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*Full Length Research Paper*

# Heavy metal concentrations in *Malapterurus electricus* and *Chrysichthys nigrodigitatus* from Ogba River in Benin City, Nigeria

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**The concentrations of heavy metals in two tropical fish species (*Malapterurus electricus* and *Chrysichthys nigrodigitatus*) from Ogba river in Benin City, Nigeria, were investigated between November 2002 and October 2003 in order to ascertain the pollution status of the river. The results showed varying levels of accumulation of Cu, Mn, Zn, Pb, Cr, Ni, and Cd in the fishes. The levels of Cu, Mn, Cr and Ni, in both fishes were higher than the WHO and FEPA recommended maximum allowable standards in food fish, while those of Zn, Pb and Cd were lower than the standards. The results suggest that the Ogba river system is contaminated with heavy metals and the consumption of fishes of the river could pose health hazards to man. Metal levels in water in Ogba River are lower than the recommended limiting standards and could be considered safe for drinking.**

**Key words:** Heavy metals, bioaccumulation, fish, river, Nigeria.

## INTRODUCTION

The occurrence of heavy metals in aquatic ecosystems in excess of natural background loads has become a problem of increasing concern. Heavy metals in the environment may accumulate to acutely toxic levels without visible signs. This may occur naturally from normal geological phenomenon such as ore formation, weathering of rocks and leaching or due to increased population, urbanization, industrial activities, agricultural practices, exploration and exploitation of natural resources (Ajayi and Osibanjo, 1981; Biney et al., 1994).

Waste water streams containing heavy metals are produced by many manufacturing processes and find their way into the environment (Soon et al., 1980; Higgings and Dasher, 1986; Oguzie, 1996; Ogbeibu and Ezeunara, 2002). Metals persist in the environment and become bioconcentrated and bioamplified along the food chain. This may be responsible for high concentrations of the metals in predators such as sharks and eagles (Broda, 1972; Martins and Coughtry, 1975).

The aquatic ecosystem is frequently the ultimate recipient of heavy metal pollution. Aquatic microflora and microfauna, which constitute fish food are capable of incorporating and accumulating heavy metals into their living cells from their environment. Consequently, small fish become enriched with the accumulated heavy metals. Predatory fish generally display higher levels of heavy metals than their prey and eventually man on consuming the predatory fish, suffers from the results of an enrichment having taken place at each trophic level (Forstner and Wittman, 1981).

Bio-accumulation in fish has been reported by many researchers (Jernelov and Lann, 1971; Goldwater, 1971; Mathis and Cummings, 1973; Chernof and Dooley, 1979; Bull et al., 1981; Biney et al., 1991; Law and Singh, 1991). The uptake of heavy metals in fish was found to occur through absorption across the gill surface or through the gut wall tract (Mathis and Cummings, 1973). Diffusion facilitated transport or absorption in gills and surface mucus are the mechanisms of uptake from water (Oguzie, 1996). The concentrations of heavy metals in fish have been reported to depend upon the rate of uptake through the gut from food and the rate of excretion (Bull et al., 1981).

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All heavy metals are potentially harmful to most organisms at some levels of exposure and absorption (Young and Blevin, 1981). At low concentrations, many heavy metals including mercury, cadmuim, lead, arsenic and copper inhibit photosynthesis and phytoplankton growth. Biney et al. (1991) reported delayed embryonic development, malformation and reduced growth of adult fish, mulluscs and crustaceans under similar conditions.

The human health aspect linked to the consumption of heavy metal contaminated fish is of great concern. Man being at the top of many food chains is highly vulnerable as in the cases of Cd and Hg poisoning (Itai – itai and Rheumatic diseases) in the Jintsu River and Minamata, Japan (Kurland et al., 1960; Shimuzu, 1972).

In Nigeria, the increasing consumption of fish by the population as well as its importance in animal feed, underscore the importance of the potential risks of heavy metals in fish.

This study is therefore aimed at evaluating the potential risk of heavy metals from fish. The results of the investigation would help in the monitoring of metal levels in fish, since they are directly or indirectly responsible for a large proportion of animal protein intake of heavy metals by humans and other animals. The use of fish as bio-indicators of heavy metal pollution of aquatic environments and possible unfitness for human consumption from a toxicological view point has been documented (Ui and Kitamura, 1971; Idodo- Umeh, 2002; Ogbeibu and Ezeunara, 2002).

The Ogba River serves as a sink for urban drainage and agro-industrial effluents in Benin City, Nigeria. It is also important in fisheries production as a large number of fisherman settlements along the river axis depend on it for their fish and other domestic uses. The river is also the source of portable water for urban Benin City as well as the government owned fish farm in the city. The choice of the fishes, *Malapterurus electricus and Chrysichthys nigrodigitatus*, in this study is based on their relative importance. *M. electricus* is used in fish biological studies because of its ability to emit severe electrical shocks. It is also used locally for medicinal proposes due to the myth associated with it. *C. nigrodigitatus* is a relished food item on the table of most people in the area. The evaluation of wholefish samples is based on the fact that the organs of many small fish are not usually removed by the local people before consumption either dry or fresh. Besides, many people eat the liver, kidney, stomach and gills of big fish. The analysis of wholefish gives the total levels of heavy metals in the fish.

## MATERIALS AND METHODS

### Study area

The study area is a transect spanning a distance of five kilometers of the upper reaches of the river (Figure 1). Within the area, the river drains and receives effluents from the city drainage system, a wood treatment factory and a rubber processing factory as well as run-offs from a large agricultural fields. The climate of the area is typically tropical with wet (April – October) and dry (November – March) seasons. Rainfall is bimodal, peaking usually in July and again in September with a brief drop in August. Minimal rainfall is in January and February, followed by the onset of heavy rainfall in April. Annual temperature ranges between 22 to 32ºC, while annual humidity is between 69 and 96%.

