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Seasonal variations of bioaccumulation of heavy metals in a freshwater fish (*Erpetoichthys calabaricus*) from Ogba River, Benin City, Nigeria

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ABSTRACT: This investigation assessed and monitored accumulation levels of Cu, Mn, Zn, Cd, Ni and Pb in a freshwater fish (*Erpetoichthys calabaricus*) from Ogba River during the dry and rainy seasons of a hydrologic year (November, 2005 – October, 2006). The same metals were also examined in the water of the river over the period. The results showed that the accumulation levels in fish exceeded the levels of the metals in water and indicated bioaccumulation in fish. The dry and rainy season levels in fish as well as in water at each of the sampling stations varied, but the differences were not significant. However, among the stations, the differences in the seasonal levels for most of the metals were significant. A correlation between seasonal levels in water and fish as well as the lack of uniformity in the distribution of the metals in the river were established. The finding also that both dry and rainy season mean levels of Cu, Mn and Ni in fish exceeded WHO recommended limits in food, suggested that the fishes of the river are not suitable for human consumption. Consequently, close monitoring of metal pollution of Ogba River is strongly advocated, in view of possible risks to health of consumers of the fishes of the river.

Key Words: Heavy metals, Seasons, Bioaccumulation, Fish, River, Nigeria.

Introduction

In recent years, the extensive inland waters of Nigeria have been subjected to ecological degradation as a result of pollution. Increase in industrialization, technological development, growing human population, oil exploration and exploitation have led to an increase in man-made pollutants in the aquatic environment. It is well known that the effects of pollution are detrimental to fisheries resources and other aquatic organisms (Patil, 1976; Obeng,1981).

Heavy metals are generally and naturally found at very low concentrations, while elevated concentrations are commonly associated with pollution from human activities (Forstner and Wittmann,1981; Idodo-Umeh,2002). Human destructive influence on the aquatic environment in the form of discharged pollutants especially at the sub-lethal level, results in chronic stress conditions with the attendant negative effects on aquatic life (Idodo-Umeh, 2002).

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While the demand for fish protein is increasing enormously with growing population, our rivers are being reduced to sewage depots for poisonous chemicals, which kill our fish and other aquatic organisms (Oladimeji, 1983). Toxic heavy metals in the aquatic environment get to man either directly from drinking water or indirectly through food chain and have been implicated in many human health conditions such as cancer, brain damage, kidney damage and behavioural problems (Forstner and Wittmann,1981; Smith and Williamson,1985).

The need to make an adequate assessment of the level of heavy metal contamination in the environment has led to the initiation of several pollution monitoring programmes and research work. In Nigeria, as in many African countries, the assessment of the concentrations of heavy metals in water, sediment and biotic resources in many natural water bodies has received considerable attention in the recent past. However, the effects of seasons and other physico-chemical properties on metal concentrations in these matrices have not been adequately addressed. This study therefore focuses on the effects of dry and rainy seasons on the concentrations of selected heavy metals in the freshwater fish (*Erpetoichthys calabaricus*) from Ogba River in Benin City. The specific objectives are to determine and compare the dry and rainy season levels of Cu, Mn, Zn, Cr, Ni and Pb in water and fish (*E. calabaricus*) of Ogba River in Benin City, Nigeria.

Materials and Methods

Study Area

This study was conducted in a stretch of Ogba River, a perennial rainforest river in Benin City, Edo State, Nigeria (Latitude 6.5^{O}N and Longitude 5.8^{O}E). Previous publications (Obasohan, 2003; Obasohan and Oronsaye, 2004; Obasohan *et al*, 2006) have treated the description of this river in detail.

The climate in the area is tropical with two major seasons; the wet (April – October) and dry (November – March) seasons. Rainfall is bimodal, peaking usually in July and again September, with a brief drop in August. Minimal rainfall is in January and February, followed by the onset of heavy rainfall in April. Mean relative humidity in the area is around 70%.

