.00	13.00	38.00	19.00±11.0
7	Total suspended solid(Mg/L)	-	6.00	7.00	7.00	8.00	7.00	7.00±0.71
8	Dissolved oxygen (Mg/L)	6	5.42	5.20	5.70	5.01	5.03	5.27±0.29
9	Total hardness (Mg/L)	3	10.00	9.02	10.01	10.02	10.04	9.82±0.45
10	Salinity (Mg/L)	3	40.00	38.70	40.00	40.00	43.00	40.34±1.59
11	Chloride (Mg/L)	3	4.05	5.00	4.06	4.08	10.00	5.44±2.58
12	Biological Oxygen Demand (Mg/L)	3	13.90	15.00	14.30	15.40	15.20	14.76±0.63

N_{obs}.Number of Observations; L1: Enugu Otu; L2: Ezi Aguleri, L3: Otuocha; L4: Otu Nsugbe; L5: Onono

The effects of season and location on the heavy metal concentrations of the water column in Anambra River are presented in Table 4.

Table 4. Seasons and Location Effects on the Mean (+S.E) Heavy Metal (mg/l) Concentrations in Water Column

	Cd	Cr	Cu	Ni	Pb	Zn	As
S_1	ND	ND	0.018±0.007	ND	ND	0.29±0.138[a]	ND
S_2	ND	ND	0.03±0.006	ND	0.001±0.0	0.43±0.234[b]	ND
L_1	ND	ND	0.015±0.005	ND	ND	0.15±0.045	ND
L_2	ND	ND	0.02±0.010	ND	ND	0.26±0.0	ND
L_3	ND	ND	0.025±0.005	ND	ND	0.35±0.09	ND
L_4	ND	ND	0.03±0.0	ND	ND	0.34±0.04	ND
L_5	ND	ND	0.03±0.010	ND	0.001±0.0	0.70±0.165	ND

Mean values bearing different superscripts within the same column are significantly different (p<0.05); S1: Rainy Season; S2: Dry Season; L1: Enugu Otu; L2: Ezi Aguleri, L3: Otuocha; L4: Otu Nsugbe; L5: Onono

Seasons had significant (p<0.05) effects on Zn, but no significant effects (p>0.05) on others. Concentrations of Cd, Cr, and Ni and as were infinitesimal in all the seasons and locations (Table 4).

Season x location interaction effects on the heavy metal concentrations are shown in Table 5. Significant (p<0.05) effects were observed in Zn in the two seasons. Cu exhibited no significant (p>0.05) difference, while Cd, Cr, Ni, Pb and As were undetected in both seasons except Pb, which resurged at minimal concentrations in dry season (Table 5).

Table 5. Season x Location Interaction Effects on the Mean Heavy Metal Concentrations (mg/l) in Water

	Cd	Cr	Cu	Ni	Pb	Zn	As
L_1	ND	ND	0.01	ND	ND	0.10[a]	ND
L_2	ND	ND	0.01	ND	ND	0.26[b]	ND
L_3	ND	ND	0.02	ND	ND	0.26[b]	ND
L_4	ND	ND	0.03	ND	ND	0.30[b]	ND
L_5	ND	ND	0.02	ND	ND	0.53[c]	ND
L_1	ND	ND	0.02	ND	ND	0.19[a]	ND
L_2	ND	ND	0.03	ND	ND	0.26[b]	ND
L_3	ND	ND	0.03	ND	ND	0.44[b]	ND
L_4	ND	ND	0.03	ND	ND	0.38[b]	ND
L_5	ND	ND	0.04	ND	0.001	0.86[c]	ND

S_1 S_2: Mean values bearing different superscripts within the same column are significantly different (p<0.05); S1: Rainy Season; S2: Dry Season; L1: Enugu Otu; L2: Ezi Aguleri, L3: Otuocha; L4: Otu Nsugbe; L5: Onono

From the questionnaire survey, Table 6 shows the response frequency for the domestic use of the water from the Anambra River.

Table 6. Domestic Use of the River

Response	Frequency	Percentage	Point	Weighted Frequency
SA	292	73	5	1460
A	53	13.25	4	212
U	21	5.25	3	63
D	24	6	2	48
SD	10	2.5	1	10
Total	400	100	15	1793

SA: Strongly Agree; A: Agree; U: Undecided; D: Disagree; SD: Strongly Disagree

"SA" gave the highest response with "SD" giving the least frequency. The domestic use of the water was observed to be significant ($p<0.05$).

