

Ecological Assessment for Trace Metal Pollution in a Freshwater Ecosystem

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Abstract: Heavy metals in the aquatic environment is of great ecological importance; hence, the study was carried out to evaluate the presence and effects of heavy metals on the water column, fish and sediment composition of Anambra River in July, 2011 and February, 2012 which covered both wet and dry season. The results of the physico-chemical properties showed significant variations ($P < 0.05$) which occurred in DO and conductivity over the sampling seasons on different locations. pH, temperature and salinity showed seasonal difference at $P < 0.05$ in different locations studied. There was no seasonal difference at $P > 0.05$ among the heavy metal concentrations detected in sediment. Post Hoc test also showed no statistical variation ($P > 0.05$) over the five locations: namely Enugu Otu, Ezi - Agulu Otu, Otuocha, Otu Nsugbe and Ukwuibili. There was stable relative non-statistical variations among the heavy metal concentration in the water column but numerical differences demonstrated variability (Otu-Nsugbe > Ezi Agulu Otu > Ukwuibili > Enugu Otu > Otuocha). For the fish species caught both in the rainy and dry season, *Clarias gariepinus* and *Mugil cephalus* showed higher ($P < 0.05$) concentrations of Zn in dry than rainy season, while *Heterotis niloticus* showed higher ($P < 0.05$) concentrations of Zn in rainy than dry season. The highest concentrations of heavy metals were detected in the sediment followed by the fish and finally the water column in a decreasing order of concentrations.

Keywords: Heavy Metal, Sediment, Fish, River

1. Introduction

Metals are considered very important and highly toxic pollutants affecting various ecosystems. However, ecotoxicologists and environmental scientists use the term "heavy metals" to refer to metals that have caused series of environmental problems [19]. According to Eneji *et al.* [5], the discharge of industrial wastes containing toxic heavy metals into water bodies may have significant effects on fish and other aquatic organisms, which may endanger public health through consumption of contaminated seafood and irrigated food crops. Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology, since they are highly persistent and all have

the potential to be toxic to living organisms [18]. Studies on heavy metals in rivers, fish and sediments have been a major environmental focus especially during the last decade [16]. Sediments are important sinks for heavy metals and also play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and in interactions between water and sediment. Fish samples can be considered as one of the most significant indicators in freshwater systems for the determination of heavy metal toxicity level [15]. Heavy metals could be found in water at the trace levels. Nonetheless, these constituents are very toxic and tend to accumulate in a long period of time [1]. Heavy metals in human body can affect his health, therefore the need to assess the toxicity of heavy metals in water, sediment

and fishes in Anambra River because of its daily usage by man and exposure to urban pollution.

2. Methods

2.1. Study Area

Anambra River is located in Anambra State. The State is located between latitudes $05^{\circ} 40'N$ and $07^{\circ} 10'N$ and longitude $06^{\circ} 35'E$ and $07^{\circ} 20'E$. It is made up of 21 local government areas and located in South-eastern Nigeria. Two climatic seasons exist in Anambra State, namely rainy season (March-October) and dry season (November-March). This variation in season across the year and the relative annual

rainfall accounts for the fluctuating water level and also the economic activities that depend on the river [14].

2.2. Sampling Design

Due to the nature of the study, a judgmental purposive sampling technique was adopted in choosing the stations from which (water and sediment) samples were collected. In this case, the researcher selected the stations purposively based on the settlement of people along the stretch of the river and activities carried out in the stations. The stations chosen are shown in Table 1.

