PHYSICO-CHEMICAL PARAMETERS AND HEAVY METAL CONTENTS OF IBUYA RIVER IN OLD OYO NATIONAL PARK, SEPETERI, OYO STATE, NIGERIA

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Abstract

The physico-chemical parameters and heavy metal contents of Ibuya River were investigated between September 2012 and August 2013 from four stations using standard methods to determine acceptable water quality standards and evaluate possible sustainability of a thriving fisheries *cum* tourist sport fishing venture. The mean concentration of total dissolved solids (103.30±5.29mg/l), conductivity (148.50±7.90 µS/cm), pH (7.58±0.05), dissolved oxygen (3.75±0.09 mg/l), water temperature (25.25±0.30 °C), hardness (44.60±2.92 mg/l$CaCO_3$), alkalinity (11.55±0.72 mg/l$CaCO_3$), copper (0.11±0.02 mg/l), zinc (0.10±0.01 mg/l), chloride (76.90±5.58 mg/l), sulphate (24.20±3.65mg/l) and nitrate (18.50±3.07 mg/l) fell within the range of allowable standards of WHO, NESREA, USEPA, FEPA and SON while turbidity (19.42±0.97FTU), magnesium (2.55±0.25 mg/l), manganese (0.19±0.03 mg/l), iron (2.20±0.27 mg/l), lead (0.59±0.09 mg/l), cadmium (0.13±0.05 mg/l) and phosphate (10.80±2.40 mg/l) fell outside the range with known consequences on the biota. The river contains pollutant, due to wastes from agricultural ventures, domestic wastes of dwellers and fuel stations. Continuous consumption of high levels of pollutant will cause stress to aquatic communities leading to death and in turn elicit socio-economic disaster since the site is a recreational park currently being considered for sports fishing venture. Surveillance is advocated to monitor and reduce anthropogenic discharges from the surrounding communities into the river.

Keywords: pollution, heavy metals, water quality, anthropogenic activities.

Accepted: 23 December, 2014.

Introduction

The physico-chemical quality of water is very vital for the life of aquatic organisms and environmental variables such as pH, temperature, dissolved oxygen, turbidity, transparency, total dissolved solids and alkalinity have effects on organisms. Natural surface waters are of importance to man for domestic uses, industrial development, navigation, boating and fishing to mention but a few. Urbanization and industrialization have profound effect on human life and aquatic environment in terms of quality and quantity (Herschy, 1999). Seasonal and climatic changes affect the quality and physico-chemistry of surface water. The quality of the river systems often fall below acceptable levels for many uses. Rivers, due to their role in carrying off the municipal and industrial wastewater and run off from agricultural land in their vast drainage basins, are among the most vulnerable water bodies to pollution (Yerel, 2010). It is in line with these that this research work was initiated. The availability of safe and reliable source of water is an essential pre-requisite for sustained development. A pressing need has therefore

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Zoological Society of Nigeria.

emerged for a comprehensive and accurate study of these water bodies in order to raise awareness of the urgent needs to address the consequences of present and future threats of contamination and degradation and their likely effect on our overall goals of poverty alleviation among fisher-folks. This study investigates the physico-chemical parameters and heavy metal contents of Ibuya River. The study-area is a conservation/tourist attraction site and no research of such nature has been reported therein – thus must be brought to fore since humans come in contact with the water as well as the anthropogenic activities in the surrounding communities. Also, it is linked on both sides by two unprotected rivers. The study will provide the necessary baseline data on the water quality of the river and for the relevant agencies in formulating appropriate measures for conservation.

Materials and methods

Study area

Ibuya River is located in the Old Oyo National Park. The park is in Sepeteri, Oyo, south-west of Nigeria. It lies between latitude $8^{0}.10'$-$9^{0}.05'$N and Longitude $3^{0}.00'$-$4^{0}.20'$E (Figure 1). The park is about 120 km long from the south-west to the north-east and about 50 km at its widest in the south. A sizeable portion of the park is the Ibuya River and is well drained by two river systems; the Ogun discharging into the Atlantic Ocean and the Tessi discharging into the River Niger. Several tributaries flows to join these two main rivers respectively. The park has diverse wildlife and cultural/historical settings. The abundance of cultural features both within and outside the park makes it a combination of an ecological and cultural/historical park.

Sampling stations

The river was divided into four sampling stations with equal distance of 5.40 km apart based on a survey as follows:

Station 1: Area around the entrance of the Ogun River within the south-west part of the river where anthropogenic activities like farming, cassava processing, sales of fuel (petrol station) take place.

Station 2: Area around the central basin of the river where wild life activity take place.

Station 3: Area around the central basin of the river wild life activity also take place here.

Station 4: Area where the river joins River Tessi and has mainly rocky bottom.