Table 7. Response on Treatment of Water from the River before Use

Response	Frequency	Percentage	Point	Weighted Frequency
SA	5	1.25	5	25
A	16	4	4	64
U	78	19.5	3	234
D	83	20.75	2	164
SD	218	54.5	1	218
Total	400	100	15	705

SA: Strongly Agree; A: Agree; U: Undecided; D: Disagree; SD: Strongly Disagree

The residents strongly disagreed on treating the water from the Anambra River before use, the trend was observed to be significant ($p<0.05$) on the Likert scale.

DISCUSSION

Season is a major factor that affects the concentration of heavy metals in freshwater ecosystem. Emoyan et al. [23] has also reported variability of heavy metal concentrations with season. It could be that as water level drops, the concentration of heavy metals in the ecosystem increases, hence higher level of heavy metals were observed in dry season or it could be attributed to the reduction in capacity of the freshwater to naturally filter the increased influx of fresh inland waters from the adjoining water bodies such as River Oyi and Ezu, which drain the neighboring locations and discharge its contaminants into the Anambra River .

Onono location consistently gave the higher concentration of pollutants sampled in the water column followed by Otuocha location. This trend could stem from the burgeoning population, industrial, marketing, and agricultural activities surrounding the areas unlike Enugu Otu and Ezi-Aguleri locations. It is noteworthy that Onono location is close to Onitsha Metropolis and mouth of River Oyi and Niger, which enlarge the pollution level of the Anambra River. The various anthropogenic activities mentioned have been shown to increase the heavy metal loading of aquatic environment [11, 23-28]. The significant ($p<0.05$) zinc level in the study area could be explained by high incidence of Iron in Nigerian soil. Zinc occurs in nature with other metals of which iron and cadmium are the most common, which supports the work of Dallas and Day [29]. It is noteworthy that most of these heavy metals could be made available in the freshwater system not only through industrial and domestic effluents but also through dumping of refuse [30].

The significant effect of season by location interactions (season x location) on the concentration of the heavy metal with regard to zinc could be that both factors jointly influence the freshwater of the Anambra River in direct proportionality. Emoyan et al. [23] similarly reported variation in heavy metal concentrations with respect to seasons and locations while working in River Ijana, Ekpan, and Warri, which receives mixtures of industrial and domestic effluents at various locations .

The heavy metal concentrations (Cu and Zn) obtained in Anambra River were higher than the levels detected in Rivers of South Carolina [26], however, lower than the levels reported by Chukwu [31] and Nwaedozie [32] in freshwater and Otitoloju [33] and Oyewo [33] in Lagoon system but comparable to River Ijana in Ekpan Warri [23].

The observed uniformity in water temperature readings of the Anambra River at various locations in the seasons sampled may be linked to the shallowness of the river and regular tidal motions, which ensured the complete mixing of the water. The temperature of the two seasons range between 26.20+ 0.63oC and 28.80+ 1.24oC. This is in line with the temperature range of 24oC to 31oC recorded by [19]. There is significant difference ($p<0.05$) in the temperature of the two seasons. However, the relative range of variation in water temperature observed in the area contradicts the reports of Longhurst [34] and Olaniyan [35], who agreed that temperature is a stable environmental factor in shallow water environment of West Africa. It is most likely that this variation in temperature constitutes an important ecological factor in the Anambra River. The dissolved oxygen (DO) levels for the mean of the two seasons was generally low and below the critical level of 5mg/l for fish by FEPA [36]. Lower dissolved oxygen concentration was usually observed at the peak of wet season during which nutrients and debris are flushed into the Anambra River with influx of freshwater from the adjoining rivers. The DO level observed in wet season of the study area is lower to the level recommended by Bolarin and Hatton [37] as cited by Olaniran [38] that the desired range for the culture of warm water fish is 5mg/l and above but not more than 12mg/l. The detected level of DO indicates a significant pollution load. The influx of water, mainly due to rainfall could be the major factor controlling the seasonal distribution of salinity in Anambra River. This reason was attributed to the variation in the salinity level observed during the sampling seasons. In the dry season, the increase in the water salinity was mainly due to low freshwater discharge and increased evaporation while the reduction in wet season water salinity was due to dilution by heavy rainfall and increase in freshwater discharge. This finding in this study agrees with many works, which had been carried out on the salinity of surface waters in Nigeria and West Africa [34, 40-41]. The biological oxygen demand (BOD) observed in all the zones indicates considerably level of nutrient such as sewage and this agrees with the report of Van-note et al. [42] that rivers with high BOD have high nutrient levels in the water. Anambra River receives high load of municipal sewage daily, which are acted upon by the aerobic microbes. The organisms consume most of the oxygen. Unpolluted natural waters will have a BOD of 5mg/l or less [41]. The seasonal change in BOD during the rainy season is attributed to the increased effect of surface run-off, soil erosion and effluents discharge into the receiving water body [42].