In the area, the secondary rain forest has been subjected to extensive land clearing and farming activities, including use of herbicides and pesticides. The marginal vegetation is composed by *Commelina, Ipomea*, *Emilia* and *Sonchifolia* species. The dorminant macrophytes are *Nymphes, Azolla* and *Ceratophyllium* species (Kolade, 1998)

### Sampling

Three sample stations designated stations I, II and III were established at a kilometer apart for the purpose of the study. Station I was close to the source of the river. This station served as control as the water at this point is relatively unpolluted. Station II was established a kilometer downstream just after the points where the city drainage channel opened into the river while Station III was another kilometer further downstream (Figure 1).

The sample materials analyzed in the investigation were water, sediment and fish. Sampling was carried out monthly from the stations for one hydrologic year (November 2002 - October, 2003). Samples of water, sediment and fish were collected from three replicate spots in each of the three stations (composite sampling) and the mean values were recorded. Water samples were collected in the middle of the river at the sample sites at 15 cm depth below water surface in 250 ml capacity plastic bottles with screw caps. The bottles were treated with 10% nitric acid and rinsed with distilled water previously before use (Laxen and Harrison, 1981)

Grab samples of sediment were also taken into 10% nitric acid treated polythene bags. All samples were stored in a deep freezer at –10ºC (Ademoroti, 1996). The fish samples (*Malapterurus electricus* and *Chysichthys nigrodigitus*) were caught using set gill nets of various sizes, baited hooks and traps set overnight prior to collection. The fish were washed in flowing water to remove adhering dirt and stored in deep freezer.

### Sample treatment

All the samples which were previously stored in deep freezer were allowed to thaw at room temperature, about 27ºC. Water samples were not given further treatment, but were mixed vigorously before aspiration into the flames of an Atomic Absorption Spectrophotometer (Varian Techtron Spectra B) for heavy metal determination. Values are expressed in mg/l.

The sediment samples were oven-dried to constant weight at 105±20ºC, ground to powder and sieved through 2 mm mesh screen to remove coarse materials. The fish samples after defrosting were each ground to powder. Digestion of all powdered sediment and fish samples was according to Sreedevi at al, 1992; Oguzie, 1996. 1 g of each sample was digested using 1:5:1 mixture of 70% perchloric acid, concentrated nitric and concentrated sulphuric acid at 80±5ºC in a fume chamber until colourless liquid was obtained. Each digested sediment and fish sample was analyzed for heavy metal concentration using a Varian Techtron Spectra B, Atomic Absorption Spectrophotometer (APHA, 1990). Levels of heavy metals are expressed in mg/kg.

Tests of significance between the stations were carried out using the Analysis of Variance (ANOVA) of the Statistical Package for Social Sciences (SPSS) computer programme. Means were separated using the Duncan Multiple Range Test.