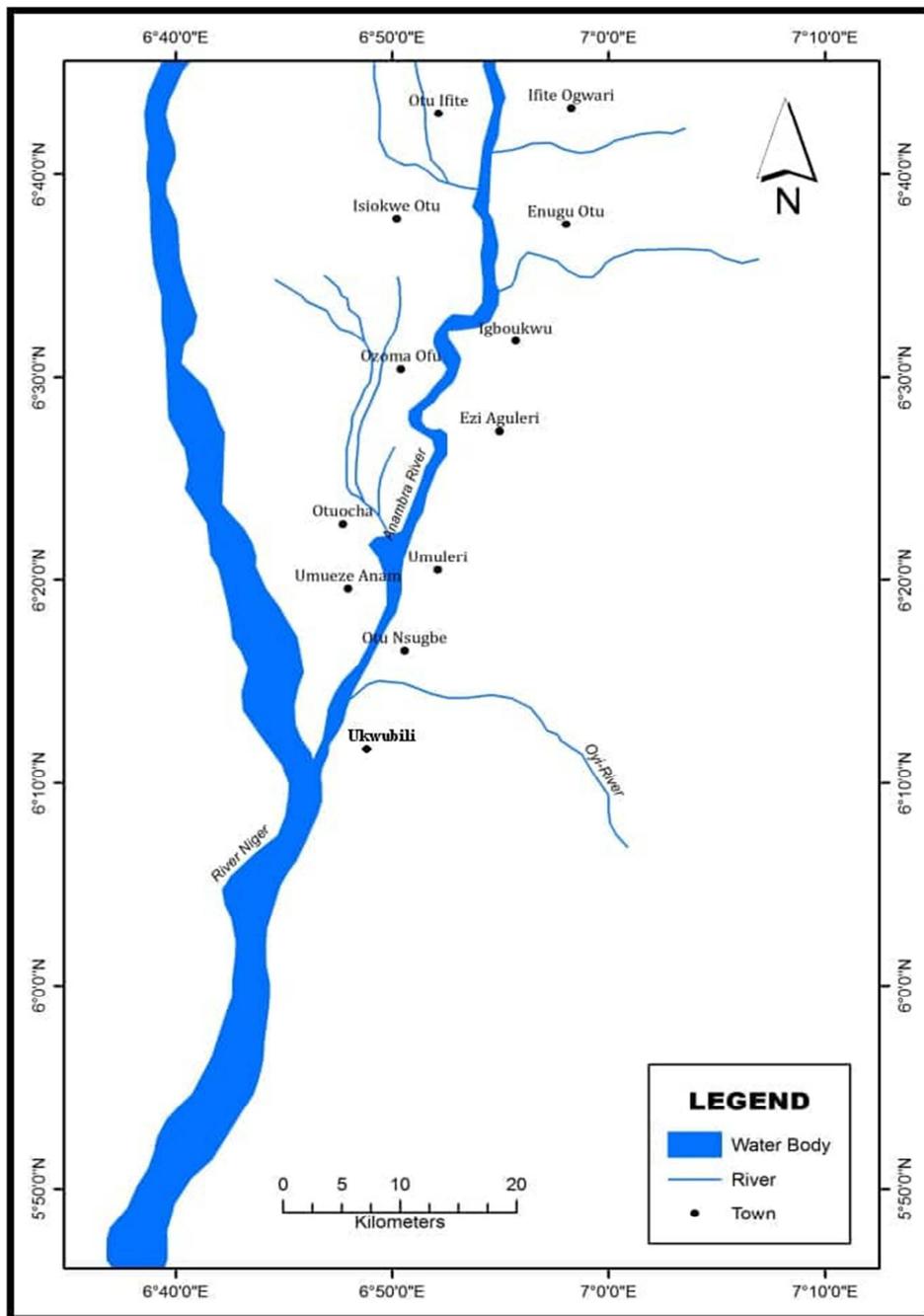


Figure 1. Map of Anambra River Showing the Sampling Stations.

Table 1. Sampled Stations.

Station	Location	Activities
A	Enugu Otu	Farming, Fishing, domestic activities, rice mill industries.
B	Ezi-Agulu Otu	Farming, fishing, domestic activities
C	Otuocha	Farming, fishing, market, rice mill industry, domestic activities and refuse dumping.
D	Otu-Nsugbe	Farming, fishing, domestic activities, sewage disposal and market
E	Ukwuibili	Farming, fishing, domestic activities, sewage disposal, market.