However, certain physico-chemical factors such as temperature, salinity, and pH enhance the distribution and bioavailability of aquatic heavy metals. The detected physico-chemical properties of the Anambra River were of reported standards for most ecotoxicity to aquatic organisms. Karakoc [43], and Karakoc and Dincer [44] have reported the absorption of zinc at varying concentrations in freshwater fish. Similarly, Heit et al. [45] and ASTDR [46] documented increased dissolved zinc in lakes with low pH and variable acidity, respectively.

Generally, the population makes use of the river for almost all their domestic activities with little or no alternative sources of water. There was pool of ignorance among the residents of the localities that use the river on the pollution effects of the various anthropogenic activities at the river on human health. They paradoxically believe that the killing substances (toxicants) in water do not harm. Anyanwu [14] had earlier reported similar load of misconception and ignorance among the resident human population that use the river. The possible public health threat is glaring owing to the strong agreement on the various uses of the river and non-treatment of the water before use. Igwilo et al. [9] earlier documented that Anambra River serves as the main source of water for the local residents and no treatment of this source of drinking water is done either by the government agencies or by individuals in their private homes before usage. Those utilities together with other prevailing issues (e.g., poverty) are predisposing factors/ activities that reduce the population coping capacity and enhance vulnerability of human to aquatic damage and toxicity. Hazard is a function of exposure and toxicity [50]. Obiakor et al. [47] have reported genotoxicity of copper and zinc acting singly and jointly against test freshwater fish. Consequently Ezeonyejiaku et al. [48, 49] have also made similar documentations on zinc lethality to aquatic animals. The water copper and zinc levels in the Anambra River are appreciable and may pose adverse health problems. Human exposure to contaminants in the water may occur through dermal absorption from the contaminated river, direct ingestion of water, or by secondary exposure through the food chain routes in which initial ingestion uptake occurs in animals and agricultural crops used for food production [50].

Season and location are key factors that determine the occurrence and distribution of heavy metals in freshwater ecosystems. There is great need to impose and enforce stricter effluent treatment regimens and emission standards. It is further recommended that Ackerman's [51] principles of water management for people and the environment should be followed, i.e., (i) value water; (ii) use water sustainably; (iii) develop suitable institutions to manage water; (iv) collect and disseminate information; (v) maintain a social and cultural perspective; (vi) ensure equitable access to water; (vii) use appropriate technology; (viii) solve causes not symptoms; (ix) take an ecosystem approach; and (x) work as multidisciplinary teams.

REFERENCES

1. World Wide Fund for Nature .2008. Living Planet Report .2008. Retrieved on: 2009-03-29.
2. Botkin, D.B; & Keller, E.A. 1998. Environmental Science, Earth as a Living Planet (2nd Ed.). ISBN 0-471-15782-1: Pp. 104-107.
3. WHO (World Health Organization) .1997. Health and Environment in Sustainable Development: Five years after the Earth Summit at http://www/who.int/environmental_information/information_resources/htmdocs/execsum
4. WHO (World Health Organization) .2002. WHO Seminar Pack for Drinking Water Quality @ www.who.int/water_sanitatio_health
5. UNFPA (United Nations Population Fund) .2003. Global Population and Water, Access and Sustainability. Population Development Strategies Series, No 6: 1-40.
6. Clark, R; & King, J. 2006. The Atlas of Water. London: Earthscan. ISBN 9781844071333, pp. 20–21.