Sample collection

Samples were collected for 12 months between September 2012 and August 2013 in the morning hours

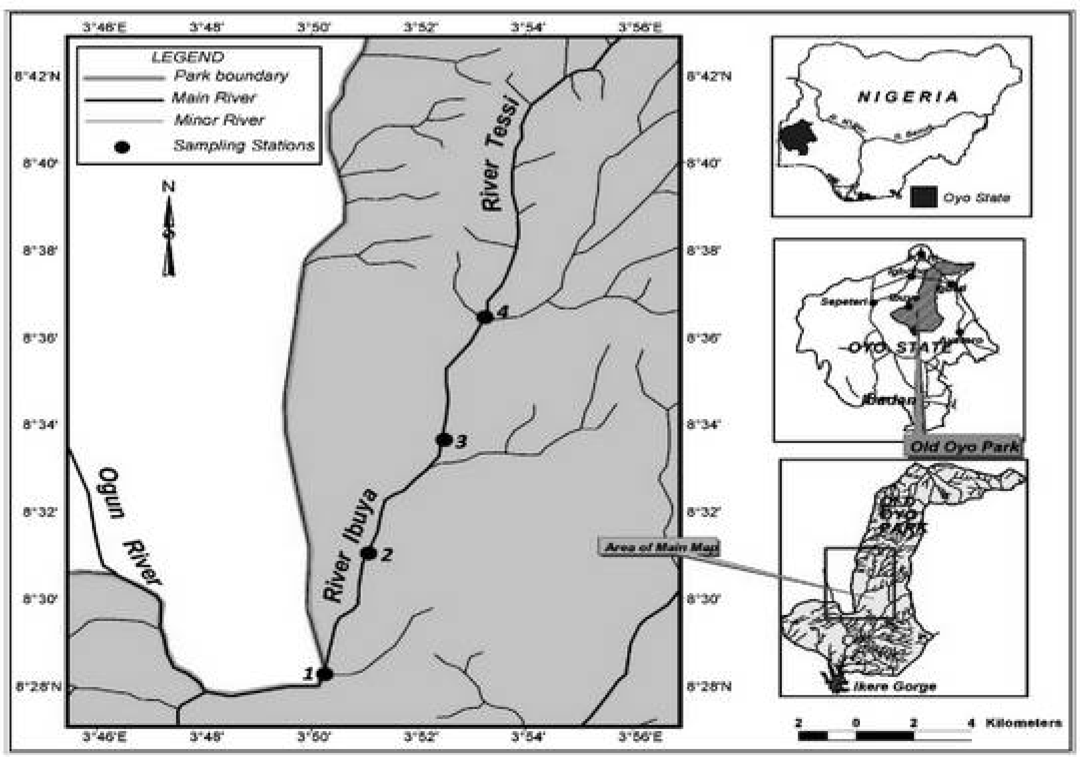


Figure 1. Map of Ibuya River showing sampling stations.

between 7 and 10 am covering the wet and dry season. One-liter containers were used to collect water samples for physico-chemical parameters at each station. A total of twenty-one parameters were measured *in-situ* in the laboratory according to standard methods (APHA, 2005). At the sampling station, temperature, pH, conductivity, TDS, transparency, and dissolved oxygen were measured in-situ using mercury in glass thermometer (in Celsius), pH-EC-TDS meter model ExStik EC500, Secchi disc (25 cm diameter) and dissolved oxygen meter model ExStik DO600 respectively. Water samples were taken to the laboratory for the analysis of hardness, turbidity, alkalinity, and heavy metals including Mg, Mn, Fe, Pb, Zn Cu, and Cd. Nutrient parameters such as nitrate, phosphate, chloride and sulphate were also determined in the laboratory spectrophotometrically at various wave lengths according to the standard method of AOAC (2010).

Statistical analysis

Microsoft Excel 2010 was used for graphical illustration, Genstat Discovery 4.103 was used for descriptive statistics and student *t*-test was used to compare means for the wet and dry seasons.

Results

The result of the physico-chemical parameters of water sample from the four stations in Ibuya River are presented in Table 1. The air and water temperature ranged from 20.70°C to 32.00.

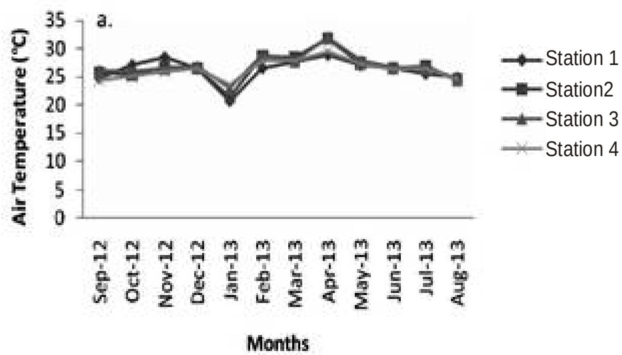


Table 1. Physico-chemical parameters of water from the four stations in Ibuya River from September 2012 to August 2013.

