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Original article

Assessment of the impact of human settlement on the heavy metal concentrations of lower cross river, Nigeria

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ABSTRACT

The impact of human settlement on heavy metal concentrations was assessed in the surface waters of Lower Cross River, Nigeria. Samples were collected from January to August, 2011 from three stations: Station 2 (Itu in Akwa Ibom State with intense human activities), station 1 (its upstream at Cross River State without human settlement) and station 3 (the downstream). The range of these heavy metals in the river were 1.0027 – 4.1225 mg/l for Mg, 0.0001 – 2.3703 mg/l for Fe, 0.0001 – 0.4118 mg/l for Zn, 0.0855 – 3.5701 mg/l for Pb, 0.0011 – 1.2582 mg/l for Cd, 0.0249 – 2.4856 mg/l for Cr, and 0.0001 – 0.9117 mg/l for Ni. The rank profile of metals according to their mean values was Mg > Pb > Fe > Cr > Cd > Ni > Zn in the study stations. The statistical analysis using the One-Way Analysis of Variance (ANOVA) showed that there was significant difference ($P<0.01$) in the concentrations of heavy metals at the study, except for Zn and Ni. Tukey's pairwise comparism indicated that Station 1 was basically responsible for the observed significant differences in the study stations. Except for Zinc, all the other heavy metals exceeded the WHO and SON maximum permitted levels for drinking water indicating pollution. This could be attributed to anthropogenic inputs from upstream and run-off during wet season. The wet season concentrations were higher than those for dry season.

1. Introduction

Humans are adjusted to be the principal drivers of change on the earth's surface (Adeogun and Fafioye, 2011). Such impact may shape the earth in small subtle ways and sometimes in big catastrophic ways (Karr, 2005). Human activities such as municipal effluents, as well as atmospheric deposition and non-point source run-off are the main sources of metals in rivers (Sanayei et al., 2009). Heavy metals are among the most common environmental pollutants, and their occurrence in waters and biota indicate the presence of natural or anthropogenic sources (Papafilippaki et al., 2008). Heavy metal pollution represents a serious problem for human health and for life in general. Its cumulative poisoning effects are serious hematological and brain damage, anaemia and kidney malfunctioning (Zheng et al., 2008).

Investigation of heavy metals of rivers is receiving global attention because of their importance to the health of people and ecology. In Nigeria, heavy metal concentration of rivers have received considerable attention by earlier workers, notable among which are those of Warri River (Atuma and Egbore, 1986; Egborge and benka-coker, 1986; Wogu and Okaka, 2011), Ikpoba River (Fufeyia and Egborge, 1998), Delimi River (Omoregie et al., 2002), Osse River (Omoigberale and Ogbeibu, 2005), Okumeshi River (Ekeanyanwu et al., 2011).

This study which is the first to give attention to the concentration of heavy metals in the Lower Cross River, investigated the impact of human settlement on the heavy metal concentrations, and provides a baseline data of heavy metals in the river.

2. Materials and methods

The Cross River Basin encompasses an area of about 70,000 km^2, of which 50,000km^2 lies within Nigeria and 20,000 km2 lies with Cameroun (Teugels et al., 1992). From observed physiographic, ecological and zoogeographical discontinuities, the section draining south-eastern Nigeria is termed the "Lower Cross" and the Cameroonian section is referred to as the "upper Cross". The Lower Cross River is located between longitudes 7°43' and 8°22' E, and Latitudes 4°28' and 5°27'N (Fig. 1).