2.3. Sampling Operation

Sampling operation at the designated stations (Fig 1) was carried out on an open man-powered canoe. All sample collections were made during the morning time (6am-11.46am each day). The timing of sampling was dictated by the two hydrological seasons prevalent in the tropics. Samples of water, sediment and fish were taken over a one year period and investigated for their heavy metal contents following the schedule given below:

2011, Wet season sampling, July

2012, Dry season sampling, Feb.

2.4. Collection of Samples (Water, Sediment and Fish) From Anambra River

Samples were collected and analyzed for seven heavy metals, (Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb) and Zinc (Zn).

2.5. Collection of Water

Water samples from the experimental stations were collected by dipping plastic containers 6-10cm below the surface film of the water body. To prevent adsorption of metals unto the walls of the containers during storage, the five water samples were acidified to $\text{pH} < 2$ [2].

2.6. Collection of Sediment

Five sediment samples from the experimental stations were collected with the aid of a stainless steel grab of the Van-veen type. The sediment samples each were put into a

clean polythene bag while awaiting chemical analysis, according to [4].

2.7. Collection of Fish

Fish samples from Anambra River were caught by employing paid fishermen. A total of seven hundred and twenty (720) fish samples of eighteen (18) different species were used for the study.

2.8. Measurement of Physicochemical Parameters

Salinity and temperature were determined *in situ* using a Becman Electrodeless salinometer (Model Rs. 5-3). Dissolved oxygen (DO) was determined in situ using digital DO meter (Jenway product, Model 3000). pH was determined using a digital pH meter (Kahl Instrument, Model 11 4W13) calibrated with freshly prepared buffer solutions (pH 4, 7, and 9) and Conductivity determined using conductivity meter (Palintest Waterproof, Model 800).

2.9. Statistical Analyses

Statistical analyses carried out in this study using SPSS (version 17) include determination of mean and analysis of variance, while differences between mean were separated using Duncan's new multiple Range Test. Two sampled T-test was used to analyze for significant difference ($p < 0.05$) due to the heavy metals and physicochemical parameters detected in the samples between the two seasons.

3. Results

3.1. Distribution of Physicochemical Properties of the Anambra River Water Column

Measurement of some physicochemical characteristics with influential capacity on the environmental mobility and toxicity of heavy metals are shown in Table 2 below. Significant variations ($P < 0.05$) occurred in DO and conductivity over the sampling seasons on different locations. pH, temperature and salinity showed seasonal difference at $P < 0.05$ in different locations studied.

Table 2. Mean (+SD) Physicochemical Properties of Water at Anambra River in Rainy and Dry Season.

Sample Location	Physicochemical Properties									
	pH		D. O		Temperature		Salinity		Conductivity	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
A	8.4400+	7.0300+	6.3500+	5.8000+	25.5000+	28.5000+	0.0100+	0.0140+	39.0500+	23.3000+
Enugu-Out	0.156*	0.014*	0.071 ^a	0.000 ^b	0.283*	0.000*	0.000	0.000	5.303 ^b	0.000 ^c
B	8.1950+	6.9250+	5.7500+	6.0000+	25.5000+	28.3000+	0.0400+	0.0170+	68.2000+	23.6000+
Ezi-Agulu Out	0.021*	0.007*	0.212 ^b	0.000 ^a	0.141*	0.000*	0.000*	0.000*	4.525 ^a	0.000 ^c
C	8.3200+	6.7150+	5.9500+	6.1000+	25.6000+	28.5000+	0.0200+	0.0110+	21.4500+	17.2000+
Otuocha	0.170*	0.007*	0.212 ^b	0.000*	0.000*	0.000*	0.014	0.000	2.333 ^c	0.000 ^d
D	8.4050+	6.9300+	6.5000+	5.9000+	25.4500+	28.7000+	0.0300+	0.0140+	19.1000+	31.5000+
Otu-Nsugbe	0.134*	0.000*	0.141 ^a	0.000 ^b	0.707*	0.000*	0.000*	0.000*	3.253 ^d	0.000 ^a
E	8.3200+	6.8600+	6.1000+	6.2000+	25.7000+	28.4000+	0.0150+	0.0170+	15.9500+	25.8000+
Ukwuibili	0.141*	0.000*	0.141 ^a	0.000 ^a	0.141*	0.000*	0.007	0.000	0.919 ^c	0.000 ^b
FEPA	6.9	6.9	5.0	5.0	40	40	1	1	n/s	n/s