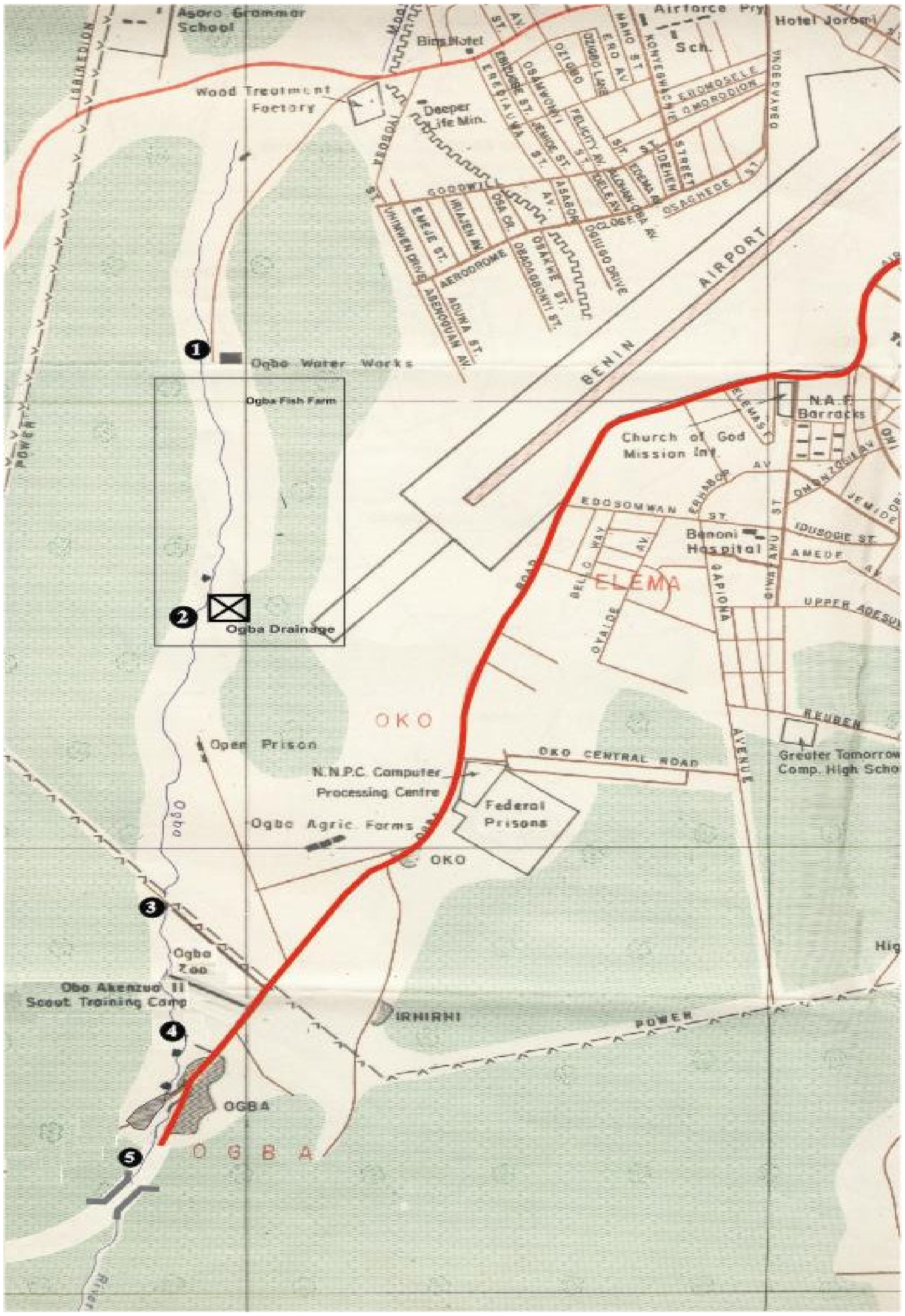


**Figure 1.** Map of Ogba River showing the sampling stations.

## RESULTS

### Heavy metal in water

The heavy metals detected in water at the stations include copper (Cu), manganese (Mn), znc (Zn), cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb). The monthly concentrations of the respective metals are presented in Table 1, while the annual mean values are illustrated in Figure 2. Annual mean values of Cu were 0.006 mg/l (Station I), 0.041 mg/l (Station II) and 0.002 mg/l (Station III). For Mn, the mean values were 0.001 mg/l (Station I), 0.075 mg/l (Station II) and 0.004 mg/l (Station III). Zn mean values were 0.003 mg/l (Station I), 0.093 mg/l (Station II) and 0.087 mg/l (Station III). For Cd, the values were 0.001 mg/l (Station I), 0.007 mg/l (Station II) and 0.002 mg/l (Station III). The mean values for Cr were 0.001 mg/l (Station I), 0.008 mg/l (Station II) and

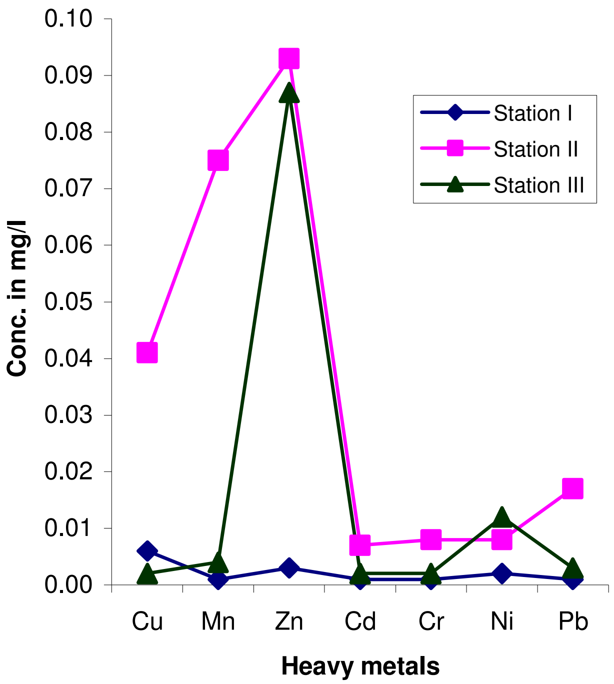


**Figure 2.** Annual mean concentrations of heavy metals in water at the three stations.

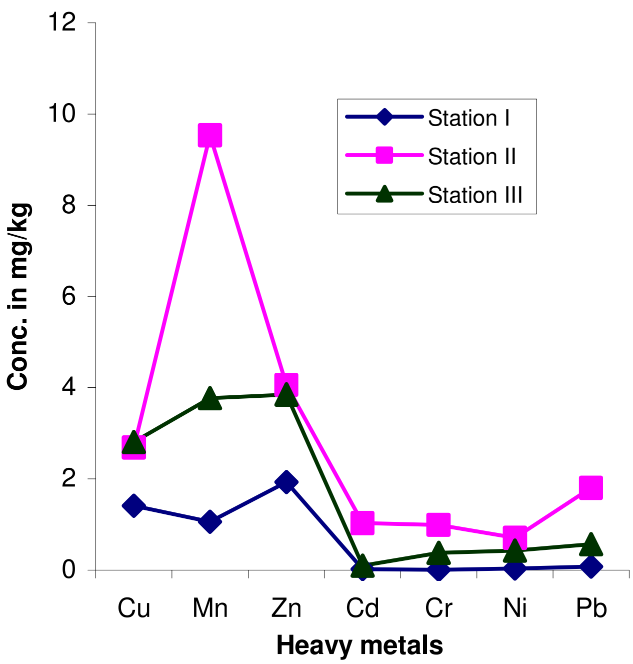


**Figure 3.** Annual mean concentrations of heavy metals in sediment at the three stations.

0.002 mg/l (Station III). Nickel (Ni) had mean values of 0.002 mg/l (Station I), 0.008 mg/l (Station II) and 0.012 mg/l (Station III), while for Pb the respective mean values were 0.001 mg/l (Station I), 0.017 mg/l (Station II) and 0.003 mg/l (Station III). Statistical analysis (ANOVA) showed that the values of the metals were significantly different (P<0.05) at the stations, except for Mn which values were not significantly different (P>0.05). Seasonal means were significantly different (P<.005) for Cu, Cd, Cr, Ni and Pb. But for Mn and Zn, the seasonal means were not significantly different (P>0.05).