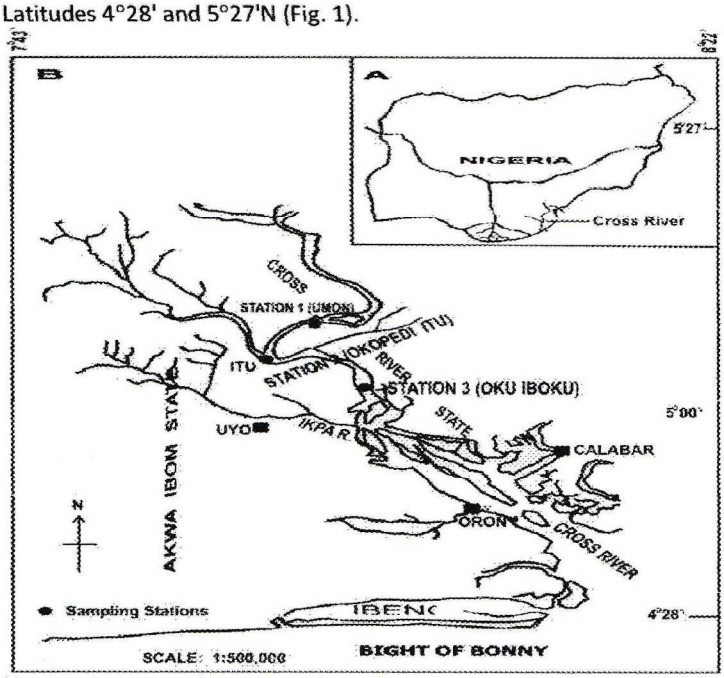

Fig. 1. Map of lower cross river showing study stations. inset: map of Nigeria showing cross river.

The main river channel covers a distance of 600km from source to mouth, where it discharges directly into the Atlantic Ocean at the Bight of Bonny (King, 1996). The estuarine catchment area is 95km2 (Ita, 1993), thus resulting in a freshwater basin area of 69,905km^2. The Lower Cross River Basin lies within a typical tropical humid climate, which is characterized by distinct dry and wet seasons, peak dry seasons occurs in December – February (King, 1989). The drainage basin is generally of low relief and lies almost entirely on the coastal plain of the tropical rainforest belt of southeastern Nigeria which is typified by high temperatures and rainfall with thick forests. The dry season which lasts from November to April is influenced by the hot northeastern continental air mass from the sahara desert and is characterized by fairly high temperature. Relative humidity is usually high throughout the year with a percentage of 80% and much higher towards the coast. Maximum rainfall occurs during the months of June – September (Tahal Consultants, 1982). The study area is made up of secondary rainforest which has been deeply subjected to deforestation and other human activities – fishing is a common activity across the entire stretch of the river.

Three stations were selected for sampling. These stations are Itu in Akwa Ibom State with intense human activities (station 2), its upstream (without human settlement) at Cross River State (Station 1) and the downstream (Station 3).

The description of each station is given below:

Station 1 is about 4 kilometers from Umon town in Cross River State. The dominant vegetation in this station are palm trees (Elaeis guineensis), bamboo (Bambusa africana), plantain and banana (Musa spp.) and guinea grass (Panicum maximum). The crops cultivated in the riparian belts are okro (Abelmoschus esculentus), garden egg (Solanum melongena) and vegetables. The station is characterized by a sandy erosional biotope and a muddy bankroot biotope made up of silt.

Station 2 which is 18 kilometers from station 1 is located in Itu town, by Mary Slessor hospital. This station is characterized by dense human settlement resulting in regular bathing and washing in the river. Okro and vegetables are also cultivated in the riparian areas of this station. The station is associated with sandy erosional biotope, and muddy bankroot biotope made up of silt and clay. This station is also characterized by Itu bridge located along Uyo-Calabar highway and is reported to be one of the landmark achievements of the Gowon administration when it was completed in 1975.

Station 3 is 21.5km from station 2. It is located in Oku Iboku, Akwa Ibom State. The dominant vegetation is palm trees. It is characterized by a sandy substratum and basically a muddy bankroot biotope. The station is tidal but the water is fresh.

Water samples were collected monthly between 0800 and 1700 hour each sampling day, from January to August, 2011. The samples were collected in pre-washed and dried one litre polyethylene bottles, acidified with nitric acid and taken to the laboratory for analysis. Analysis of the water samples was based on APHA et al. (1985). Magnesium was determined by EDTA titrimetric method. Samples for Fe, Zn, Pb, Cd, Cr and Ni were analyzed by Atomic Absorption Spectrophotometer using UNICAM 939 Atomic Absorption Spectrophotometer. All laboratory equipment and sample bottles were thoroughly cleaned with nitric acid according to the method of Martin et al. (1992). All analytical quality control requirements were strictly adhered to.