3.2. Distribution of Heavy Metals in the Anambra River Water Column

The observed concentrations of heavy metals detected in the water column were shown to portray no difference ($P>0.05$) with respect to season and location. Season-location interaction effect was also insignificant ($P>0.05$) over the regimes of sampling (Table 3). Generally, there was stable

relative non-statistical variations among the heavy metal concentration in the water column but numerical differences demonstrated variability (Otu-Nsugbe > Ezi Agulu Otu > Ukwuibili > Enugu Otu > Otuocha. Arsenic (As) and Cd were not detected below 0.001mg/L limit over the seasons while Cr remained undetected throughout the dry season.

Table 3. Mean (+ SD) Concentration (mg/l) of Heavy Metals in Water Samples Collected from Different Locations in Anambra River in Rainy and Dry Season.

Sample Location	Heavy Metal Concentrations							
	As		Cd		Cr		Cu	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
A Enugu-Out	ND	ND	ND	ND	0.0030+ 0.001	ND	0.0060+ 0.003	0.0120+ 0.000
B Ezi-Agulu Out	ND	ND	ND	ND	0.0040+ 0.001	ND	0.0270+ 0.024	0.0100+ 0.000
C Otuocha	ND	ND	ND	ND	0.0010+ 0.001	ND	0.0050+ 0.001	0.0040+ 0.000
D Otu –Nsugbe	ND	ND	ND	ND	ND	ND	0.0015+ 0.001	0.0200+ 0.000
E Ukwuibili	ND	ND	ND	ND	ND	ND	0.0015+ 0.001	0.0180+ 0.000
WHO	0.001	0.001	0.003	0.003	0.01	0.01	0.029	0.029
NESREA	0.05	0.05	0.005	0.005	0.001	0.001	0.001	0.001

Table 3. Continued.

Sample Location	Heavy Metal Concentrations					
	Fe		Pb		Zn	
	Rainy	Dry	Rainy	Dry	Rainy	Dry
A Enugu-Out	0.0140+ 0.008	0.0360+ 0.000	0.0015+ 0.001	ND	0.1340+ 0.044	0.2015+ 0.001
B Ezi-Agulu Out	0.0410+ 0.001	0.0410+ 0.000	0.0030+ 0.000	ND	0.2585+ 0.036	0.2160+ 0.000
C Otuocha	0.0055+ 0.002	0.0150+ 0.000	0.0010+ 0.000	ND	0.0450+ 0.028	0.1480+ 0.000
D Otu –Nsugbe	0.0035+ 0.001	0.0600+ 0.000	ND	0.0040+ 0.000	0.0360+ 0.004	0.4100+ 0.000
E Ukwuibili	0.0040+ 0.001	0.0560+ 0.000	ND	0.0020+ 0.000	0.0365+ 0.008	0.2560+ 0.000
WHO	0.03	0.03	0.01	0.01	<1	<1
NESREA	0.05	0.05	0.01	0.01	0.1	0.1

3.3. Distribution of Heavy Metals in the Anambra River Sediment

Table 4 shows the occurrences and distributions of sampled heavy metals in sediments of the Anambra River from various locations of study over the sampling regime. There was no seasonal difference at $P>0.05$ among the heavy metal concentrations detected. Post Hoc test also showed no statistical variation ($P>0.05$) over the five locations: namely

Enugu Otu, Ezi - Agulu Otu, Otuocha, Otu Nsugbe and Ukwuibili. Consequently, numerical variations exist among the metal concentrations, detected in the studied locations as follows, Otuocha > Ezi-Agulu Otu> Otu Nsugbe > Ukwuibili > Enugu Otu. Arsenic (As) was not detected in all the locations over the sampling regime. Cd, Cr, and Pb exhibited detected (D) and not detected (ND) variations during the sampling in different locations.