Sampling

Three sampling stations (1, 2 and 3) were selected along the stretch of the river, for the purpose of this study (Fig 1). Water and fish (*Erpetoichthys calabaricus*) samples were collected monthly from the stations over a twelve-month (November, 2005 – October, 2006) period. Station 1 was about 500m from the source of the river. The water at this point is relatively unpolluted. Station 2 was about 2.0km downstream of Station 1, at about 100m from the point where the main drainage channel opened into the river. Station 3 was another 2.0km further downstream. Human activities such as bathing, washing of clothes and sand escavation were more intensive at Station 3.

Water samples were collected in the middle of the river at 30cm below the surface, using 1litre polythene bottles with screw caps. The bottles had been washed and soaked in 5% Nitric acid for 24 hours and rinsed with deionised water before use (Laxen and Harrison, 1981). The water samples were acidified immediately after collection by adding 5ml nitric acid (Analar grade) to minimise adsorption of heavy metals onto the walls of the bottles (APHA, 1989; Ademoroti, 1996). Fish samples were caught with nylon nets of various mesh sizes (50mm – 76mm); hooks and lines and local traps and were transported in polythene bags and stored in deep freezer at -10^{0}C, while awaiting treatment and analysis.

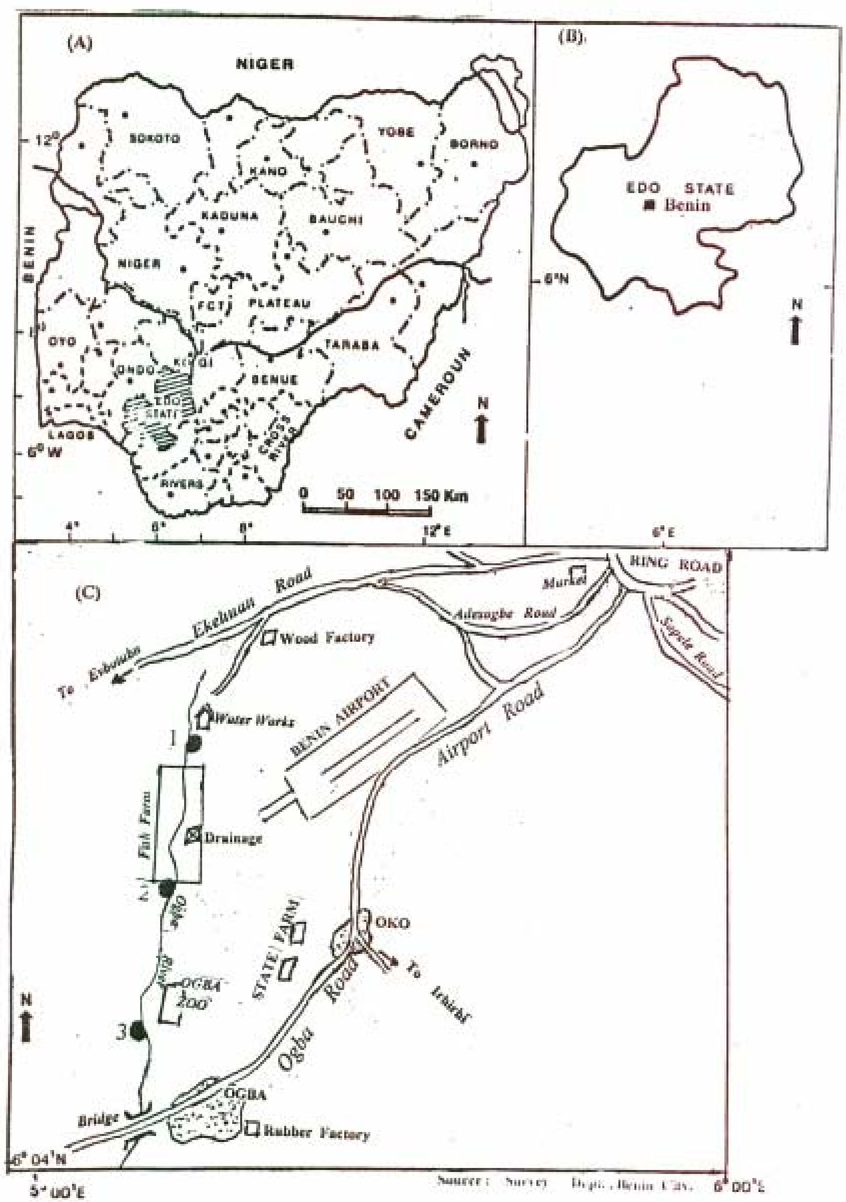

FIG. 1: (A) Map of Nigeria showing position of Edo State.
(B) Edo State showing position of Benin City.
(C) Benin City showing Ogba River and Study Stations (●)