All measures of central tendency and dispersion to characterize the stations in terms of the heavy metals concentrations, test of significance using parametric One Way Analysis of Variance (ANOVA) and detecting point of significant differences using Tukey's pairwise comparison were conducted using Past Statistical Package.

Maximum permitted level of each heavy metal concentration for drinking water was provided for Standard Organization of Nigeria (SON, 2007), and World Health organization (WHO, 2011).

3. Results

The heavy metal concentrations of Lower Cross River study stations are summarized in Table 1, using measures of central tendency and dispersion. The results of statistical analysis to test for significant differences in parameters among the study stations, and maximum permitted levels for SON and WHO are also indicated.

Spatially, the concentrations of the heavy metals decreased progressively from station 1 to station 3 on monthly basis, except for zinc with constant concentration of 0.0001 mg/l in January. Temporally, the wet season concentrations of the heavy metals were higher than those of the dry season.

The highest mean concentrations of all the heavy metals were in station 1, while the lowest were in station 3. Magnesium ranged from 1.0027 – 4.1225 mg/l (Fig. 2). Iron ranged from 0.0001 – 2.3703 mg/l (Fig. 3).

Table 1
Summary of the heavy metals concentrations of the Lower Cross River Study Stations (January – August, 2011). Values are mean ± SE. The minimum and maximum values are noted in parentheses.

Parameters	Station 1	Station 2	Station 3	Statistical significance	Maximum permitted levels	
					SON	WHO
Magnesium (mg/l)	3.283±0.267 (2.0651–4.1225)A	2.757±0.280 (1.3903–3.5719)A	2.252±0.271 (1.0027–3.004)B	P < 0.05	0.20	
Iron (mg/l)	1.842±0.181 (1.0728–2.3703)A	0.636±0.179 (0.0067–1.2006)B	0.187±0.079 (0.0001–0.5129)B	P < 0.01	0.3	0.3
Zinc (mg/l)	0.164±0.0624 (0.0001-0.04118)	0.059±0.0215 (0.0001–0.1651)	0.042±0.0163 (0.0001–0.1107)	P > 0.05	3	
Lead (mg/l)	2.592±0.308 (1.2309–3.5701)A	1.844±0.276 (0.5812–2.6180)A	0.532±0.150 (0.0855–1.0917)B	P < 0.01	0.01	0.01
Cadmium (mg/l)	0.699±0.177 (0.0108–1.2582)A	0.468±0.174 (0.0026–1.1701)A	0.118±0.052 (0.0011–0.3669)B	P > 0.05	0.003	0.003
Chromium (mg/l)	1.550±0.281 (0.3064–2.4856)A	0.849±0.208 (0.1720–1.5199)A	0.478±0.153 (0.0249–1.0543)B	P > 0.05	0.05	0.05
Nickel (mg/l)	0.393±0.131 (0.0146–0.9117)	0.225±0.094 (0.0029–0.6121)	0.048±0.099 (0.0001–0.1380)	P > 0.05	0.02	0.07

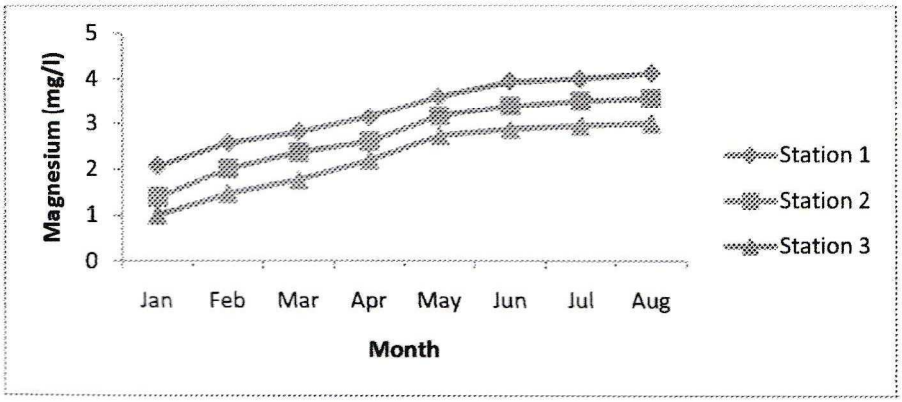

Fig. 2. Spatial and temporal variations in the concentration of magnesium at the study stations, January – August, 2011.