	Station 1			Station 2			Station 3			Station 4		
Parameters	Min	Max	Mean±SE	Min	Max	Mean±SE	Min	Max	Mean±SE	Min	Max	Mean±SE
Air temperature (°C)	20.70	28.80	26.18±0.62	21.40	31.70	26.61±0.72	22.90	32.00	26.87±0.65	23.50	29.50	26.32±0.50
Water temperature (°C)	19.80	27.70	24.97±0.58	20.10	28.60	25.29±0.66	21.60	30.70	25.57±0.64	21.70	28.50	25.17±0.59
pH	6.88	8.39	7.41±0.11	7.31	8.23	7.64±0.09	7.36	8.12	7.61±0.08	6.89	8.16	7.65±0.11
DO (mg/l)	2.95	4.73	3.58± 0.15	3.06	5.01	3.90±0.214	3.03	5.00	3.85± 0.18	2.61	4.47	3.66±0.15
Cond. (µS/cm)	69.90	272.00	152.30±19.65	92.20	208.00	153.70±12.94	90.00	255.00	151.20±16.89	76.60	207.00	136.90±14.51
TDS (mg/l)	48.80	188.00	104.80±13.82	62.00	140.00	106.60±8.68	60.40	171.00	104.8±10.72	56.20	146.00	96.71±9.57
Hard. (mg/l $CaCO_3$)	24.60	81.40	47.98±5.48	23.40	71.40	43.34± 4.81	24.00	111.40	43.91±6.97	21.40	96.00	43.37± 6.52
Alkal. (mg/l $CaCO_3$)	4.50	24.35	11.91±1.72	5.85	19.50	11.30±1.23	6.65	27.00	12.52±1.79	5.35	16.65	10.49±0.96
Trans. (cm)	6.50	20.00	11.76±1.23	9.00	18.00	11.45±0.67	10.00	16.50	12.30± 0.55	9.50	19.50	12.28±0.75
Turb. (FTU)	13.57	31.20	20.61±1.49	12.97	33.60	18.80±1.78	6.55	35.26	17.36±2.61	13.38	35.30	20.89±1.73
Mg (mg/l)	0.20	6.07	2.67±0.61	0.57	6.95	2.74±0.52	0.47	5.22	2.51±0.42	0.28	5.01	2.28±0.45
Mn (mg/l)	0.03	0.57	0.23±0.06	0.00	0.69	0.18±0.06	0.00	0.64	0.18± 0.05	0.02	0.46	0.16±0.05
Cu (mg/l)	0.00	0.48	0.11±0.04	0.00	0.22	0.09±0.02	0.00	0.41	0.11±0.03	0.00	0.50	0.12±0.04
Fe (mg/l)	0.64	6.41	2.40±0.51	0.12	6.34	2.31±0.56	0.03	8.32	2.46±0.70	0.08	4.80	1.63±0.39
Cd (mg/l)	0.00	1.07	0.11±0.09	0.00	1.64	0.16±0.14	0.00	1.24	0.13±0.10	0.00	1.27	0.13±0.10
Pb (mg/l)	0.00	2.11	0.61±0.21	0.00	1.91	0.63±0.21	0.00	1.69	0.56±0.19	0.00	1.47	0.55±0.16
Zn (mg/l)	0.02	0.33	0.11±0.03	0.00	0.34	0.11± 0.03	0.01	0.23	0.10±0.03	0.00	0.20	0.07±0.02
Cl^- (mg/l)	21.60	162.00	81.82±11.40	14.40	137.00	74.13±10.55	17.75	168.00	77.70±13.56	21.60	126.00	73.80±10.18
PO_4^- (mg/l)	0.01	42.60	10.16±4.64	0.00	37.20	9.71±4.35	0.01	47.30	12.69±5.68	0.01	45.80	10.66±5.05
SO_4^- (mg/l)	0.10	72.60	23.48±6.69	0.00	77.80	23.18±7.46	0.00	96.45	28.04±9.01	0.07	82.80	21.97±6.63
NO_4^- (mg/l)	0.10	78.36	21.20±7.44	0.00	42.65	14.08±4.08	0.11	68.34	17.67±6.09	0.13	66.24	20.90±6.97

Key: Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity, TDS = Total Dissolved Solids°C and 19.80°C to 30.70°C respectively. The spatial variations in air and water temperature of the river are presented in (Figures 2a and b).There was a drop in water temperature in January in relation to a corresponding drop in air temperature. However, these variations were not significantly different ($p>0.05$). The mean water temperature for the wet season (25.02±0.25°C) was lower than the dry season value of 25.48±0.55°C.

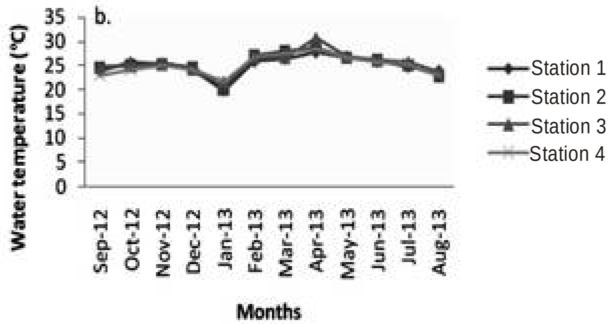
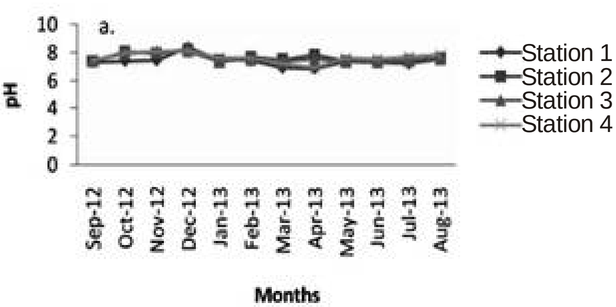
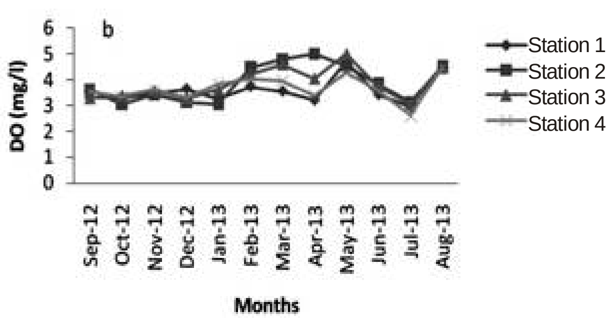
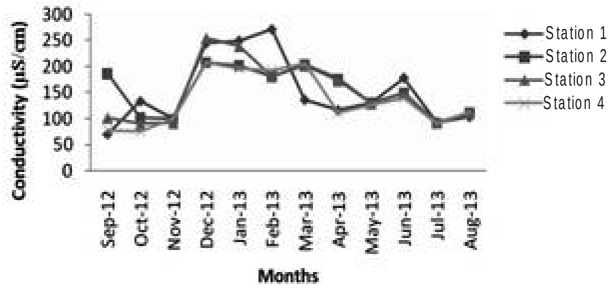


Figure 2: Spatial Variation in: (a) air temperature (b) water temperature for stations in Ibuya River.