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FIG. 1: Map of Benin City showing Ogba River and Study Stations (1- 3)

Treatment and Analyses

Water samples were analysed without further treatment. The stored fish samples were allowed to thaw at room temperature (27 - 30^{O} C). Samples from each station were placed in aluminium crucibles and dried at 105±20^{O}C. The dried samples were ground into power and 1.0g of each, was digested with 5ml conc. nitric acid; 1ml perchloric acid and 1ml conc. sulphuric acid (Oguzie, 2003). Deionise water was added to the solution and then aspirated into an Atomic Absorption Spectrophotometer (Varian Spectrum AA – 10) for heavy metal determination.

Statistical Analyses

All data were analysed using the Statistical Package for Social Scientists (SPSS) computer program. Seasonal means were compared using the Duncan Multiple Range Test. The significant level throughout was P<0.05.

Results

The monthly and seasonal mean concentrations of the heavy metals (Cu, Mn, Zn, Cd, Ni and Pb) in water and fish are presented in Tables 1 and 2, while the comparison of the dry and rainy season heavy metal mean levels in fish and the bio-concentration factors between fish and water at the sample stations are shown in Tables 3 and 4 respectively.

Seasonal mean concentrations of heavy metals in Water

The seasonal mean concentrations of Cu ranged between 0.002mg/l recorded at both dry and rainy season at Station 3 and 0.048mg/l recorded at Station 2 during the dry seasons. Cu mean levels in the dry and rainy seasons at Station 1, were similar (0.006mg/l). At Station 2, the dry season mean level was 0.048mg/l, while the rainy season mean level was 0.036mg/l. At Station 3, both dry and rainy season mean levels were equal (0.002mg/l). Seasonal mean levels at each of the stations were not significantly different (P>0.05), but between the stations, there were significant differences (P<0.05).

Mn Seasonal mean levels ranged from 0.001mg/l (dry and rainy season) at Station 1, to 0.053mg/l (rainy season) at Station 2. At Station 1, the dry and rainy season mean levels were similar (0.001mg/l), while at Station 2, the dry season mean level was 0.09mg/l and the rainy season mean level was 0.053mg/l. At Station 3, the dry season mean level (0.005mg/l) was higher than the rainy season level (0.004mg/l). Mn seasonal levels were not significantly different (P>0.05) at the stations.

Zn seasonal mean levels ranged between 0.002mg/l (dry season) at Station 1 to 0.094mg/l (dry season) at Station 2. At Station 1, dry season mean level (0.002mg/l) was lower than the rainy season mean level of 0.003mg/l. At Station 2, the dry season mean level (0.094mg/l) was higher than the rainy season mean level of 0.093mg/l. At Station 3, dry season mean value was 0.090mg/l, while the corresponding rainy season value was 0.086mg/l. Zn mean levels at the stations were not significantly different (P>0.05).

Cd seasonal mean level at Station 1 was 0.002mg/l for both dry and rainy seasons. At Station 2, the dry season mean level was 0.009mg/l, while the rainy season mean level was 0.005mg/l. Station 3 recorded similar level (0.002mg/l) during both dry and rainy seasons. Statistical analysis showed no significant differences (P>0.05) in Cd seasonal mean levels at each of the stations.