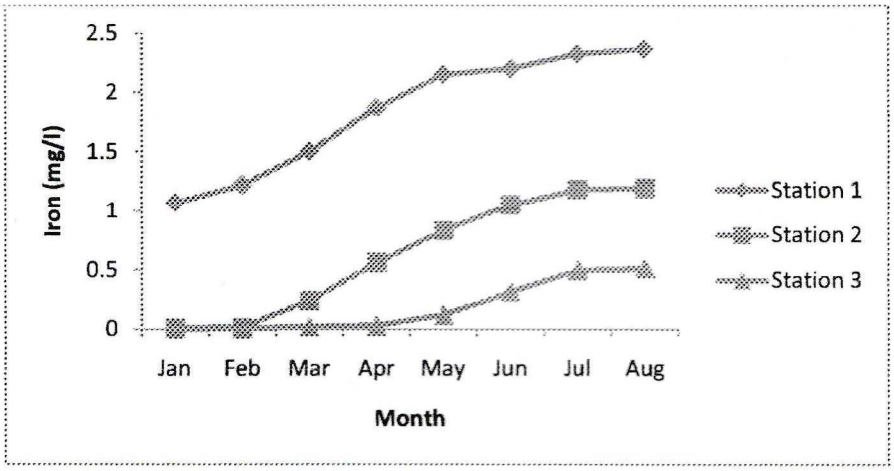

Fig. 3. Spatial and temporal variations in the concentration of iron at the study stations, January – August, 2011.

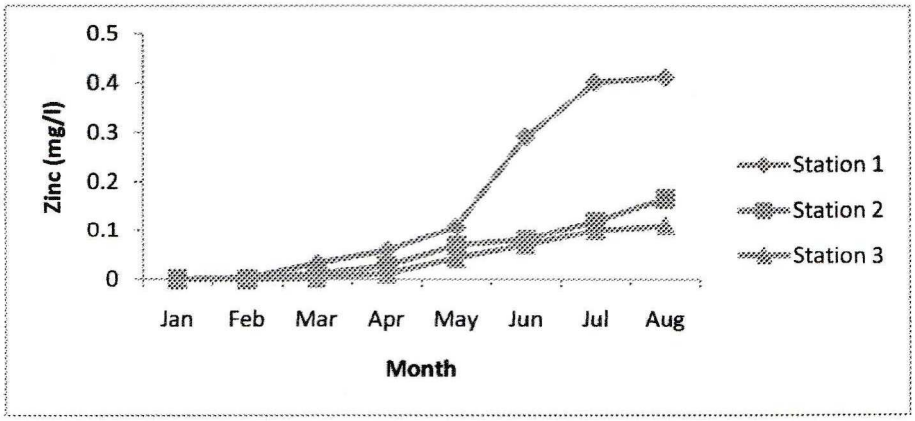

Fig. 4. Spatial and temporal variations in the concentration of zinc at the study stations, January – August, 2011.

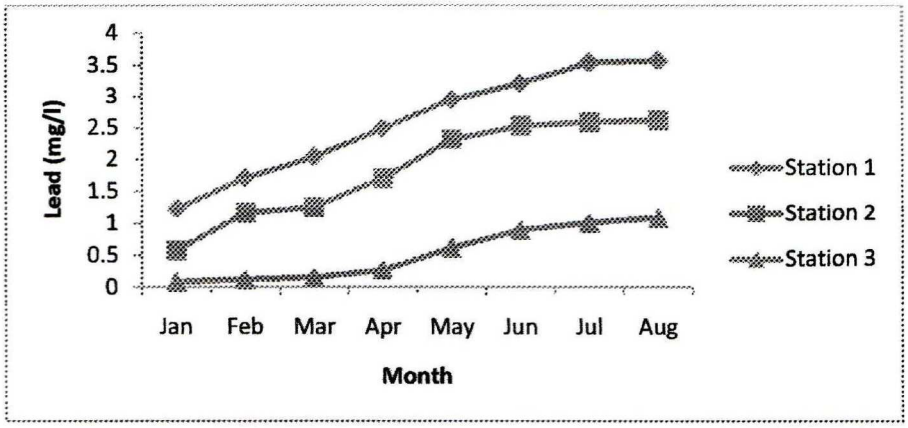

Fig. 5. Spatial and temporal variations in the concentration of lead at the study stations, January – August, 2011.