Table 4. Mean (+SD) Concentration (mg/kg) of Heavy Metals in Sediment Samples Collected from Different Locations in Anambra River in Rainy and Dry Season.

Heavy Metal Concentrations							
As		Cd		Cr		Cu	
Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
ND	ND	0.0025+ 0.001	0.0030+ 0.000	0.0065+ 0.006	0.0010+ 0.000	0.0900+ 0.003	0.0415+ 0.001
ND	ND	0.0045+ 0.001	0.0040+ 0.000	0.0040+ 0.001	0.0010+ 0.000	0.1105+ 0.008	0.0860+ 0.000
ND	ND	ND	0.0060+ 0.000	0.0010+ 0.000	0.0030+ 0.000	0.0505+ 0.013	0.1250+ 0.000
ND	ND	ND	0.0020+ 0.000	ND	0.0030+ 0.000	0.0695+ 0.002	0.0510+ 0.001

Heavy Metal Concentrations							
As		Cd		Cr		Cu	
Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
ND	ND	0.0060+ 0.001	0.0030+ 0.000	0.0020+ 0.001	0.0020+ 0.000	0.1255+ 0.021	0.0595+ 0.001
0.027	0.027	0.006	0.006	0.025	0.025	0.04	0.04

Table 4. Continued.

Heavy Metal Concentrations					
Fe		Pb		Zn	
Rainy	Dry	Rainy	Dry	Rainy	Dry
0.0505+ 0.022	0.1750+ 0.000	0.0060+ 0.007	ND	0.3435+ 0.018	0.5200+ 0.000
0.0880+ 0.018	0.2400+ 0.000	0.0015+ 0.0010	0.0030+ 0.000	0.4220+ 0.002	0.7805+ 0.001
0.0310+ 0.006	0.2620+ 0.000	ND	0.0050+ 0.000	0.2905+ 0.063	0.9300+ 0.000
0.0635+ 0.013	0.2060+ 0.001	ND	0.0010+ 0.000	0.1955+ 0.127	0.7040+ 0.000
0.0625+ 0.067	0.2380+ 0.000	0.0015+ 0.001	0.0020+ 0.000	0.4210+ 0.154	0.7700+ 0.000
0.04	0.04	0.03	0.03	0.123	0.123

3.4. Distribution of Heavy Metals in Fishes in the Anambra River

The heavy metals detected in the tissue of the sampled fishes in the Anambra River are presented in Table 5. There was difference in the abundance and availability of various fish species studied. Some fish species caught in rainy season were not caught in dry season. On the basis of heavy metal concentrations in the fish species caught both in the rainy and dry season, *Clarias gariepinus* and *Mugil cephalus* showed

higher ($P < 0.05$) concentrations of Zn in dry than rainy season, while *Heterotis niloticus* showed higher ($P < 0.05$) concentrations of Zn in rainy than dry season. In similar fashion, (*Clarias gariepinus*, and *Heterotis niloticus*) recorded higher ($P < 0.05$) concentrations of Cr, Fe, and Cd in dry season than rainy season, respectively. While *Mugil cephalus* recorded higher ($p < 0.05$) concentrations of Cr and Fe in dry season than rainy season. *Protopterus annectens* singularly recorded higher ($P < 0.05$) concentrations of Fe, Pb & Zn in dry season than in rainy season.

Table 5. Mean (+SD) Concentration (mg/kg) of Heavy Metals in Fish Samples Collected from Anambra River in Rainy and Dry Season.

