

## Assessment of Qualities of Surface Water, Sediments and Aquatic Fish from Selected Major Rivers in South-Western Nigeria

E.U. Etim and G.U. Adie

Department of Chemistry, University of Ibadan, Nigeria

**Abstract:** Available sources of portable water for drinking, domestic and industrial chores in Nigeria are dwindling because of concomitant increase in population, urbanization and industrial activities. This study assessed the qualities of Surface Water (SW), Sediment (SD) and Tilapia Fish (*Oreochromis niloticus*) (TF) samples collected from Asejire, Oni, Ona, Ogun, Ogunpa, Eleyele and Majidun rivers and Lagos lagoon in south-western Nigeria. Samples of SW, SD and TF were collected at strategic locations from each water source and analyzed using standard procedures. SW for all locations were grossly polluted with organics as indicated by high COD (72.8-292 mg/L) and BOD (30.8-143 mg/L) and low DO (1.04-6.68 mg/L) levels. Lead levels in SW for all locations exceeded WHO and NIS limits for drinking water. Cadmium levels in sediments from Oni, Ona, Ogun and Ogunpa rivers also exceeded Canadian Interim Sediment Quality Guidelines (ISQG) of 0.6 mg/kg. Fish from Lagos lagoon were most polluted with Pb, Cr, Ni and Cu. Principal Component analysis showed that 86.4% of overall metal load for SW was from Ogunpa and Eleyele rivers, whereas 62.9% metal load for S was from Ogunpa, Eleyele and Ogun rivers. The metal pollution index order was Pb>Cu>Co>Ni>Cr>Cd. Lead and nickel showed strong positive correlation between SW and SD, suggesting common source while Pb and Cr showed strong negative correlation with Cd between SW and TF. Unsafe disposal practices of wastes into or within the vicinity of water bodies should be discouraged.

**Keywords:** Lagoon, lead, pollution index, principal component analysis, sediment, tilapia fish

### INTRODUCTION

Surface water quality is a serious global issue that is discussed within the scientific community, especially in developing countries and countries whose economy is under transition. Sustainable river water quality balance is dwindling each passing day (Shiklomanov and Rodda, 2003). The river system constitutes a major source of fresh water supply, comprising both the main course and the tributaries, carrying the one-way flow of a significant load of matter in dissolved and particulate phases from both natural and anthropogenic sources. The quality of a river at any point reflects several major influences, including the lithology of the basin, atmospheric inputs, climatic conditions and anthropogenic inputs (Bricker and Jones, 1995; Shrestha and Kazama, 2007). On the other hand, rivers play a major role in assimilating or transporting municipal and industrial wastewater and runoffs from agricultural activities. Municipal and industrial wastewater discharge constitutes a constant pollution source (Peter and Rodney, 2007; Dan'Azumi and Bichi, 2010), whereas surface runoff is a seasonal phenomenon, largely affected by climate within the basin (Singh *et al.*, 2004). The discharge of municipal, industrial and agricultural wastes into fresh water and the resultant deleterious changes in water ecology have been reported by several researchers (Okoronkwo and

Odeyemi, 1985; Abida and Hariskrishna, 2008; Dan'Azumi and Bichi, 2010). Seasonal variations in precipitation, surface runoff, interflow, groundwater flow and pumped in and outflows have a strong effect on river discharge and, subsequently, on the concentration of pollutants in river water (Vega *et al.*, 1998). In many regions of the world, especially, those with high population density, river water pollution is becoming increasingly evident. The most common symptom is the dissemination of aquatic biota (Gabriel *et al.*, 2006; Hsua *et al.*, 2006), colorization of the water, waste load of the water and poses a threat to human health (World Bank, 1993). Water quality deterioration due to industrial effluent and municipal sewage discharge has been documented in literatures. Previous reports on pollution of major rivers in southwestern Nigeria showed that major sources of pollutants are from agricultural and other anthropogenic activities within the vicinities of the banks of the rivers and discharge of waste water from industrial activities (Ajayi and Osibanjo, 1981; Ipeaiyeda and Onianwa, 2009; Olatunji and Abimbola, 2010; Osibanjo *et al.*, 2011).

In south-western Nigeria, fresh water resources are highly affected by environmental stress imposed by human population growth, urbanization and industrialization. Despite increasing public sensitization, water pollution continues to generate

unpleasant implications for health and economic development. The protection of water quality and aquatic ecosystem as a vulnerable resource essential to sustainable development is of utmost importance to prevent further pollution and degradation of fresh water resources in this region. It is important to continually investigate the quality of surface water to check the influence of the teeming growing population, urbanization and industrialization on it. This study investigated water, sediment and fish qualities in seven major rivers and Lagos lagoon in the south-western Nigeria and compared with previous studies. The study was carried out in September 2010.