7. Hoekstra, A.Y. 2006. The Global Dimension of Water Governance: Nine Reasons for Global Arrangements in Order to Cope with Local Problems.Value of Water Research Report Series No. 20 UNESCO-IHE Institute for Water Education. Retrieved on: 2009-03-18.
8. Obodo, G.A. 2004. The Bioaccumulation of Heavy Metals in Fish from Anambra River. J. Chem. Soc. Nigeria, 29(1): 60-62.
9. Igwilo, I.O., O.J, Afonne; U.J, Maduabuchi; & O.E, Orisakwe. 2006. Toxicological Study of the Anambra River in Otuocha, Anambra State, Nigeria. Archives of Environmental and Occupational Health, 61 (5): 205-208.
10. Odo, G.E., N.C, Didigwu; and J.E, Eyo. 2009. The Fish Fauna of Anambra River Basin, Nigeria: Species Abundance and Morphometry. Rev. Biol. Trop, 57 (1-2): 177-186.
11. Clark, R.B. 1992. Marine Pollution. (3rd Ed) Oxford University Press, p169.
12. Jenkins, S.H. 1982. Disposing of Sewage Sludge at Sea. Mar. Pollut. Bull, 13: 37-39.
13. Fodeke, V.A. 1979. Studies on Heavy Metals and Microbial Contamination of Tilapia sp. in Lagos Lagoon. M.SC Thesis, University of Lagos, Nigeria.
14. Anyanwu, J.C. 2006. Study of Entrophication of Nkisi and Anambra Rivers and Anthropogenic Activities in Anambra State. M.SC Thesis, Nnamdi Azikiwe University, Awka, Anambra, Nigeria, p11.
15. Margalef, R. 1961. Communication of Structure in Planktonic Populations. Limnol. And Oceanogr, 6: 124-128.
16. Fay, R.C. 1982. Sewage Sludge. Mar. Pollut. Bull, 13: 214.
17. Kappor. 2001. In: Arachie, A.C. 2009. Environmental Health Implications of Rural Drinking Water Sources in Adazi-Nnukwu Town, Anambra State. B.Sc Thesis, Nnamdi Azikiwe University, Awka, Anambra State.
18. Awachie, J.B.E; and L, Hare. 1977. The Fisheries of the Anambra, Ogun and Oshun River Systems in Southern Nigeria; CIFA Technical paper 5: pp. 170-184.
19. Odo, G.E. 2004. Studies on the Ecology of Macro Invertebrate Fauna as Fish Food in Anambra River Basin, Nigeria. Ph.D Thesis. University of Nigeria, Nsukka, Nigeria. 192 p.
20. Shahin, M. 2002. Hydrology and Water Resources of Africa. Springer, ISBN-1-402-00866-x. Pp. 307-309.
21. APHA (American Public Health Association) .1995. Standard Methods for the Examinations of Water and Wastewater, 16th Ed. American Public Health Association. APHA. Am. Water works Assoc, and water pollution .Control Fed, Washington DC.
22. Idoko, I.F; and C.R, Iyadi. 2008. Changes as a Correlate to Organizational Performance in Nigeria. Journal of Management Sciences, (1): 211-220.
23. Emoyan, O.O., F.E, Ogban; and E, Akarah. 2006. Evaluation of Heavy Metals Loading of River Ijana in Ekpan-Warri, Nigeria. J. Appl. Sc. Environ. Mgt 10 (2): 121-127.
24. Kiffney, P.M; and W.H, Clement. 1993. Bioaccummulation of Heavy Metal by Benthic Invertebrates at the Arkansas River, Colarado. Environmental Toxicology and Chemistry, 12 (98): 1507-1517.
25. Alabaster, J.S; and R, Lloyd. 1980. Water Quality Criteria for Fish (2nd Ed.) London: Butterworths.
26. Koli, A.K., W.T, Canty; K.I, Felix; R.J, Reed; and R, Whitmore. 1978. Trace Metals in some Fish Species of South Carolina. Bull Env. Cont. Toxic., 20 (3): 328-331.
27. Agbozu, I.E., I.K.E, Ekweozor; and K, Opuene. 2007. Survey of Heavy Metals in the Catfish, Synodontis Clarias. Int. J. Envirom. Sci. Tech., 4 (1): 93-97.
28. Nduka, J.K. 2009. Heavy Metal Pollution in Nigeria. Ph.D Seminar Presentation. Nnamdi Azikiwe University Awka, Anamnra State, Nigeria. Pp. 7-19.
29. Dallas, H.F; and J.A, Day. 1993. The Effect of Water Quality Variables on Riverine Ecosystems: A Review, Water Research Commission Project. No 351, Pretoria, South Africa, 200p.
30. Nduka, J.K.C; O.E, Orisakwe; L.O, Ezenweke; C.O, Abiakam; K.C, Nwanguma; and J.M.U, Maduabuchi. 2006. Metal Contamination and Infiltration into the Soil at Refuse Dumpsites in Awka, Nigeria. Arch Environ & occup. Health, 61 (5): 197-204.
31. Chukwu, L.D. 1991. Studies on Heavy Metal Contamination of Water, Sediment and Decapod Crustaceans from River Sasa. Ph.D Thesis University of Lagos, 164p.
32. Otitoloju, A.A. 2001. Joint Action Toxicity of Heavy Metals and their Bioaccumulation by Benthic Animals in the Lagos Lagoon. Ph.D Thesis, University of Lagos. 231p.
33. Oyewo, E.O. 1998. Industrial Sources and Distribution of Heavy Metals in Lagos Lagoon and their Biological Effects on Estuarine Animals. Ph.D. Thesis, University of Lagos, Nigeria, 230-274pp.
34. Longhurst, A.R. 1958. An Ecology Survey of the West African Marine Benthos. Colonial office Fisheries Publication 11: 102.
35. Olaniyan, C.I.O. 1969. The Seasonal Variation in the Hydrograph and Total Plankton of the Lagoons of South West Nigeria. Nig. J. Sc., 3(2): 101-119.
36. Federal Environmental Protection Agency (FEPA) .1991. Guidelines and Standards for Environmental Pollution Control in Nigeria. Decree 58 of 1988, 238p.
37. Bolarin, J; and Hatton, J.D. 1981. Tilapia –A Guide to their Biology and Culture in Africa Unit of Aquatic Pathology, Sterling University, p.174.
38. Olaniran, T.S. 1991. Performance of Red Tilapia Fed Varying Levels of Processed Poultry Feather Meal Based Diets. M.Sc Project, University of Ibadan.
39. Ajao, E. A. 1990. The Influence of Domestic and Industrial Effluents on Populations of Sessile and Benthic Organisms in Lagos Lagoon. Ph.D. thesis. University of Ibadan, Nigeria. 413p.