Fish Species	Heavy Metal Concentrations							
	As		Cd		Cr		Cu	
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
<i>Clarias gariepinus</i>	ND	ND	0.0029+ 0.005 ^b	0.0045+ 0.001 ^a	0.0010+ 0.000 ^b	0.0020+0.000 ^a	0.0246+ 0.012	0.1035+ 0.040
<i>Clarias walker</i>	ND	ND	0.0016+ 0.001	NA	ND	NA	0.0237+ 0.012	NA
<i>Cynoglossus senegalensis</i>	ND	ND	0.0018+ 0.001	NA	ND	NA	0.0240+ 0.012	NA
<i>Heterotis niloticus</i>	ND	ND	0.0020+ 0.001	ND	ND	0.0015+0.001 ^a	0.0280+ 0.001	0.0140+ 0.011
<i>Mugil Cephalus</i>	ND	ND	0.0052+ 0.005	0.0034+ 0.002	0.0010+ 0.000 ^b	0.0018+ 0.000 ^a	0.0191+ 0.007	0.0811+ 0.064
<i>Parachana obscura</i>	ND	ND	0.0053+ 0.001	0.0035+0.001	0.0028+ 0.003	0.0023+0.001	0.0408+ .017	0.0433+ 0.056
<i>Protopterus annectens</i>	ND	ND	0.0046+ 0.002	0.0038+0.003	0.0043+ 0.0042	0.0024+0.001	0.0163+ 0.008	0.0896+0.093
<i>Schilbe mystus</i>	ND	ND	0.0035+ 0.005	NA	0.0010+ 0.000	NA	0.0162+ 0.006	NA
<i>Synodontis clarias</i>	ND	ND	0.0034+ 0.002	0.0020+0.001	ND	0.0050+0.000	0.0269+ 0.009	0.0040+0.001
<i>Labeo senegalensis</i>	ND	ND	NA	0.0025+0.001	NA	0.0015+0.001	NA	0.0475+0.023
<i>Phractolaemus ansorgii</i>	ND	ND	NA	ND	NA	0.0020+0.000	NA	0.0240+0.011
<i>Sarotherdon galilaeus</i>	ND	ND	NA	0.0020+0.00	NA	0.0010+0.000	NA	0.0065+0.006
<i>Tilapia mariae</i>	ND	ND	NA	0.0032+0.001	NA	0.0030+0.001	NA	0.0695+0.082
<i>Alestes baremose</i>	ND	ND	NA	0.0010+0.000	NA	0.0010+0.000	NA	0.0060+0.0028
<i>Auchenoglanis occidentalis</i>	ND	ND	NA	0.0030+0.000	NA	0.0025+0.001	NA	0.0305+0.001
<i>Chrysichthys nigrodigitatus</i>	ND	ND	NA	0.0020+0.000	NA	ND	NA	0.1075+0.011
<i>Gymnarchus niloticus</i>	ND	ND	NA	0.0043+0.001	NA	0.0015+0.001	NA	0.0250+0.039
<i>Hyperopisus bebe</i>	ND	ND	NA	0.0015+0.001	NA	ND	NA	0.0040+0.001
WHO	0.12	0.12	0.01	0.01	0.05	0.05	30	30
FAO	0.02	0.12	0.5	0.5	N/S	N/S	30	30

Table 5. Continued.

Fish Species	Heavy Metal Concentrations							
	Fe		Pb		Zn			
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	
<i>Clarias gariepinus</i>	0.1035+ 0.040	0.0136+ 0.017 ^b	0.1660+ 0.119 ^a	0.0016+ 0.001	0.0050+0.000	0.0672+ 0.022 ^b	0.4460+0.009 ^a	
<i>Clarias walker</i>	NA	0.0032+ 0.002	NA	ND	NA	0.0440+ 0.015	NA	
<i>Cynoglossus senegalensis</i>	NA	0.0368+ 0.007	NA	0.0013+ 0.001	NA	0.0773+ 0.018	NA	