The pH of the river was mostly in the neutral/alkaline range of 6.88 to 8.39 (Figure 3a). The lowest pH (6.88) was recorded in Station 1 in April while the highest (8.39) was recorded in December in the same station. The pH for the wet season (7.53±0.05) was lower than the dry season value of 7.62±0.09. pH showed no significant variation with seasons ($p>0.05$). Dissolved oxygen fluctuated between 2.61mg/l and 5.01mg/l (Figure 3b) throughout the study period. DO concentration (3.76±0.11 mg/l) for the dry season was higher than the wet season value of 3.74±0.14 mg/l. DO showed no significant difference with season ($p>0.05$) Conductivity and TDS concentrations (Figures 3c and d) ranged from 69.90 mg/l to 272.00 mg/l and 48.80 mg/l to 188.00 mg/l respectively.The conductivity and TDS values were lower during the wet season than the dry season (Table 2). *t*-test showed a high significant difference between season for both conductivity and TDS at $p<0.001$.







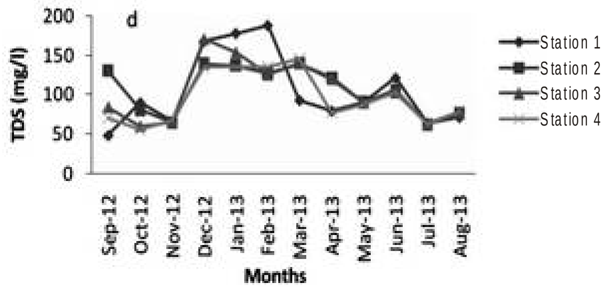


Figure 3. Spatial Variation in: (a) pH (b) Dissolved Oxygen (c) Conductivity and (d) Total Dissolved Solids for stations in Ibuya River.

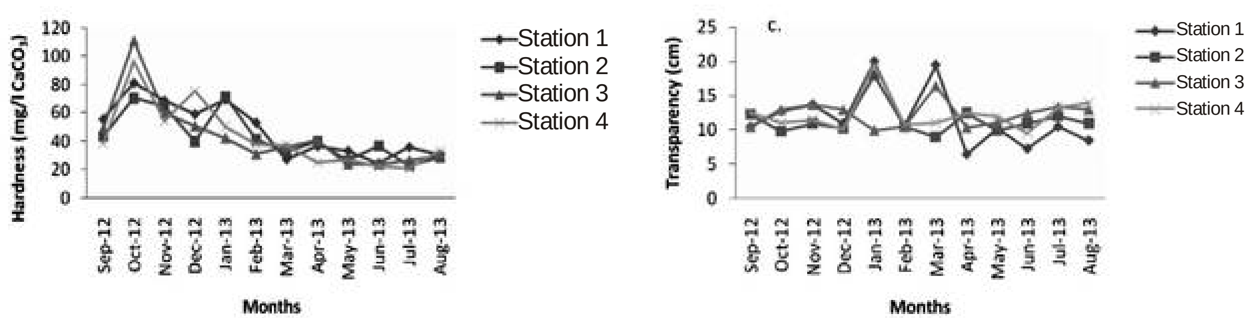
July recorded the lowest value of 21.4 mg/l $CaCO_3$ for hardness in Station 4, while the highest value of 111.4 mg/l $CaCO_3$ was recorded in Station 3 in October (Figure 4a). Hardness showed an increase during the dry season and then decrease progressively during the wet season.*t*-test showed no significant difference ($p>0.05$) between seasons. October recorded the highest value of 27.00 mg/l $CaCO_3$for alkalinity and August recorded the lowest value of 4.5mg/l $CaCO_3$ (Figure 4b). The mean value for the wet season (11.78±1.28mg/l $CaCO_3$) was higher than the dry season value of 11.33±0.69mg/l $CaCO_3$ (Table 2). Alkalinity showed no significant difference withseason ($p>0.05$). The lowest value of 6.5 cm for transparency was recorded in April in Station 1 while the highest value of 20.00 cm was recorded in January in same station (Figure 4c). The mean transparency for the wet season (11.31±0.34 cm) was lower than the dry season value of 12.59±0.73 cm. *t*-test showed no significant difference ($p>0.05$) between seasons for transparency. The lowest valueof 6.55 FTU for turbidity was recorded in February in Station 3 (Figure 4d) while the highest value of 35.26 FTU was recorded in July in the same station.The mean turbidity for the wet season (22.43±1.52 FTU) was higher than the dry season value (16.41±0.84FTU). Turbidity showed a high significant difference between the wet and dry seasons at $p<0.001$.

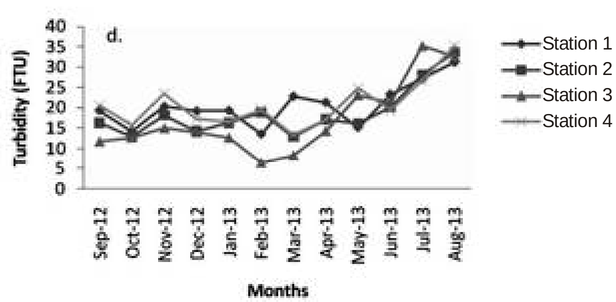
Table 2. Physico-chemical parameters and heavy metal contents for the wet and dry seasons in Ibuya River compared to Standard Organizations.