40. Dublin-Green, C.O. 1990. Seasonal Variations in some Physico – chemicals Parameters of the Bonny Estuary, Niger Delta. NIOMR. Techn. Paper 591, 5p.
41. Ayoola, S.O; and M.P, Kuton. 2009. Seasonal Variation in Fish Abundance and Physicochemical Parameters of Lagos Lagoon, Nigeria. African Journal of Environmental Science and Technology, 3 (5):149-156.
42. Oyewo, E.O; T.O, Ajayi; G.O, Dublin – Green; E.A., Ajao; and L.F, Anosike. 1999. Impact of Pollution in Aquatic Living Resources in Africa. Proceedings of the 5th Session of the Inter-African Committee Oceanography, Sea and Inland Fisheries.
43. Karakoc, M. 1999. Effects of Salinity on Accumulation of Copper in Liver, Gill and Muscle Tissue of Tilapia nilotica. Tr. J. Zool, 23: 299-303
44. Karakoc, M; and S, Dincer. 2003. Effect of Temperature on Zinc Accumulation in the Gill, Liver and Kidney of Oreochromis niloticus. Bull. Environ. Contam. Toxicol, 71: 1077-1083.
45. Heit, M; C, Schofield; C.T, Driscoll; et al. 1989. Trace Element Concentrations in Fish from Three Adirondack Lakes with Different pH Values. Water Air Soil Pollut. 44: 9-30.
46. ATSDR (Agency for Toxic Substances and Disease Registry).1989. Decision Guide for Identifying Substance Specific Data Needs Related to Toxicological Profiles; Notice. Federal Register, 54(174): Pp. 37618-37634.
47. Obiakor, M.O., J.C, Okonkwo; C.D, Ezeonyejiaku; and C.O, Ezenwelu. 2010. Genotoxicology: single and joint action of copper and zinc on Synodontis clarias and Tilapia nilotica. Journal of Applied Sciences and Environmental Management, 14 (3): 59-64.
48. Ezeonyejiaku, C.D; and M.O, Obiakor. 2010a. Toxicological Study of Single Action of Zinc on Tilapia Species (Oreochromis niloticus). Online Journal of Animal and Feed Research, 1 (4): 13-1-143.
49. Ezeonyejiaku, C.D; Obiakor, M.O; and Ezenwelu, C.O. 2012. Lethal Influence of Zinc Exposure to Clarias gariepinus (Burchell, 1822, Pisces, Clariidae). Journal of Animal Science Advances 2 (1): 177-183.
50. Asomugha, R; O.E., Orisakwe, O.J., Afone, E., Obi, J.C., Nduka, C.E., and Dioka. 2005. Impact of Effluent from Cable Manufacturing Plant on Food, Water and Soil Qualities in Nnewi, Nigeria: Pak. J. Biol. Sci 8(5): 744-747.
51. Ackerman, M. 1997. Principles of Water Management for People and the Environment. IUCN Wetlands Programme Newsletter, 15:Pp. 25-29.