Fish Species	Heavy Metal Concentrations						
	Fe		Pb		Zn		
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
<i>Heterotis niloticus</i>	0.0140+ 0.011	0.0500+ 0.000 ^b	0.0770+ 0.011 ^a	0.0010+ 0.000	ND	0.8700+ 0.099 ^a	0.2615+0.023 ^b
<i>Mugil Cephalus</i>	0.0811+ 0.064	0.0109+ 0.015 ^b	0.0986+ 0.112 ^a	0.0070+ 0.007	0.0025+ 0.002	0.0662+ 0.019 ^b	0.3236+0.260 ^a
<i>Parachana obscura</i>	0.0433+0.056	0.0050+ 0.001	0.0381+0.037	ND	0.0021+0.001	0.0535+ 0.013	0.1771+0.247
<i>Protopterus annectens</i>	0.0896+0.093	0.0063+ 0.004 ^b	0.1343+0.102 ^a	0.0010+ 0.000 ^b	0.0023+0.001 ^a	0.0470+ 0.015 ^b	0.3161+0.308 ^a
<i>Schilbe mystus</i>	NA	0.0345+ 0.012	NA	ND	NA	0.0362+ 0.035	NA
<i>Synodontis clarias</i>	0.0040+0.001	0.0290+ 0.012	0.0145+0.012	0.0010+ 0.000	0.0020+0.000	0.0808+ 0.014	0.0060+0.001
<i>Labeo senegalensis</i>	0.0475+0.023	NA	0.0800+0.009	NA	ND	NA	0.1545+0.016
<i>Phractolaemus ansorgii</i>	0.0240+0.011	NA	0.0065+0.0021	NA	ND	NA	0.0465+0.026
<i>Sarotherdon galilaeus</i>	0.0065+0.006	NA	0.0135+0.012	NA	0.0010+0.000	NA	0.0205+0.002
<i>Tilapia mariae</i>	0.0695+0.082	NA	0.0826+0.070	NA	0.0045+0.004	NA	0.1570+0.224
<i>Alestes baremose</i>	0.0060+0.0028	NA	0.0120+0.006	NA	0.0020+0.000	NA	0.0095+0.002
<i>Auchenoglanis occidentalis</i>	0.0305+0.001	NA	0.0050+0.001	NA	ND	NA	0.3050+0.013
<i>Chrysichthys nigrodigitatus</i>	0.1075+0.011	NA	0.0070+0.001	NA	ND	NA	0.0650+0.021
<i>Gymnarchus niloticus</i>	0.0250+0.039	NA	0.1433+0.161	NA	0.0055+0.001	NA	0.2833+0.345
<i>Hyperopisus bebe</i>	0.0040+0.001	NA	0.0130+0.003	NA	0.0020+0.000	NA	0.0025+0.001
WHO	30	50	50	0.05	0.05	30	30
FAO	30	50	50	0.5	0.5	30	30

3.5. Bioaccumulation Factors (BAF) of Fishes in the Anambra River

The ecological survey carried out in this study has shown that the levels of some heavy metals in the bodies of the fishes resident in the Anambra River were atimes higher than

the concentrations of the metals prevailing in the Anambra River water and/or sediment. The bioaccumulation factors (BAF) for the sampled fish species for rainy and dry season are shown in Tables 6 and 7.

Table 6. Bioaccumulation Factors of Fish Species in the Anambra River in Rainy Season.

Fish Species	Heavy metals											
	Cd		Cr		Cu		Fe		Pb		Zn	
	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
<i>Clarias garipepius</i>					3.0		1.0		1.0			
<i>mugil cephalus</i>	1.6	1.2			2.4				1.0			
<i>Schilbe mystus</i>		1.0			2.0		2.5					
<i>Synodontis clarias</i>					3.4		2.1					
<i>Clarias walkeri</i>					3.0							
<i>Heterotis niloticus</i>					3.5		3.6				8.5	2.6
<i>Protopterus annectens</i>		1.3	1.3	1.0	2.0							
<i>Parachanna obscura</i>	1.2		1.0		5.1							
<i>Cynoglossus senegalensis</i>					3.0		2.6					

Table 7. Bioaccumulation Factors of Fish Species in the Anambra River in Dry Season.