TABLE 1: MONTHLY AND SEASONAL VARIATIONS OF HEAVY METALS IN WATER AT THE SAMPLE STATIONS (MG/L)

STATION 1:

	DRY SEASON						RAINY SEASON							
Metals	Nov	Dec	Jan	Feb	Mar	Mean	Apr	May	Jun	July	Aug	Sept	Oct	Mean
Cu	0.004	0.006	0.007	0.006	0.004	0.006	0.001	0.001	0.006	0.009	0.007	0.009	0.009	0.006
Mn	0.001	0.001	0.002	ND	ND	0.001	ND	0.001	0.001	0.002	0.002	0.001	0.002	0.001
Cd	0.003	0.004	0.001	0.002	0.002	0.002	0.004	0.003	0.002	0.001	0.003	0.002	0.004	0.002
Zn	0.002	0.001	0.003	0.001	ND	0.002	ND	0.003	ND	0.002	ND	0.001	0.001	0.003
Ni	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.004	0.002	0.002	ND	0.001	0.001	0.002
Pb	0.001	0.001	0.002	0.001	0.001	0.001	ND	ND	ND	0.001	ND	0.001	0.002	0.001

STATIONS 2:

	DRY SEASON						RAINY SEASON							
Metals	Nov	Dec	Jan	Feb	Mar	Mean	Apr	May	Jun	July	Aug	Sept	Oct	Mean
Cu	0.049	0.063	0.041	0.046	0.039	0.048	0.031	0.036	0.026	0.020	0.041	0.044	0.051	0.036
Mn	0.010	0.010	0.09	0.09	0.07	0.09	0.05	0.06	0.06	0.05	0.07	0.07	0.009	0.053
Cd	0.009	0.007	0.009	0.008	0.010	0.009	0.008	0.002	0.006	0.003	0.005	0.005	0.006	0.005
Zn	0.09	0.08	0.10	0.09	0.11	0.94	0.11	0.10	0.13	0.19	0.07	0.08	0.006	0.093
Ni	0.010	0.009	0.008	0.011	0.010	0.010	0.009	0.007	0.006	0.006	0.009	0.006	0.009	0.007
Pb	0.009	0.031	0.029	0.030	0.026	0.025	0.029	0.001	0.009	0.008	0.009	0.010	0.009	0.011

STATION 3:

	DRY SEASON						RAINY SEASON							
Metals	Nov	Dec	Jan	Feb	Mar	Mean	Apr	May	Jun	July	Aug	Sept	Oct	Mean
Cu	0.003	0.003	0.002	0.001	0.002	0.002	0.001	0.002	0.002	0.001	0.001	0.002	0.003	0.002
Mn	0.006	0.006	0.007	0.004	0.003	0.005	0.003	0.004	0.002	0.003	0.004	0.005	0.005	0.004
Zn	0.094	0.092	0.089	0.093	0.076	0.090	0.082	0.090	0.086	0.079	0.086	0.089	0.091	0.086
Cd	0.002	0.002	0.001	0.002	0.003	0.002	0.001	0.002	0.002	0.001	0.002	0.003	0.003	0.002
Ni	0.010	0.009	0.012	0.013	0.009	0.011	0.012	0.013	0.014	0.009	0.009	0.014	0.014	0.012
Pb	0.003	0.002	0.005	0.004	0.002	0.003	0.003	0.004	0.002	0.004	0.003	0.004	0.005	0.003

TABLE 2: MONTHLY AND SEASONAL VARIATIONS OF HEAVY METALS IN FISH AT THE SAMPLE STATIONS (MG/KG)

STATION 1:

	DRY SEASON						RAINY SEASON							
Metals	Nov	Dec	Jan	Feb	Mar	Mean	Apr	May	Jun	July	Aug	Sept	Oct	Mean
Cu	2.67	3.01	4.11	6.32	3.21	3.86	4.00	2.92	4.97	4.25	3.80	3.81	2..92	3.81
Mn	0.56	0.29	0.91	0.89	0.59	0 .65	0.41	0.30	0.69	0.9 6	0.77	0 .57	0.39	0.58
Zn	6.15	4.91	4.21	2.01	4. 06	4.27	6.01	5.86	6.21	4.11	4. 14	4. 10	5.49	5.13
Cd	0.10	1.09	1.01	ND	ND	0.07	0.02	0. 01	0.01	ND	0.02	ND	0.06	0.02
Ni	0.02	0.09	0.01	0.02	0. 04	0.04	0.09	0.06	0.03	0.01	1.01	0.01	0. 11	0.05
Pb	0.42	0.52	0.01	N D	0.06	0.25	0 .01	0.02	ND	0. 02	0.02	ND	0.20	0.05