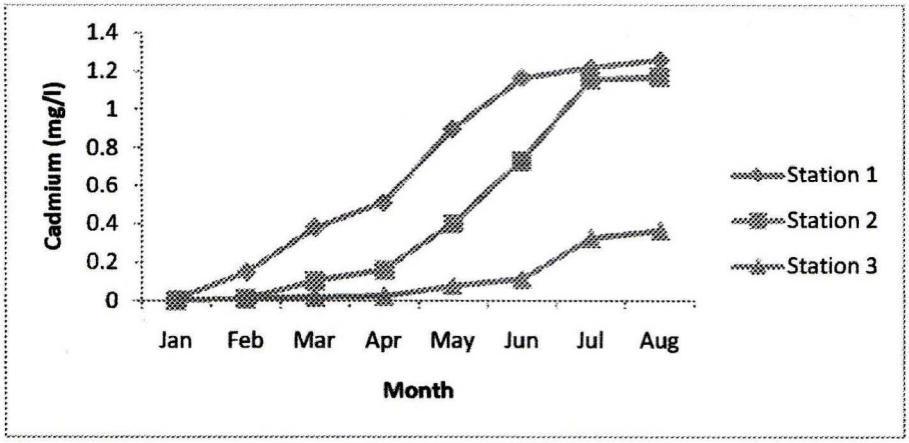

Fig. 6. Spatial and temporal variations in the concentration of cadmium at the study stations, January – August, 2011.

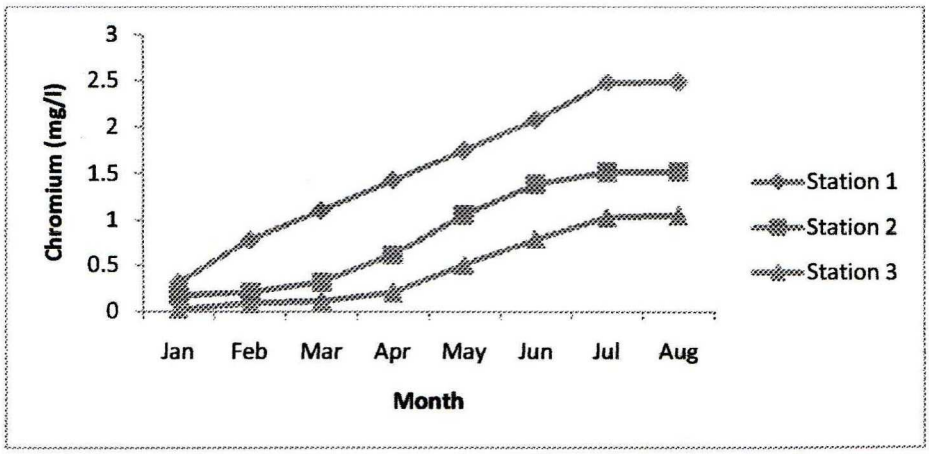

Fig. 7. Spatial and temporal variations in the concentration of chromium at the study stations, January – August, 2011.

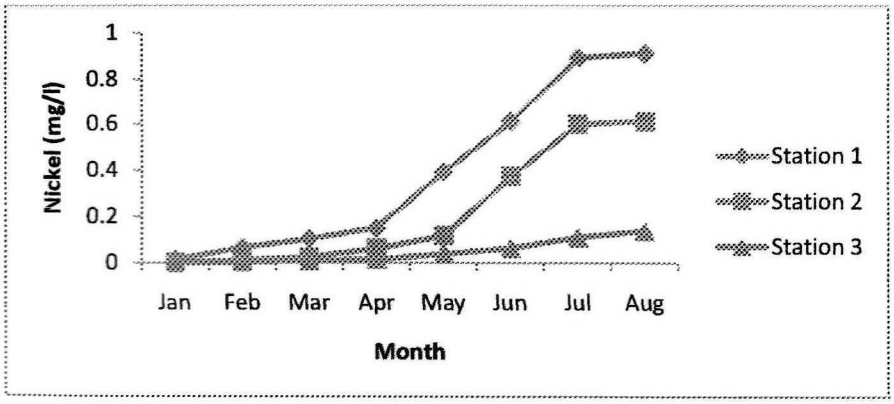

Fig. 8. Spatial and temporal variations in the concentration of nickel at the study stations, January – August, 2011.