## Heavy metals in sediment

The monthly values for the different metals in sediment at the stations are presented in Table 2, while the annual mean values are illustrated in Figure 3. The annual mean concentrations for Cu were 1.41 mg/kg (Station I), 2.69 mg/kg (Station II) and 2.81 mg/kg (Station III). For Mn, the values were 1.06 mg/kg (Station I), 9.53 mg/kg (Station II) and 3.85 mg/kg (Station III). The respective values for Zn were 1.93 mg/kg (Station I), 4.06 mg/kg (Station II) and 3.85 mg/kg (Station III). Cadmium (Cd) values were 0.02 mg/kg (Station I); 1.03 mg/kg (Station II) and 0.10 mg/kg (Station III). For Cr, the values were 0.01 mg/kg (Station I), 0.99 mg/kg (Station II) and 0.38 mg/kg (Station III). Ni mean values at the stations were 0.41 mg/kg (Station I), 0.71 mg/kg (Station II) and 0.43 mg/kg (Station III). The respective values for Pb were 0.08 mg/kg (Station I), 1.08 mg/kg (Station II) and 0.57 mg/kg (Station II). Statistical analyses showed that the concentrations of all the metals at the stations were significantly different (P<0.05). Seasonal means were also significantly different (P<0.05) for the metals, except for Cr and Pb, which were not significantly different (P>0.05).

## Heavy metals in fish

The monthly concentrations of the heavy metals in the two fish species are shown in Tables 3 and 4, while the annual mean values are illustrated in Figures 4 and 5. Cu mean values varied from a minimum of 4.17 mg/kg in *C. nigrodigitatus* at Station I to 6.46 mg/kg in *M. electricus* at station III. For Mn, the minimum level was 0.74 mg/kg in *M. electricus* at Station I, while the maximum level was 1.01 mg/kg in *C. nigrodigitatus* at Station III. Zn mean values ranged from a minimum of 5.01 mg/kg in *M. electricus* at Station I to a maximum of 6.92 mg/kg at Station II. The values for Cd ranged from 0.03 mg/kg in *M. electricus* at Stations I and III to a maximum of 0.13 mg/kg in *C. nigrodigitatus* at Station II. For Cr, the minimum value was 0.02 mg/kg in *M. electricus* at Station I, while the maximum was 0.79 mg/kg in *C. nigrodigitatus* at Station II. Ni values ranged between a minimum of 0.004 mg/kg in *M. electricus* at Station I to a maximum of 0.88 mg/kg in *M. electricus* at Station II. The values for Pb varied between a minimum of 0.10 mg/kg in both fish species at Station I to a maximum of 0.83 mg/kg in *M.*

**Table 1.** Monthly variations of heavy metals in water (conc. in mg/l).

| | Station 1 | | | | | | | Station 2 | | | | | | | Station 3 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **METALS** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** |
| NOV. | .004 | .001 | .003 | .002 | .001 | .001 | .001 | .049 | .10 | .09 | .009 | .009 | .010 | .009 | .003 | .006 | .094 | .002 | .001 | .010 | .003 |
| DEC. | .006 | .001 | .001 | .001 | .007 | .002 | .001 | .063 | .10 | .08 | .007 | .006 | .009 | .031 | .003 | .006 | .092 | .002 | .003 | .009 | .002 |
| JAN. | .007 | .002 | .001 | .003 | .001 | .001 | .002 | .041 | .09 | .10 | .009 | .006 | .008 | .029 | .002 | .007 | .089 | .001 | .003 | .012 | .005 |
| FEB. | .006 | ND | .002 | .001 | .001 | .002 | .001 | .046 | .09 | .09 | .008 | .007 | .011 | .030 | .001 | 004 | .093 | .002 | .001 | .013 | .004 |
| MAR. | .004 | ND | .002 | ND | ND | .001 | .001 | .039 | .07 | .11 | .010 | .009 | .010 | .026 | .002 | .003 | .076 | .003 | .003 | .009 | .002 |
| **DRY SEASON MEAN** | **.006** | **.001** | **.002** | **.002** | **.001** | **.001** | **.001** | **.048** | **.09** | **.094** | **.009** | **.007** | **.010** | **.025** | **.002** | **.005** | **.090** | **.002** | **.002** | **.011** | **.003** |
| APRIL | .001 | ND | .004 | ND | ND | .001 | ND | .031 | .05 | .11 | .008 | .008 | .009 | .029 | .001 | .003 | .082 | .001 | .002 | .012 | .003 |
| MAY | .001 | .001 | .003 | .003 | .001 | .004 | ND | .036 | .06 | .10 | .002 | .009 | .007 | .001 | .002 | .004 | .090 | .002 | .002 | .013 | .004 |
| JUNE | .006 | .001 | .002 | ND | .001 | .002 | ND | .026 | .06 | .13 | .006 | .010 | .006 | .009 | .002 | .002 | .086 | .002 | .001 | .014 | .002 |
| JULY | .009 | .002 | .001 | .002 | .002 | .002 | .001 | .020 | .05 | .09 | .003 | .009 | .006 | .008 | .001 | .003 | .079 | .001 | .002 | .009 | .004 |
| AUG. | .007 | .002 | .003 | ND | ND | .001 | ND | .041 | .07 | .07 | .005 | .008 | .009 | .009 | .001 | .004 | .086 | .002 | .002 | .009 | .003 |
| SEPT. | .009 | .001 | .002 | .001 | .001 | .001 | .001 | .044 | .07 | .08 | .005 | .008 | .006 | .010 | .002 | .005 | .089 | .003 | .002 | .014 | .004 |
| OCT. | .009 | .002 | .004 | .001 | .001 | .001 | .002 | .051 | .009 | .006 | .006 | .006 | .009 | .009 | .003 | .005 | .091 | .003 | .002 | .014 | .005 |
| **Rainy season mean** | **.006** | **.001** | **.003** | **.002** | **.001** | **.002** | **.001** | **.036** | **.053** | **.091** | **.005** | **.008** | **.007** | **.011** | **.002** | **.004** | **.086** | **.002** | **.002** | **.012** | **.004** |
| **Annual mean** | **.006** | **.001** | **.003** | **.001** | **.001** | **.002** | **.001** | **.041** | **.075** | **.093** | **.007** | **.008** | **.008** | **.017** | **.002** | **.004** | **.087** | **.002** | **.002** | **.012** | **.003** |