STATION 2:

DRY SEASON							RAINY SEASON							
Metals	Nov	Dec	Jan	Feb	Mar	Mean	Apr	May	Jun	July	Aug	Sept	Oct	Mean
Cu	4.36	4.11	6.03	4.44	6.00	4.99	3.04	5.99	3.75	5.00	4.33	5.25	5, 18	4.66
Mn	1.02	1.00	1.00	0.91	0.90	0.97	1.99	1.00	1.02	0.87	1.12	0.73	1.52	1.04
Zn	7.92	3.11	6.41	7.02	4.11	5.71	5.01	5.90	3.43	492	5.41	4.00	8.90	5.76
Cd	0.21	0.20	0.19	0.16	0.10	0.17	0.10	0.09	0.11	0.09	0.09	0.09	0.19	0.11
Ni	1.01	0.70	0.66	1,01	0.60	0.79	0.59	0.90	0.70	0.53	1.00	0.93	0.83	0.78
Pb	0.90	0.99	0.90	0.97	0.99	0.95	0.99	0.89	0.90	1.00	0.76	0.99	1.10	0.95

STATION 3:

	DRY SEASON						RAINY SEASON							
Metals	Nov	Dec	Jan	Feb	Mar	Mean	Apr	May	Jun	July	Aug	Sept	Oct	Mean
Cu	7. 40	6.02	ND	6.10	5.61	6.28	ND	7.79	3.77	ND	3.99	6.11	ND	5.07
Mn	0.84	1.01	ND	089	0.90	0.91	ND	1.00	0.79	ND	0.90	1.00	ND	0.67
Zn	7.42	5.92	ND	6.91	8.00	7.06	ND	3.92	7.36	ND	3.92	6.66	ND	5.47
Cd	O.11	0.13	ND	O.06	0.02	0.05	ND	0.10	0.07	ND	0.10	0.04	ND	0.05
Ni	0.08	0. 13	ND	0.31	0.12	0.16	ND	0.10	0.0 9	ND	0.03	0.11	ND	0.08
Pb	0.84	0.69	ND	1.00	0.44	0.74	ND	0.36	0.39	ND	0.92	0.77	ND	0.61

TABLE 3: COMPARISON OF DRY AND RAINY SEASON MEAN METAL LEVELS IN FISH AT THE SAMPLE STATIONS (CONC. IN MG/KG).

STATION	**1**		**2**		**3**		**WHO (1985) Limit in food fish**
SEASON	**DRY**	**RAINY**	**DRY**	**RAINY**	**DRY**	**RAINY**	
Cu	*3.86	*3.81	*4.99	*4.66	*6.28	*5.07	1-3.0
Mn	*0.65	*0.58	*0.97	*1.04	*0.91	*0.67	0.1-0.5
Zn	4.27	5.13	5.71	5.76	7.06	5.47	1000
Cd	0.07	0.02	0.17	0.11	0.05	0.05	2.0
Ni	0.04	0.05	*0.79	*0. 78	0.16	0.08	0.5-0.6
Pb	0.25	0.05	0.95	0.95	0.74	0.61	2.0

*Concentrations higher than WHO and FEPA limits in food

Ni seasonal mean levels at Station 1 were 0.001 mg/l (dry season) and 0.002mg/l (rainy season). At Station 2, the corresponding values were 0.010mg/l (dry season) and 0.007mg/l (rainy season). The values at Station 3 were 0.011mg/l (dry season) and 0.012mg/l (rainy season). Ni seasonal mean levels among the stations were significantly different (P<0.05), but at each station, the dry and rainy season mean levels were not significantly different (P>0.05).