Fish Species	Heavy metals											
	Cd		Cr		Cu		Fe		Pb		Zn	
	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
<i>Alestes baremose</i>												
<i>Sarotherdon galilaeus</i>												
<i>Hyperopisus bebe</i>												
<i>Parachanna obscura</i>		1.0		1.0	2.9							
<i>Protopterus annectens</i>		1.0		1.0	5.9	1.2	3.2				1.3	
<i>Tilapia mariae</i>					4.6		2.0		1.7	1.7		
<i>Chrysichthys</i>					7.2	1.5						

Fish Species	Heavy metals											
	Cd		Cr		Cu		Fe		Pb		Zn	
	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment	Water	Sediment
<i>nigrodigitatus</i>												
<i>Synodontis clarias</i>				2.5								
<i>Mugil cephalus</i>				1.0		5.4	1.0	2.4		1.0	1.0	1.3
<i>Phractolaemus ansorgii</i>						1.6	1.0					
<i>Clarias gariepinus</i>		1.2		1.0		7.0	1.4	4.0		1.7	1.7	1.8
<i>Auchenoglanis occidentalis</i>				1.5		2.1						1.2
<i>Heterotis niloticus</i>				1.0				1.8				1.0
<i>Gymnarchus niloticus</i>		1.0		1.0		1.7		3.4		2.0	2.0	1.0
<i>Labeo senegalensis</i>				1.0		3.2		2.0				

4. Discussion

The temperature of the two seasons ranged between 25.45-28.70°C. This is in line with the temperature range of 24°C to 31°C recorded by Odo [13] and Obiakor [12]. The heavy metal concentrations detected were shown to have varying concentrations at different locations of study over the sampling regimes. The highest concentrations of metals detected in sediment and water column in Otuocha and Otu-Nsugbe, respectively could be attributed to the fact the areas are surrounded by heavy populations, industries and markets unlike other zones, Otuocha and Otu-Nsugbe regularly receive very high quantities of domestic, industrial and market wastes, which have been reported to contain appreciable quantities of heavy metals [8]. However, the detection of high concentration of heavy metals in Anambra River implies that apart from domestic, commercial and industrial wastes/effluents discharged into the river, Ezu River and Oyi River which drains into Anambra River might also be major contributors to the overall metal content in the Anambra River. Comparisons of the concentrations of most of the metals detected in the various media (sediment, fish and water) revealed that generally, the highest concentrations of most of the metals were detected in the sediment, followed by the fish and finally, the water sample. The detection of higher concentrations of heavy metals in fish samples in freshwater ecosystem has been reported by many authors [7]. Furthermore, the comparisons of heavy metal concentrations detected in the water, fish and sediment of the Anambra River during the sampling regimens to that of other water bodies in some other locations around the world revealed it to be higher than levels detected in River of South Carolina [10], however, lower than the levels reported by Ekeanyanwu *et al.* [6] but the water column comparable to the value concentrations of Warri River, Delta State of Nigeria [20].

The biological significance of increasing concentrations of heavy metals with time in the principal media (water, biota and sediment) of the Anambra River is the danger or risk of potential disruption of the delicate ecological balance of the ecosystem. That could occur when concentrations of the metals in the water body reach levels that will cause harmful effects such as reduction in mobility, immobilization,

emigration or death of a significant percentage of populations of important plant and animal species. Such reductions in numbers of individuals if sustained, would subsequently lead to loss of biological diversity of the river ecosystem.

The bioaccumulation of heavy metals by fish observed in this work likely occurred because the experimental animals were able to absorb the metals directly across body surfaces, membranes and ingested food at a faster rate than they were able to metabolize and excrete the absorbed metals. The findings of the study are also in line with the observations of Rajeshkumar and Li [17], in their study on bioaccumulation of heavy metals in fish species from the Meiliang Bay, Taihu Lake, China where they concluded that bioaccumulation of heavy metals in fish species and water have led to various potential health hazards associated with their consumption.

5. Conclusion

The observed increase in metal concentrations over the sampling regimes should justify the need to carryout regular monitoring of the metal content of the river. It should also necessitate the development and enforcement of a stricter effluent and water body metal limitation standards and guidelines, as well as, the installations of wastewater treatment plants in the various industrial establishment in Anambra State.

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