**Table 2.** Monthly variations of heavy metals in sediment (Conc. in mg/kg).

| | Station 1 | | | | | | | Station 2 | | | | | | | Station 3 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metals** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** |
| NOV. | 1.00 | 1.09 | 2.99 | 0.03 | 0.01 | .041 | 0.20 | 3.01 | 8.37 | 3.33 | 1.10 | 0.99 | 0.93 | 2.10 | 3.71 | 4.11 | 3.99 | 0.11 | 0.96 | 0.53 | 0.59 |
| DEC. | 1.10 | 0.93 | 2.20 | 0.02 | 0.02 | .039 | 0.10 | 3.47 | 9.63 | 5.61 | 0.99 | 0.92 | 0.86 | 2.11 | 3.90 | 4.00 | 4.11 | 0.10 | 0.44 | 0.41 | 0.59 |
| JAN. | 1.89 | 1.41 | 1.90 | 0.04 | 0.01 | .022 | 0.09 | 2.92 | 11.29 | 6.02 | 1.09 | 1.00 | 0.90 | 1.49 | 3.70 | 3.86 | 4.52 | 0.09 | 0.45 | 0.52 | 0.61 |
| FEB. | 2.04 | 1.22 | 1.90 | 0.02 | 0.02 | .019 | 0.10 | 3.00 | 10.14 | 4.91 | 1.00 | 1.00 | 0.90 | 2.31 | 3.11 | 4.25 | 4.61 | 0.12 | 0.31 | 0.39 | 0.52 |
| MAR. | 0.98 | 0.92 | 2.01 | 0.01 | .002 | 0.024 | 0.11 | 3.61 | 8.82 | 4.86 | 1.02 | 1.04 | 0.88 | 1.87 | 2.59 | 4.04 | 3.52 | 0.08 | 0.41 | 0.47 | 0.58 |
| **Dry season mean** | **1.20** | **1.11** | **2.22** | **0.02** | **.012** | **.029** | **0.12** | **3.20** | **9.65** | **4.95** | **1.04** | **0.99** | **0.89** | **2.00** | **3.40** | **4.05** | **4.15** | **0.10** | **0.51** | **0.46** | **0.58** |
| 0.76 | 0.20 | 2.00 | 0.01 | .001 | .001 | 0.06 | 3.00 | 10.05 | 5.10 | 0.93 | 1.01 | 0.89 | 1.77 | 2.49 | 3.91 | 3.51 | 0.08 | 0.23 | 0.45 | 0.61 | |
| 0.93 | 0.86 | 0.91 | 0.02 | .002 | .041 | 0.03 | 2.76 | 9.15 | 3.47 | 1.13 | 1.00 | 0.61 | 1.99 | 2.21 | 4.22 | 2.98 | 0.09 | 0.29 | 0.36 | 0.55 | |
| 1.01 | 0.90 | 1.92 | 0.02 | 0.02 | .061 | 0.06 | 2.09 | 9.92 | 3.41 | 1.10 | 0.87 | 0.61 | 1.00 | 1.70 | 5.00 | 3.77 | 0.11 | 0.32 | 0.41 | 0.49 | |
| 1.99 | 1.00 | 1.89 | 0.02 | 0.01 | .053 | 0.05 | 1.91 | 7.98 | 2.98 | 1.01 | 0.98 | 0.39 | 1.01 | 2.09 | 3.79 | 4.02 | 0.10 | 0.40 | 0.40 | 0.56 | |
| 2.36 | 1.39 | 1.91 | 0.01 | 0.02 | .044 | 0.01 | 1.98 | 9.65 | 3.36 | 1.00 | 1.04 | 0.42 | 2.06 | 2.09 | 3.86 | 3.91 | 0.09 | 0.39 | 0.39 | 0.56 | |
| 2.00 | 1.41 | 1.20 | 0.02 | 0.01 | .049 | 0.01 | 2.00 | 8.77 | 2.31 | 1.00 | 1.06 | 0.49 | 1.97 | 4.02 | 3.69 | 4.19 | 0.10 | 0.44 | 0.41 | 0.59 | |
| 0.90 | 1.36 | 2.20 | 0.03 | 0.02 | .036 | 0.16 | 2.51 | 10.64 | 3.41 | 1.00 | 1.00 | 0.69 | 2.00 | 3.61 | 3.54 | 3.23 | 0.13 | 0.46 | 0.42 | 0.60 | |
| **Rainy season mean** | **1.42** | **1.02** | **1.72** | **0.02** | **.009** | **.041** | **.054** | **2.32** | **9.45** | **3.43** | **1.02** | **0.99** | **0.59** | **1.69** | **2.60** | **4.00** | **3.66** | **0.10** | **0.36** | **0.41** | **0.57** |
| **Annual mean** | **1.41** | **1.06** | **1.93** | **0.02** | **.01** | **.04** | **.08** | **2.69** | **9.53** | **4.06** | **1.03** | **0.99** | **0.71** | **1.80** | **2.81** | **3.77** | **3.85** | **0.10** | **0.38** | **0.43** | **0.57** |