Pb seasonal mean values for both dry and rainy seasons were similar (0.001mg/l) at Station 1. The levels at Stations 2 were 0.025mg/l (dry season) and 0.011mg/l (rainy season). At Stations 3, the dry and rainy seasons recorded equal mean value of 0.003mg/l. ANOVA showed no significant differences (P>0.05)in seasonal mean levels at each of the stations, but among the stations the levels were significantly different (P<0.05).

Seasonal Mean Concentrations of Heavy Metals in Fish

The dry and rainy season mean concentrations are presented in Table 3. The seasonal mean concentrations of Cu at Station 1 were 3.86mg/kg (dry season) and 3.81mg/kg (rainy season). At Station 2, the values were 4.99mg/kg (dry season) and 4.66mg/kg (rainy season). The corresponding values at Station 3 were 6.28mg/kg (dry season) and 5.07mg/kg (rainy season). ANOVA showed significant differences (P<0.05) in seasonal mean levels of Cu among the stations.

Mn seasonal mean levels at Station 1 were 0.65mg/kg (dry season) and 0.58mg/kg (rainy season). At Station 2, the mean levels were 0.97mg/kg for dry season and 1.04mg/kg for rainy season. Station 3 recorded 0.91mg/kg for dry season and 0.67mg/kg for the rainy season. Statistically, Mn seasonal mean levels among the stations were not significantly different (P>0.05).

Zn seasonal mean levels at Station 1 were 4.27mg/kg for dry season and 5.13mg/kg for rainy season. At Station 2, the values were 5.71mg/kg (dry season) and 5.76mg/kg (rainy season), while at Station 3, the corresponding values were 7.06mg/kg for dry season and 5.47mg/kg for rainy season. Statistically, Zn seasonal mean levels amongst the stations were significantly, different (P<0.05).

Cd seasonal means at Stations 1 were 0.07mg/kg (dry season) and 0.02mg/kg (rainy season). The values at Station 2 were 0.17mg/kg (dry season) and 0.11mg/kg (rainy season). At Station 3, the values were similar (0.05mg/kg) for both dry and rainy seasons. However among the stations, ANOVA showed significant differences (P<0.05) in Cd seasonal mean levels.

The seasonal mean levels of Ni at Station 1 were 0.04mg/kg for dry season and 0.05mg/kg for rainy season. At Station 2, the values were 0.79mg/kg and 0.78mg/kg for the dry and rainy seasons. The corresponding values at Station 3 were 0.16mg/kg and 0.08mg/kg for the dry and rainy seasons. Ni seasonal mean levels were not significantly different (P>0.05) among the stations.

Pb seasonal mean values at Station 1 were 0.25mg/kg and 0.05mg/kg for the dry and rainy seasons. Station 2 recorded an equivalent value of 0.95mg/kg for both dry and rainy seasons, while at Stations 3, the dry season value was 0.74mg/kg and the rainy season value was 0.16mg/kg. Statistically, Pb seasonal mean values among the stations were significantly different (P<0.05).

TABLE 4: METAL BIOCONCENTRATION FACTORS IN WATER AT THE SAMPLE STATIONS OF OGBA RIVER.