Parameters	Seasons		Standard Organizations			
	Wet	Dry	WHO (2004)	NESREA (2011)	FME (2000)	USEPA (2010)
Air Temp (°C)	25.99±0.21	27.00±0.56	-	-	-	-
Water Temp (°C)	25.02±0.25	25.48±0.55	-	-	-	-
pH	7.53±0.05	7.62±0.09	6.5-9.5	6.5-8.5	-	6.5-8.5
DO (mg/l)	3.74±0.14	3.76±0.11	6.0	-	4	-
Cond. (µS/cm)	115.89±6.20***	181.15±11.13***	200	-	-	-
TDS (mg/l)	82.30±4.19***	124.21±7.65***	500	-	-	-
Hard. (mg/l $CaCO_3$)	41.53±4.99	47.77±3.01	<200	-	-	-
Alkal. (mg/l $CaCO_3$)	11.78±1.28	11.33±0.69	-	-	-	20
Trans. (cm)	11.31±0.34	12.59±0.73	-	-	-	--
Turb. (FTU)	22.43±1.52***	16.41±0.84***	5	5	-	5
Mg (mg/l)	1.80±0.23**	3.30±0.38**	0.1	-	-	-
Mn (mg/l)	0.23±0.04	0.14±0.03	0.4	-	0.1	0.05
Cu (mg/l)	0.14±0.03*	0.07±0.01*	2.0	-	-	1.3
Fe (mg/l)	3.23±0.39***	1.17±0.23***	0.03	-	-	0.3
Cd (mg/l)	0.24±0.10*	0.02±0.01*	0.003	-	-	0.005
Pb (mg/l)	0.66±0.14	0.51±0.13	0.01	-	-	0.015
Zn (mg/l)	0.09±0.01	0.11±0.02	3	-	-	5
Cl^- (mg/l)	59.45±5.80***	94.27±8.21***	250	300	-	250
PO_4^- (mg/l)	21.56±3.68***	0.05±0.01***	-	3.5	0.05	-
SO_4^- (mg/l)	37.18±5.82***	11.16±2.40***	400	-	-	250
NO_3^- (mg/l)	24.35±4.94*	12.58±3.31*	10	9.1	-	10

*Significant $p<0.05$ level. **Significant $p<0.01$ level.
***Significant $p<0.001$ level.

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity, TDS.





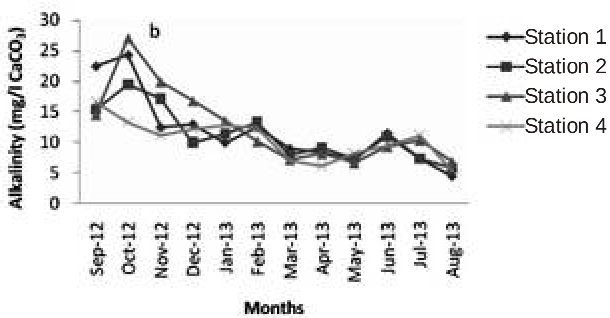
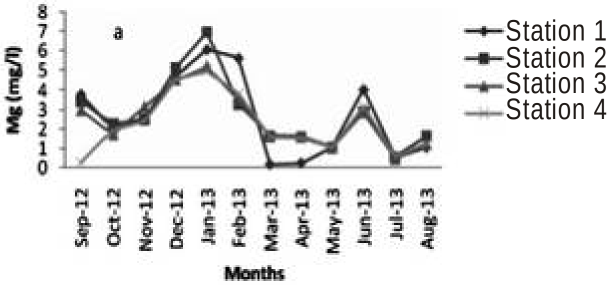
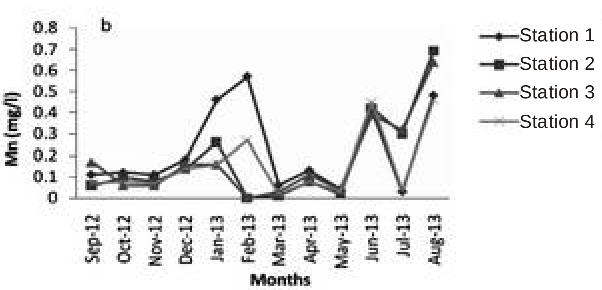
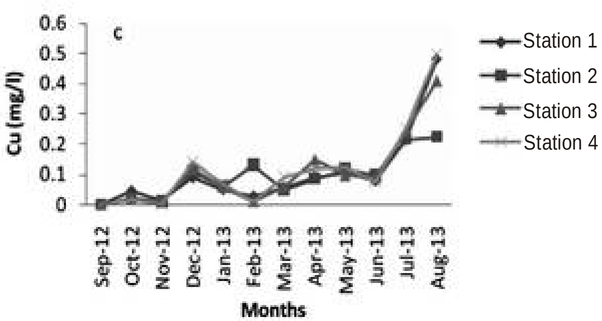


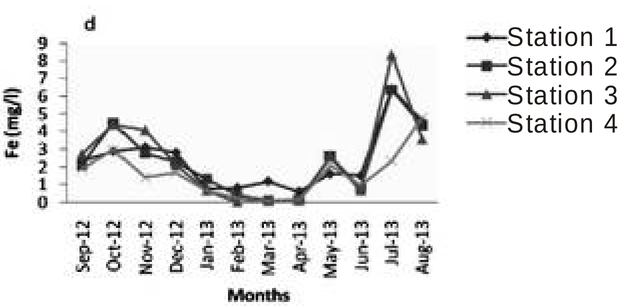
Figure 4. Spatial Variation in: (a) Hardness (b) alkalinity (c) Transparency (d) Turbidity for stations in Ibuya River.