**Table 3.** Monthly variations of heavy metals in *Malapeterurus electricus* (Conc. in mg/kg).

| | Station I | | | | | | | Station 2 | | | | | | | Station 3 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metals** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** |
| NOV. | 3.67 | 0.66 | 5.99 | ND | 0.03 | 0.07 | 0.01 | 3.98 | 0.97 | 3.67 | 0.26 | 1.02 | 0.96 | 1.10 | 3.18 | 0.96 | 7.21 | 0.07 | 0.99 | 0.09 | 0.76 |
| DEC. | 3.12 | 0.65 | 3.99 | 0.06 | 0.03 | 0.10 | 0.63 | 3.76 | 0.79 | 9.22 | 0.19 | 1.01 | 1.01 | 1.00 | 6.18 | 0.99 | 7.44 | 0.10 | 0.25 | 0.09 | 0.30 |
| JAN. | 4.15 | 0.69 | 6.02 | 0.02 | 0.01 | 0.03 | 0.03 | 3.68 | 1.02 | 6.92 | 0.19 | 0.56 | 1.01 | 0.92 | 7.02 | 0.91 | 4.19 | 0.01 | 0.39 | 0.39 | 1.00 |
| FEB. | 3.39 | 1.02 | 3.00 | 0.03 | 0.04 | 0.04 | ND | 4.02 | 1.11 | 6.09 | 0.12 | 0.60 | 0.92 | 1.10 | 6.10 | 0.92 | 4.82 | 0.01 | 0.53 | 0.29 | 0.90 |
| MAR. | 7.93 | 1.00 | 5.86 | 0.04 | 0.01 | ND | 0.01 | 5.11 | 1.00 | 8.10 | 0.09 | 0.11 | 0.73 | 0.93 | 4.33 | 0.91 | 5.15 | 0.02 | 0.30 | 0.10 | 0.93 |
| **Dry season mean** | **4.45** | **0.81** | **4.97** | **0.04** | **0.02** | **0.05** | **0.17** | **4.11** | **0.98** | **6.8** | **0.19** | **0.66** | **0.93** | **1.01** | **5.36** | **0.94** | **5.76** | **0.04** | **0.49** | **0.19** | **0.78** |
| APRIL | 1.99 | 0.66 | 5.92 | 0.05 | 0.03 | 0.09 | 0.01 | 4.81 | 0.93 | 7.82 | 0.10 | 0.66 | 0.82 | 0.39 | 3.69 | 0.90 | 6.60 | ND | ND | 0.09 | 0.21 |
| MAY | 3.94 | 0.49 | 7.14 | 0.01 | ND | 0.07 | 0.01 | 7.03 | 0.86 | 7.32 | ND | 0.43 | 0.81 | 0.53 | 5.60 | 1.00 | 4.64 | 0.01 | ND | 0.10 | 0.41 |
| JUNE | 5.50 | 0.55 | 3.94 | 0.03 | 0.01 | 0.05 | ND | 7.04 | 0.99 | 9.02 | ND | 0.63 | 0.69 | 0.79 | 4.82 | 0.99 | 9.00 | ND | 0.12 | 0.45 | 0.52 |
| JULY | 3.73 | 0.99 | 5.21 | 0.03 | ND | 0.02 | 0.05 | 5.36 | 0.96 | 6.00 | 0.09 | 0.42 | 0.65 | 0.59 | 9.00 | 0.90 | 4.55 | 0.01 | 0.47 | 0.02 | 0.66 |
| AUG. | 3.73 | 0.90 | 3.99 | 0.02 | 0.03 | 0.02 | ND | 3.90 | 1.00 | 5.60 | ND | 0.38 | 0.96 | 0.52 | 5.21 | 0.97 | 5.29 | 0.07 | 0.46 | 0.08 | 0.87 |
| SEPT. | 6.41 | 0.69 | 2.99 | ND | ND | 0.06 | 0.01 | 4.91 | 1.02 | 5.92 | 0.06 | 0.57 | 0.99 | 1.11 | 8.00 | 1.11 | 4.20 | 0.01 | 0.43 | 0.09 | 0.92 |
| OCT. | 2.84 | 0.53 | 6.11 | 0.01 | 0.01 | 0.07 | 0.10 | 3.96 | 0.89 | 7.37 | 0.29 | 1.02 | 0.99 | 0.96 | 7.52 | 0.82 | 6.14 | 0.02 | 0.52 | 0.10 | 0.90 |
| **Rainy season mean** | **4.02** | **0.69** | **5.04** | **0.03** | **0.02** | **0.05** | **0.04** | **5.29** | **0.82** | **7.01** | **0.14** | **0.59** | **0.84** | **0.70** | **6.26** | **0.96** | **5.77** | **0.02** | **0.40** | **0.13** | **0.64** |
| **Annual mean** | **4.20** | **0.74** | **5.01** | **0.03** | **0.02** | **0.06** | **0.10** | **4.80** | **0.89** | **6.92** | **0.12** | **0.62** | **0.88** | **0.83** | **5.89** | **0.95** | **5.77** | **0.03** | **0.37** | **0.16** | **0.70** |