METAL	PERIOD	STATION 1	STATION 2	STATION 3
Cu	Dry Season	$\frac{3.86}{0.006}$ = **643.33**	$\frac{4.99}{0.048}$ = **103.96**	$\frac{6.28}{0.002}$ = **3140**
	Rainy Season	$\frac{3.81}{0.006}$ = **635**	$\frac{4.66}{0.036}$ = **129.44**	$\frac{5.07}{0.002}$ = **2535**
Mn	Dry Season	$\frac{0.65}{0.001}$ = **650**	$\frac{0.97}{0.09}$ = **10.78**	$\frac{0.91}{0.005}$ = **182**
	Rainy Season	$\frac{0.58}{0.001}$ = **580**	$\frac{1.04}{0.053}$ = **19.62**	$\frac{0.67}{0.004}$ = **167.50**
Zn	Dry Season	$\frac{4.27}{0.002}$ = **2135**	$\frac{5.71}{0.094}$ = **60.75**	$\frac{7.06}{0.090}$ = **78.44**
	Rainy Season	$\frac{5.13}{0.003}$ = **1710**	$\frac{5.76}{0.091}$ = **63.30**	$\frac{5.47}{0.086}$ = **63.61**
Cd	Dry Season	$\frac{0.07}{0.002}$ = **35**	$\frac{0.17}{0.009}$ = **18.89**	$\frac{0.05}{0.002}$ = **25**
	Rainy	$\frac{0.02}{0.003}$ = **6.67**	$\frac{0.11}{0.005}$ = **22**	$\frac{0.05}{0.002}$ = **25**
Ni	Dry Season	$\frac{0.04}{0.001}$ = **40**	$\frac{0.79}{0.010}$ = **79**	$\frac{0.16}{0.011}$ = **14.55**
	Rainy Season	$\frac{0.05}{0.002}$ = **25**	$\frac{0.78}{0.007}$ = **111.43**	$\frac{0.08}{0.012}$ = **6.67**
Pb	Dry Season	$\frac{0.25}{0.001}$ = **250**	$\frac{0.95}{0.025}$ = **38**	$\frac{0.74}{0.003}$ = **246.67**
	Rainy Season	$\frac{0.05}{0.001}$ = **50**	$\frac{0.95}{0.011}$ = **86.36**	$\frac{0.61}{0.003}$ = **203.33**

Seasonal bio-concentration factors (BF) of the various metals were also calculated between seasonal concentrations in fish and water and the values are as presented in Table 4.

Cu bio-concentration factor values ranged from a minimum of 103.96 in the dry season at Station 2 to a maximum of 3140 also in the dry season at Station 3. Mn values were a minimum of 10.78 in the dry season at Station 2 and a maximum of 650 in the dry season at Station 1. For Zn, the values were a minimum of 60.75 in the dry season at Station 2 and a maximum of 2135 also in the dry season at Station 1. Cd values ranged between 6.67 in the rainy season at Station 1 and 35 in the dry season also at Station 1. For Ni, the values were a minimum of 6.67 in the rainy season at Station 3 and 111.43 in the rainy season at Station 2, while for Pb, the corresponding values ranged from a minimum of 38 in the dry season at Station 2 to a maximum of 250 in the dry season at Station 1.

Discussion

Seasonal mean concentrations in water

The results of this investigation (Tables 1) revealed that the seasonal mean levels of all the metals (except Cu) in water at Station 1 were lower than the seasonal mean levels in water at Stations 2 and 3. The possible explanation for this could be the closeness of Station 1 to the source of the river. At this point, the water is relatively unpolluted unlike Stations 2 and 3 that are influenced by sewage effluents and surface runoffs from the surrounding agricultural fields. The high level of Cu at this station could be due to local sources.

Seasonal mean levels at Station 2 were significantly higher than the corresponding mean levels at Stations 1 and 3 indicating the lack of uniformity in the distribution and possible bio-availability of the metals at the sample stations of the river. The situation could be due to the effect of sewage effluents from the drainage system, which opens into the river close to the station. The effluents made up of sewage and surface runoffs from the city could be laden with heavy metals, thus raising the levels of the metals at the station. The generally lower seasonal mean levels of the metals at Station 3 in comparison to Station 2, demonstrated a self- purification ability of the river further away from the sewage entry point..

A comparison of the dry and rainy season means (Table1) showed that at Station 1, the levels of Cu, Mn, Cd, and Pb were similar. The mean levels of Zn and Ni were higher in the rainy season, but the differences between the dry and rainy season levels were not significant ($P>0.05$). At Station 2, the dry season levels of all the metals were higher than the rainy season levels. The possible explanation could be concentration of the metals due to reduced volume associated with higher evaporation rate induced by the higher water temperature in the dry season. Idodo- Umeh (2002) and Oguzie (2003) attributed similar results in the water bodies of Olomoro and Ikpoba River in Benin City, Nigeria to increased evaporation rate in the dry season. The differences in the seasonal means of the metals at the station were however, not significant ($P>0.05$).