Zinc ranged from 0.0001 – 0.4118 mg/l (Fig. 4). Lead ranged from 0.0855 – 3.5701 mg/l (Fig. 5). Cadmium ranged from 0.0011 – 1.2582 mg/l (Fig. 6). Chromium ranged from 0.0249 – 2.4856 mg/l (Fig. 7), while nickel ranged from 0.001 – 0.9117 mg/l (Fig. 8). The rank profile of heavy metals according to their mean values was Mg > Pb>Fe>Cr>Cd> Ni>Zn among the stations.

The statistical analysis using the One-Way Analysis of Variance (ANOVA) showed that there was significant difference in the concentrations of heavy metals at the study stations, except for zinc and nickel (Table 1). The concentrations of magnesium, lead, cadmium and chromium in stations 1 and 2 were significantly higher than those of station 3, while the concentration of iron in station 1 was significantly higher ($P<0.01$) than those of stations 2 and 3 which were not different from each other.

Except for zinc, all the other heavy metals exceeded the SON and WHO maximum permitted levels for drinking water.

4. Discussion

Human settlement within the study stations had no significant impact on the concentrations of heavy metals in the river due to the absence of industrial activities in the area. However, the concentrations of the heavy metals were high when compared to other rivers in southern Nigeria such as Osse River (Omoigberale and Ogbeibu, 2005); Okumeshi River (Ekeanyanwu et al., 2011); New Calabar River (Ekeh and Sikoki, 2003); Ikpoba River (Fufeyin and Egborge, 1998), except for iron and zinc; Warri River (Atuma and Egbore, 1986; Wogu and Okaka, 2011). The concentrations of the heavy metals could be considered low when compared with the high values recorded for Forcados River (Nwabueze, 2011). The rank profile of the heavy metals indicated that Zn had the least concentration, which could be due to low input from sewage and refuse dumps. Fufeyin and Egbore (1998) posited that the highest record of Zn in Ikpoba River was probably due to its ready source from sewage and refuse dumps at the banks. Except for Zn, all the metal concentrations were higher than WHO and SON permitted levels for drinking water, indicating that the river water was polluted.

The higher record of heavy metal concentrations in station 1 could be as a result of anthropogenic activities such as introduction of effluents from the upstream. Tarig et al. (1991) associated the high concentrations of heavy metals in the aquatic ecosystem to effluent from industries, refuse and sewage. The anthropogenic sources of heavy metals are associated mainly with industrial and domestic effluents, urban storm, water run-off, land fill leachate, mining of coal and ore, atmospheric sources and inputs from rural areas (Kabata-Pendias and Pendias, 1992; Zarazua et al., 2006).

The higher record of metals in the wet season could be attributed to input from anthropogenic sources due to run-off resulting from rainfall. The high record in the wet season is in agreement with report of studies by earlier workers. Okonkwo and Mothiba (2005) reported same for rivers in Thohoyandou, South Africa and attributed it to run-off from land into the rivers during the wet season. Omoigberale and Ogbeibu (2005) reported no clear seasonal difference in metal distribution in Osse River indicating the lack of major sources of external input which could become obvious during rain events.

5. Conclusion

Heavy metals have been used as indices of pollution because of their toxicity to human and aquatic life (Omoigberale and Ogbeibu, 2005). Although human settlement within the study stations had no significant impact on the heavy metals in the river, due to the absence of industrial activities in the area, the higher records than WHO and SON maximum permitted levels indicated that the river water was polluted. This could be attributed to anthropogenic inputs from upstream, and run-off during wet season. Since there is presently no adverse industrial influence in the study area, this study could serve as a baseline for the area.

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