**Table 4.** Monthly variations of heavy metals in *Chrysicthys nigrodigitatus* (Conc. in mg/kg).

| | Station 1 | | | | | | | Station 2 | | | | | | | Station 3 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metals** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** | **Cu** | **Mn** | **Zn** | **Cd** | **Cr** | **Ni** | **Pb** |
| NOV. | 2.0 | 0.59 | 6.12 | 0.09 | 0.01 | 0.09 | ND | 5.96 | 1.14 | 9.01 | 0.28 | 1.06 | 0.98 | 1.09 | ND | ND | ND | ND | ND | ND | ND |
| DEC. | 2.95 | 0.87 | 7.02 | 0.10 | ND | 0.08 | 0.66 | 3.90 | 1.01 | 6.00 | 0.14 | 1.01 | 0.62 | 0.96 | 3.93 | 1.02 | 6.01 | 0.03 | 0.29 | 0.20 | 0.81 |
| JAN. | 5.01 | 1.01 | 4.49 | 0.03 | 0.03 | 0.01 | 0.02 | 3.49 | 0.93 | 5.33 | 0.09 | 0.91 | 0.79 | 0.89 | ND | ND | ND | ND | ND | ND | ND |
| FEB. | 5.61 | 0.93 | 4.77 | 0.03 | 0.03 | 0.03 | 0.03 | 3.10 | 0.96 | 7.11 | 0.15 | 0.89 | 0.87 | 0.72 | ND | ND | ND | ND | ND | ND | ND |
| MAR. | 6.44 | 0.83 | 3.91 | 0.03 | 0.03 | 0.03 | 0.09 | 3.94 | 0.91 | 6.00 | 0.10 | 0.62 | 0.81 | 0.68 | 6.02 | 0.95 | 7.00 | 0.02 | 0.40 | 0.09 | 0.41 |
| **Dry season mean** | **4.40** | **0.85** | **5.26** | **0.06** | **0.03** | **0.05** | **0.22** | **4.08** | **0.99** | **6.69** | **0.15** | **0.90** | **0.81** | **0.87** | **4.98** | **0.99** | **6.51** | **0.03** | **0.35** | **0.15** | **0.61** |
| APRIL | 3.14 | 0.39 | 7.02 | 0.03 | 0.02 | 0.03 | 0.06 | 7.66 | 1.00 | 5.32 | 0.08 | 0.62 | 0.67 | 0.69 | ND | ND | ND | ND | ND | ND | ND |
| MAY | 4.02 | 0.62 | 4.93 | ND | 0.02 | 0.01 | ND | 6.91 | 0.99 | 7.81 | 0.11 | 0.72 | 0.62 | 0.92 | ND | ND | ND | ND | ND | ND | ND |
| JUNE | 3.93 | 0.72 | 7.00 | 0.02 | 0.03 | 0.02 | 0.02 | 5.36 | 0.93 | 5.44 | 0.10 | 0.82 | 0.62 | 0.92 | 7.00 | 1.06 | 5.02 | 0.03 | 0.09 | 0.15 | 0.39 |
| JULY | 5.10 | 1.02 | 4.09 | 0.02 | 0.03 | 0.01 | 0.02 | 3.92 | 1.11 | 5.71 | ND | 0.77 | 0.49 | 1.00 | ND | ND | ND | ND | ND | ND | ND |
| AUG. | 4.14 | 1.00 | 6.02 | ND | 0.03 | 0.04 | 0.02 | 3.01 | 0.78 | 4.32 | ND | 0.43 | 0.51 | 0.93 | ND | ND | ND | ND | ND | ND | ND |
| SEPT. | 4.72 | 0.98 | 4.26 | 0.01 | ND | ND | 0.01 | 6.08 | 0.99 | 4.36 | 0.07 | 0.72 | 1.02 | 1.02 | 8.90 | 1.00 | 6.80 | 0.07 | 0.65 | 0.02 | 0.76 |
| OCT. | 3.00 | 0.41 | 7.04 | 0.04 | 0.02 | 0.14 | 0.04 | 4.00 | 0.81 | 6.02 | 0.22 | 0.96 | 1.00 | 1.01 | ND | ND | ND | ND | ND | ND | ND |
| **Rainy season mean** | **4.01** | **0.73** | **5.77** | **0.03** | **0.03** | **0.04** | **0.03** | **5.28** | **0.94** | **5.57** | **0.12** | **0.72** | **0.70** | **0.93** | **7.95** | **1.03** | **6.0** | **0.05** | **0.37** | **0.09** | **0.60** |
| **Annual mean** | **4.17** | **0.78** | **5.56** | **0.04** | **0.02** | **0.04** | **0.10** | **4.78** | **0.96** | **6.04** | **0.13** | **0.79** | **0.75** | **0.90** | **6.46** | **1.01** | **6.25** | **0.04** | **0.36** | **0.12** | **0.59** |

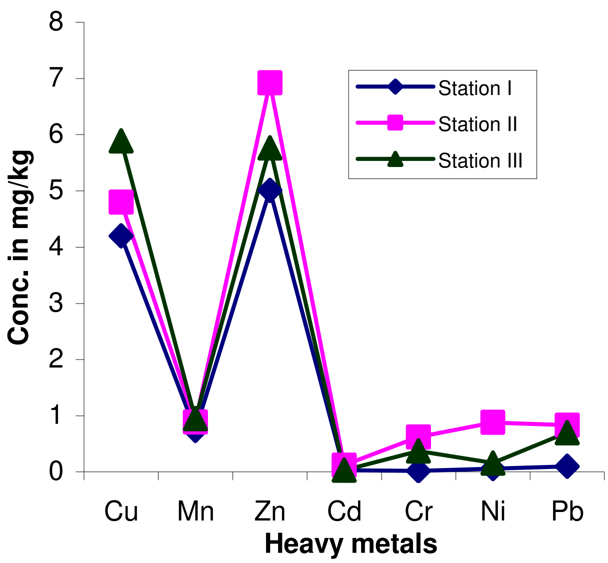


**Figure 4.** Annual mean concentrations of heavy metals in *Malapeterurus electricus* at the three stations.

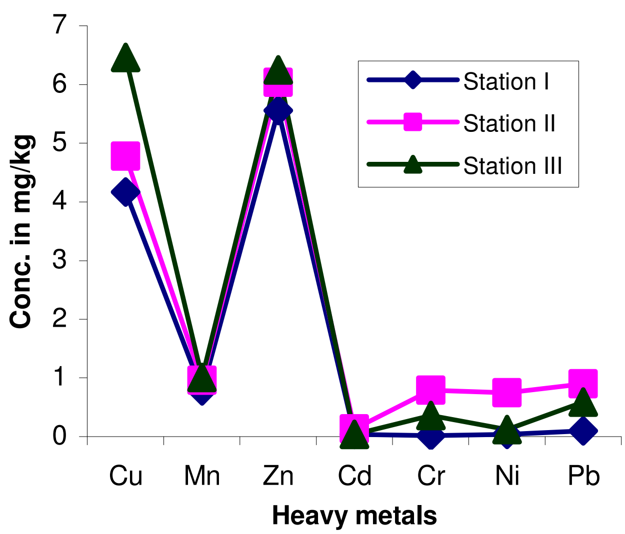


**Figure 5.** Annual mean concentrations of heavy metals in *Chrysicthys nigrodigitatus* at the three stations.

*electricus* at Station II.