Seasonal mean levels between the stations were however significant ($P<0.05$) for Cu, Cd, Ni and Pb and indicated the lack of uniformity in their distribution at the stations. This can be attributed to the different pollution levels at the stations and the differences in their chemistry in water. The levels for Mn and Zn were not significantly different and indicated their uniform distribution in the water of the river.

Seasonal Bioaccumulation levels in fish

In fish, seasonal mean levels of Mn, Cd, Ni and Pb follow the same pattern as in water, in being higher at Station 2 (Table 3). This indicated a close correlation between concentrations in water and fish. Fish has been reported to accumulate metals from water by diffusion via skin and gills as well as oral consumption/drinking of water (Nussey *et al*, 2000; Oguzie, 2003). The situation with Cu and Zn, which did not correlate with the levels in water, could be attributed to various physicochemical properties of the water (Nussey *et al*, 2000) and or the dynamic processes, which take place within the body of the fish (Heath, 1991). The higher Cu and Zn seasonal mean levels in fish at Station 3, suggested that their uptake was probably through food. Enk and Mathis (1977) and Fortner and Wittmann (1981) reported that the bio-availability and nature of food items, affect metals bioaccumulation in fish. *E. calabaricus* is a known carnivorous predator, which feeds on small fish such as *Synodontis nigrita* (Reed *et al*,1967) and mollusks (Idodo-Umeh,2000) and therefore forms an important link in the food web of aquatic ecosystems in the locality. At Station 3, the pollution level has reduced and the river probably harbored more food items.

Within each station, the dry season mean levels in fish were higher than the corresponding rainy season levels, except Ni at Station 1, where the rainy season level was higher. Higher dry season levels could be attributed to changes associated with higher water temperature during the season. Higher temperatures can cause higher activity and ventilation rates in fish. This is due to increasing temperatures that lower the oxygen affinity of the blood and increases the rate of pollution accumulation (Grobler, 1988). A higher metabolic rate may also induce more frequent feeding sessions, which in turn might result in increased metal concentrations, if these metals are taken up via the food chain (Nussey *et al*, 2000) Low rainy season metal levels could also result from low bio-availability due to reduced metal concentrations in the river arising from dilution, associated with heavy rains during the rainy season. Similar observations were reported in Ikpoba river by Fufeyin, 1998; Oguzie, 2003 and in Olomoro water bodies by Idodo-Umeh,

2002. Ni dry and rainy season levels were not significantly different (P>0.05) among the stations and within each station. The dry rainy season mean levels of Cu, Mn and Ni exceeded WHO (1985) and FEPA (2003) allowable limits in food fish (Table 4). Based on the above finding, the fish of Ogba river, could be considered unfit for human consumption.

The calculated bio-concentration factor values provide indication of the bio-availability of the metals to the fish from the water. High bio-concentration factor indicate high metal bio-availability. The relatively low bio-concentration factor values at Station 2 in comparison with the corresponding values at Stations 1 and 3, recorded in this study did not correlate with the high metal concentrations in the water at Station 2. This could be attributed to the physico-chemical properties of the water (Heath, 1991). Dry season bio-concentration factor values of the metals were higher than the corresponding rainy season values at Stations 1 and 3, but at Station 2, the reverse was the case. The higher rainy season bio-concentration factor values at Station 2, could arise from the altered water chemistry induced by the high degree of sewage influx at the station. Similar results reported for the water bodies in Burkina Faso were attributed to high influx of sewage effluents (Etienne *et al*,1997).

Conclusion

The results of this investigation showed that heavy metal concentrations in water and fish (*Erpetoichthys calabaricus*) of Ogba River were affected by seasons, as the dry season concentrations were significantly higher than the rainy season concentrations. It was further shown that heavy metals distribution in the river (water and fish), follow the same pattern, indicating a close correlation between the levels in water and in fish. The fact that both dry and rainy season mean levels of Cu, Mn and Ni exceeded WHO (1985) and FEPA (2003) recommended levels in food, suggested that the fishes of the river might be unfit for human consumption. Based on the above finding, a close monitoring of metal pollution of Ogba River is strongly advocated, in view of the possible health implication to consumers of the fishes of the river.

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