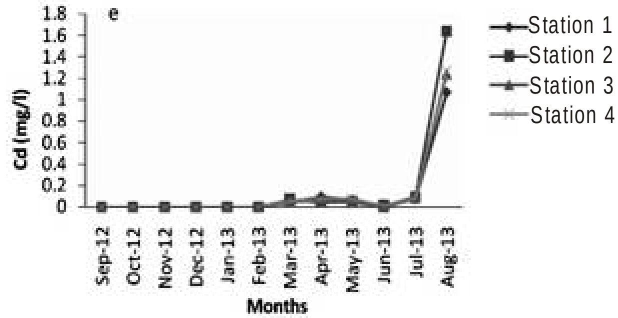
The mean concentration of Mn, Cu, Fe, Cd, and Pb were higher in the wet season than in the dry season while Mgand Zn concentrations were higher in the dry season than wet seasons.Mn, Pb and Zn showed no significant difference with seasons (*p*>0.05); Cd and Cu varied with seasons and the variations were significantly different at *p*< 0.05; Fe and Mg showed a high significant difference at *p*<0.001 and *p*<0.01 respectively between seasons. Figures 5a-g show spatial variations of the heavy metals across sampling stations in Ibuya River.

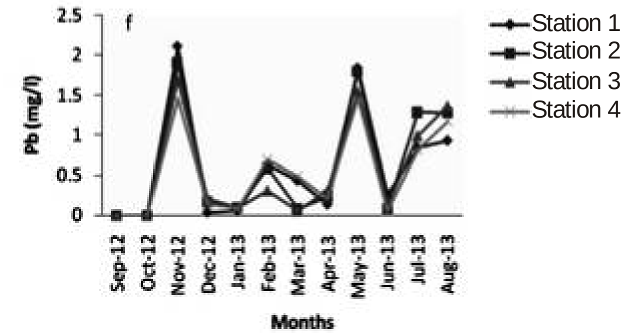












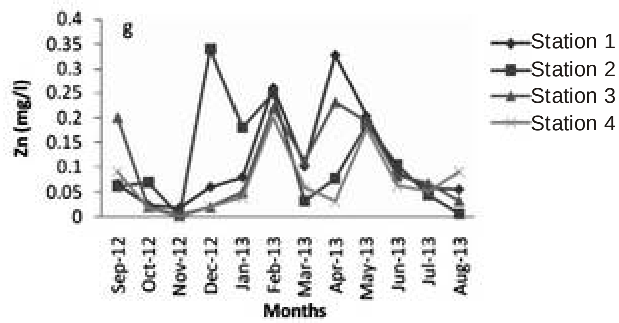
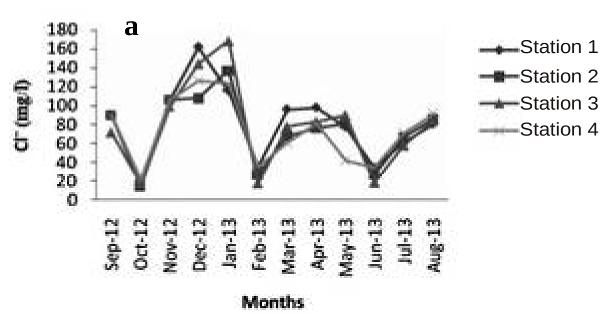


Figure 5. Spatial Variations in: (a) cadmium, (b) magnesium, (c) manganese, (d) copper, (e) iron, (f) lead and (g) zinc of the metals along sampling stations in Ibuya River.

The spatial variation in nutrient parameters is shown in Figures 6a-d. The concentration of PO_4^-, SO_4^- and NO_3^- were higher in the wet season than in the wet season than the dry season while Cl^- was higher in the dry season. Cl^-, PO_4^- and SO_4^- varied with seasons at *p*<0.001 while NO_3^- showed a variation between season at *p*<0.05.