Statistical analysis (ANOVA) of metal levels in *M. electricus* at the stations, showed significant differences (P<0.05), except for Cu whose levels were not significantly different (P>0.05). Seasonal means were significantly different (P<0.05) for Mn. Zn and Ni, but for Cu, Cd, Cr and Pb. Seasonal mean levels at the Stations were not significantly different (P>0.05). In *C. nigrodigitatus*, ANOVA showed significant differences (P<0.05) in levels of Cd, Cr, Ni and Pb. But for Cu, Mn and Zn the levels were not significantly different (P>0.05). The seasonal levels of the metals in *C. nigrodigitatus* were not significantly different (P<0.05) at the Stations.

## DISCUSSION

The aquatic ecosystem has been reported to be the ultimate recipient of heavy metal pollution (Biney et al., 1991; Idodo-Umeh, 2002). The levels of heavy metals recorded in water in this investigation were lower than the levels for sediment and fish. The higher levels in sediment could be linked to absorption to sediment particles, while the high levels in fish could be linked to bioaccumulation. Metal levels in water were lowest in Station I, followed by Stations III and II in ascending order. The low levels in Station I could be due to its nearness to the river source, while the high level in Station II could be attributed to the influence of the drainage effluents which drains into the river near the station (Figure 1). Metal levels in water in Ogba river are lower than the recommended limiting standards for drinking water set by WHO (1985) and FEPA (2003) and therefore, Ogba river water could be considered safe for drinking.

In sediment, metal levels differed significantly (P<0.05) and were highest at Station II, except Cu which level was highest at Station III. The highest metal levels in sediment at Station II, is similar to the situation in water and could also be due to the nearness of Station II to the drainage discharge point. Sediment metal levels recorded in this study were low when compared to the levels for unpolluted inland water sediment (GESAMP, 1982).

In the fishes (*M. electricus* and *C. nigrodigitatus),* all metals were bioaccumulated to varying levels. Zn was the most bioaccumulated metal, except at Station III, where Cu was the most accumulated metal. The general pattern of accumulation was similar in both fishes with Zn, Cu, Mn and Pb being the more accumulated metals in descending order, while Cr, Ni and Cd were least accumulated. At Station I, Cr was the least accumulated by both fishes. The explanation for this could be that Cr was least available, since the concentrations in water and sediment were least at the stations (Tables 1 and 2). Aquatic organisms including fish have been reported to accumulate metals from their surrounding medium or food by absorption or ingestion (Forstner and Prosi, 1981; Ademoroti, 1996).

At Stations II and III, both fishes bioaccumulated Cd least, probably because Cd was the least available metal in water and sediment at the stations. The levels of accumulation of all the metals by both fishes were least in Station I when compared to the accumulation levels in fishes at Stations II and III. Station I is close to the source of the stream, with less human activities, surface runoffs and hence less pollution as shown by the generally lower metal levels in water and sediment at the station when compared to the other stations. Consequently, the levels of metals accumulation in the fishes at the Station were expectedly lowest because of the low availability. The fishes from Station II accumulated higher levels of Cd, Cr, Ni and Pb than those at Station III, but Cu and Mn levels in both fishes were higher at Station III than at Station II. The higher levels of Cd, Cr, Ni and Pb in the fishes at Station II could be linked to the proximity of the station to the drainage effluent entry point (Figure 1). The levels of these metals were highest in the sediment at Station II and being bottom dwellers, the fishes were probably more exposed to the metals at the station than at Station III. The situation with Cu and Mn, which were higher in the fishes at Station III may not be unconnected with the omnivorous feeding habits of the fishes.

At Station I, *C. nigrodigitatus* accumulated higher levels of Mn, Zn and Cd than *M. electricus,* while the levels of Cu and Ni were lower than those of *M. electricus.* The accumulation levels of Cr and Pb in both fishes at Station 1 was similar. At Station II, *M. electricus* accumulated more Cu, Zn and Ni than *C. nigrodigitatus,* while at Station III, *C. nigrodigitatus* accumulated higher metal levels except Cr, Ni and Pb, which were higher in *M. electricus.*

The differences in the metals accumulation levels of the fishes at the respective Stations (Figures 4 and 5) could be attributed to differences in their metabolic rates. It has been reported that different organisms have different metabolic rates and different food requirements and amounts. Organisms with high food intake tend to accumulate more metals (Ademoroti, 1996). The higher concentration of majority of the metals in *C. nigrodigitatus* may also be connected to the larger samples of the fish when compared to the average size of *M. electricus* samples. Ademoroti (1996) listed size of organism as one of the major factors influencing bioaccumulation.

Seasonal metal means recorded in both fishes (Tables 3 and 4) showed higher dry season levels than the rainy season levels, except Zn (Station I), Cu and Zn (Station II), Cu, Mn and Zn (Station III) in *M. electricus* and Zn (Station I) Cu and Pb (Station II) and Cu, Mn, Cd and Cr (Station III) in *C. nigrodigitatus.* The higher dry season metal levels could be attributed to more bioaccumulation due to metal concentration arising from reduced water volume during the dry season. The higher rainy season levels of Zn, Cu, Cd and Cr especially at Station III may not be unconnected with increased surface runoffs and human activities (washing of clothes, bathing and swimming) at the station during the rainy season.

A comparison of the metal mean levels detected in the fishes in this study with the maximum allowable limits in food fish set by the WHO (1984) and FEPA (2003) showed that the levels of Cu, Mn, Cr and Ni were higher than the limits while those of Zn, Cd and Pb were lower. The finding is consistent with the results obtained for other fish species of the river (Wangboje and Oronsaye, 2001; Obasohan, 2003). The implication of this finding is that the consumption of the fishes of Ogba river by man could lead to health hazards induced by heavy metals.

The investigation showed that the Ogba river system in Benin City, Nigeria is contaminated by heavy metals and that the levels of contamination of the fishes of the river suggest that their consumption may induce health hazards to man. Further studies on the pollution of Ogba River are also highly recommended in view of the importance of the river in the supply of potable water and fish to the expanding population of Benin City.

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