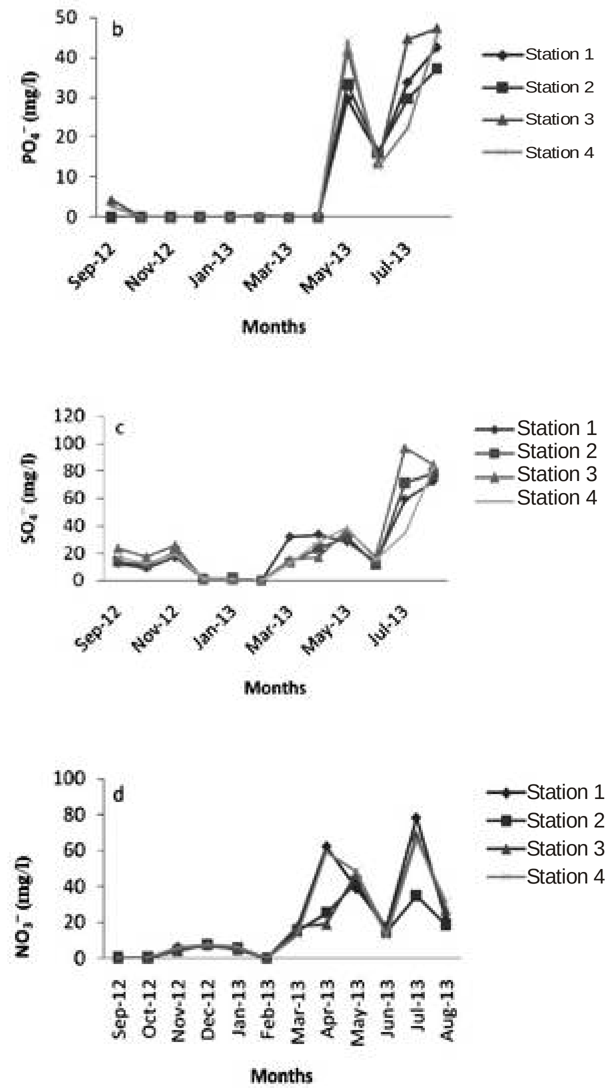


Figure 6. Spatial Variations in: (a) Cl^-, (b) PO_4^-, (c) SO_4^- and (d) NO_3^- of the nutrient parameter along sampling stations in Ibuya River.

Discussion

Water temperatures in Ibuya River fluctuated throughout the study-period in relation to the air temperature but they were within the acceptable levels for survival, metabolism and physiology of aquatic organisms (Gupta and Gupta, 2006). The water level was higher in the wet season than in the dry season. Thus, suggesting that the river's main water supply is rainwater though the river receives urban runoffs and seepage all year round. The pH (6.88-8.39) for the river was within the range reported for rivers flowing through areas with thick vegetation (Osimen, 1997 and Uwadiae *et al* 2009) and for inland waters according to WHO (2004) and SON (2007) guidelines. Pidgeon and Cains (1987) observed that organic acids resulting from decaying vegetation might be responsible for low pH in most aquatic ecosystems. Dissolved oxygen values of 2.61 to 5.01 in this study were similar to the 1.20 to 9.40 reported by Edokpayi and Osimen (2001) in Ibiekuma River in Ekpoma. High organic content from human and animals faeces, decayed plants materials, domestic and industrial waste and agricultural run offs that found their ways into the river may be responsible for the low dissolved oxygen. According to USDA (1992), the level of oxygen depletion depends primarily on the amount of waste added, the size, velocity, turbulence of the stream and the temperature of the water.

According to Adeleke (1982), conductivity levels below 50 µS/cm are regarded as low; those between 50 µS/cm to 600 µS/cm are medium while those above 600 µS/cm are high conductivity levels. The mean conductivity value of 152.04±8.42 µS/cm in this study falls within the range for many inland waters. Thus, with respect to electrical conductivity, the river water is portable. Conductivity tends to decrease in the wet season compared with the dry season which is similar to the report of Oben (2000) in limnological assessment of the impact of agricultural and domestic effluent on three man-made lakes in Ibadan.

Total Dissolved Solids (TDS) level in this study varied but the variation did not exceed the contaminant level. According to USEPA (2010), WHO (1993) and FEPA (1991), the maximum contamination level for TDS is 500 mg/l. When TDS levels exceed 1000 mg/l it is generally considered unfit for human consumption. With respect to water hardness classification by Lind (1979), the values during the wet season (43.70±4.97 mg/l $CaCO_3$) and dry season (47.77±4.53 mg/l $CaCO_3$) was considered as being normal. Thus, the river is suitable for fish production with respect to water hardness. Water bodies in the tropics usually show a wide range of fluctuations in total alkalinity, the values depending on the location, season, plankton population and nature of bottom deposits. However, the mean alkalinity recorded in this study was 11.55±0.72mg/l $CaCO_3$. According to FEPA (1991) guide lines, the alkalinity values should not be more than 50 mg/l. A minimum level of alkalinity is desirable because it is considered a "buffer" that prevents large variations in pH. Boyd (1982) recommended suitability of alkalinities between 20 and 50 mg/l for plankton production and fish culture.

Transparency was higher during the dry season (12.59±0.59cm), the high values could be attributed to low water volume favouring settling of suspended materials. Similar observations were reported by Kemdirim (1990) in Upland and Lowland Impoundment in Plateau State. The low transparency observed during the rainy season (11.31±0.59cm) could be due to dilution as a result of high water levels. Higher turbidity recorded during the wet season (22.43±1.23 FTU) compared to the dry season (16.41±1.23 FTU) is attributed to heavy rainfall and decay of organic matter in suspension in addition to surface runoff carrying sand and silt into the water. The adverse effect of turbidity on freshwater include decreased penetration of light hence reduced primary and secondary production, oxygen deficiency, clogging of filter feeding apparatus and digestive organs of aquatic organisms (Gupta and Gupta, 2006). However, turbidity values in this study were above the acceptable limits of 5 FTU for natural water by WHO (1993), FEPA (1991) and SON (2007) which is an indication that the water turbid.

All the heavy metals assessed showed slightly different pattern of manifestation during the study period. It must be noted that metals are unstable in the presence of water and have the tendency to transform or degrade to a more stable and often soluble form – a process recognized as corrosion (USEPA, 2010). The rate at which this takes place is governed by many chemical and physical factors; it may be very rapid or extremely slow (WHO, 1993). However, because a metal concentration in the aquatic environment is low and considered to be naturally occurring does not mean that the concentration could not cause adverse ecological effects (USEPA, 2002). Their sub-lethal concentrations become lethal to fish or other aquatic organisms when the duration of exposure to these metals is prolonged (Stag and Shuttleworth, 1982; Cenini and Turner, 1983; Collvin, 1984; Reash, 1986 and Everall, 1987).

All the stations had mean Mg concentrations higher than the permissible limit. The average Mg concentration for the river was 2.55±0.25 mg/l while the health based guideline figure for water is a maximum of 0.01 mg/l (WHO, 1993) and 0.2 mg/l (SON, 2007). High organic content from domestic and industrial waste and agricultural runoffs that found their ways into the river may be responsible for the high Mg concentration.The mean Mn concentration of water in this study was 0.19±0.03 mg/l though there were variations across the stations that were not significantly different (p>0.05). The Mn level in this study was above the recommended maximum contaminant level (MCL) for Mn (0.05 mg/l) (USEPA, 2010). Cu is a natural occurring element commonly found in surface water, ground water, sea water and drinking water (USEPA, 1991). The river's mean Cu concentration of 0.11±0.02 mg/l was below the recommended level for drinking water and aquatic life. A Cu level of 2.00 mg/l in water should not cause any adverse effect and provides an adequate margin of safety (WHO, 1996). The mean value of 2.20±0.27 mg/l for Fe recorded in this study exceeds the maximum contamination level (MCL) of <0.3 mg/l (USEPA, 2010). This result indicates that the river is contaminated with Fe. Fe is an important metal in both plants and animals,especially in the cellular processes (Lovell, 1989).

Fe is found in natural fresh and ground water, but have no health-based guideline value, although high concentrations give rise to consumer complaints due toits ability to discolour aerobic waters at concentrations above 0.3 mg/l (WHO, 2004). The concentrations of Cd in large amount constitute a serious health hazard. Cd is very soluble in water and it is important in several enzyme systems. Cd is one of the most toxic elements with wide spread carcinogenic effects in humans (Goering, *et al* 1994). The mean Cd concentrations in this study of 0.13±0.05 mg/l was above the MCL of 0.005 mg/l (USEPA, 2010) and 0.003 mg/l (WHO, 1993 and SON, 2007), thus indicating that the water is contaminated with Cd posing a threat to both humans and aquatic life.

All the stations had mean Pb concentrations higher than the permissible limit. The average Pb concentration for the river was 0.59±0.09 mg/l while the health based guideline for water is a maximum of 0.01 mg/l (WHO, 2004 and SON, 2007) and 0.0015 mg/l (USEPA, 2010). The United States Environmental Protection Agency has classified Pb as being potentially hazardous and toxic to most forms of life (USEPA, 1986). It has been found to be responsible for chronic neurological disorders in foetuses and children especially when it is greater than 0.1 mg/l. Lead may impair renal function, red blood cell production, the nervous system and blindness (Asonye *et al* 2007). Zn is present in large amount in natural water (USEPA, 2010). The mean Zn concentrations of 0.10±0.01 mg/l was below the MCL of 3.0 mg/l recommended by WHO (2004) and SON (2007).

The presence of chloride, where it does not occur naturally, indicates possible water pollution. Chloride contaminates rivers and ground water and can make it unsuitable for humans and aquatic life. The normal range according to Egereonu and Dike (2007) for river surface water is 45-155 mg/l and WHO (1993) is 250 mg/l. The average mean value of chloride (76.90±5.58 mg/l) in all the analyzed water samples signifies that chloride is not a threat in the river. Phosphate may occur in surface water as a result of domestic sewage, detergents, and agricultural effluents with fertilizers. The mean phosphate concentration of 10.80±2.40mg/l in this study was higher than the acceptable limit of 3.50 mg/l by NESREA (2011). However, natural inputs from decomposition of organic matter might be a contribution to the phosphate concentration in this river. Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals and discharge of industrial wastes and domestic sewage tends to increase its concentration (Shrinivasa Rao and Venkateswaralu, 2000).

Sulphate varied among sampling stations, but none of the samples were up to the portable water maximum acceptable concentration limit of 100 mg/l as stipulated by SON (2007). The observed nitrate concentration of 18.50±3.07 mg/l is below the acceptable value in natural surface water of 50 mg/l (WHO, 2004 and SON, 2007). The low nitrate concentration in the river could possibly be due to high photosynthetic activities by aquatic plants. Nitrate concentration in the wet season was higher (24.30±5.13 mg/l) than the dry season (12.58±4.68 mg/l). The decreased value in the dry season might be explained by the high uptake of nitrate by aquatic plants during photosynthesis.

Conclusion

In this study the water quality properties in terms of its physico-chemical parameters, for total dissolved solids, conductivity, pH, dissolved oxygen, temperature, hardness and alkalinity were within the recommended values of World Health Organization (WHO), Federal Environmental Protection Agency (FEPA) and Standard Organization of Nigeria (SON) for survival, metabolism and physiology of aquatic organisms. However, data obtained for heavy metals such as magnesium, manganese, cadmium, iron and lead were above the permissible limit. Micro-nutrient like phosphate was dangerously higher than the maximum contaminant levels (MCL) recommended for unpolluted or drinking water which creates health hazards on continuous consumption. This study also showed that the river contained pollutants due to waste from agricultural ventures, domestic waste from urban dwellers and fuel stations.

Acknowledgment

Appreciation goes to the Old Oyo National Park Authorities for the opportunity to carry out this research work in the park.

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Akponine, J. A. and Ugwumba, O. A.
© *The Zoologist, 12:* 54-63 (2014), ISSN 1596 972X.
Zoological Society of Nigeria.