## MATERIALS AND METHODS

**Description of study area:** There is a high network of rivers within the south-western Nigeria, all of which flow directly into the Atlantic Ocean. Notably are Osun, Oni, Ona, Ogunpa, Eleyele Ogun, Majidun and the Lagos lagoon. The region is characterized by high humidity with annual rainfall of 145-250 cm. These rivers have average flow velocities ranging from 2 to 14 m<sup>2</sup> with high silt content. The watersheds transverse many settlements with average stream length of 350 km. Different agricultural practices such as fishing and irrigation and solid waste disposal points are commonly practiced along the river banks.

**Sampling and sampling design:** Four sampling points depicting regions of high activities and low activities were identified for surface water, sediment and fish collection along the length of each of the seven rivers and the lagoon system. A total of 32 surface water, 32 sediment and 32 fish samples were obtained during the period of study (September 2010). Surface water samples were collected using clean plastic cups into polyethylene plastic containers which were previously washed, rinsed and dried. Sediment and fish samples were collected and stored (in ice) in polythene bags. All sample containers were properly labeled to indicate sample code, collection point, date and sampling time. Standard methods were used for sample preservation.

**Chemical analysis of samples:** Surface water quality parameters were determined according to Standard Procedures of the Society for Analytical Chemistry (1973) and the APHA-AWWA-WPCF (1985) manual as follows: pH was determined electronically using a pH meter; alkalinity (acid-base titrimetric method); chloride (mercuric nitrate titrimetric method); total hardness, calcium and magnesium (EDTA titrimetric method); total dissolved solids and total solids (gravimetric method); dissolved oxygen (Winkler titrimetric method); biochemical oxygen demand (dilution Winkler method); chemical oxygen demand (reflux oxidation titrimetric method); nitrate

(phenoldisulphonic acid colorimetric method); phosphate (Ascorbic acid colorimetric method); sulphate (turbidimetric method); ammonia (Nessler's colorimetric method) and metal -Pb, Cr, Cd, Co, Cu and Ni by atomic absorption spectrophotometric method.

Sediment samples were air-dried in a clean room in the laboratory and then sieved with a 2 mm mesh sieve. The parameters determined on sediment samples were as follows: pH was determined by electrometric method in a 1:1 sediment water mixture (IITA, 2001). Percentage sand, clay and silt were determined using the hydrometer method (Bouyoucos, 1951) and organic carbon content was determined using Walkley and Black (1934) method. Metals were determined by weighing exactly 5.0 g of dried sediment sample into a covered glass bottle and extracted with 50.0 mL of 2 M HNO<sub>3</sub> placed on a boiling water bath for 2 h. After this, the extracts were then filtered using Whatman No. 2 filter paper into standard flask and made up to mark. This extract was stored in a polyethylene plastic container at 4°C until analysis. This extraction method has been established to yield the ecologically significant fraction of the metal content (Anderson, 1976). The fish sample was oven dried in the laboratory at 80°C for 2 days. Exactly 5.0 g of the dried fish were ashed at 550°C in a muffle furnace for 4-5 h when the entire fish sample was observed to have a uniform ash. The ash was dissolved in 25 mL of 2 M HNO<sub>3</sub>; this mixture was warmed where necessary to dissolve all the ash. A blank sample was incorporated for every five sediment and fish samples processed. The extracts were analysed for lead, cadmium, chromium, cobalt, copper and nickel using 200A Buck Scientific flame atomic absorption spectrophotometer. Commercial BDH stock standards were used for the instrument calibration. A recovery study of the extraction procedure for sediments was carried out by spiking portions of five previously analyzed sediment samples with standards of lead, chromium, copper, cobalt and nickel. These were processed using the same analytical steps as the original samples.

**Statistical data treatment:** The Principal Component Analysis (PCA) biplot was employed to show tendencies or clustering pattern. Also, Analysis of Variance at  $p = 0.05$  was conducted to establish any relationship among the quality parameters at different sampling locations. Person's correlation coefficient was used to categorize the correlation of surface water and sediment and surface water and fish quality.

## RESULTS AND DISCUSSION

**Assessment of surface water quality parameters:** The average water quality parameters for all rivers in this study are presented in Table 1. The average pH values for all water samples varied between 6.36 and

Table 1: Average concentration (Mean±S.D.) of water qualities for all rivers compared with regulatory limits

Parameter	Asejire	Oni	Ona	Ogun	Ogunpa	Eleyele	Majidun	Lagos lagoon	Regulatory limits	
									WHO <sup>a</sup>	NIS <sup>b</sup>
pH	7.21±0.26	6.75±0.05	6.63±0.08	6.76±0.13	6.64±0.09	6.95±0.08	6.82±0.02	6.36±0.33	6.5-9.5	6.5-8.5
Temperature °C	27.0±0.53	27.3±0.57	27.7±0.57	27.0±1.00	27.4±0.51	27.5±0.50	28.3±0.06	33.7±1.15	-	Ambient
Alkalinity (mgCaCO <sub>3</sub> /L)	93.6±23.2	62.5±7.60	105±20	75.0±5.00	152±35.1	148±10	63.7±7.6	44.3±19.0	-	-
Total hardness (mgCaCO <sub>3</sub> /L)	143±50	78.9±6.7	230±30	178±61	337±18	180±2	241±18	237±9	<200	150
Calcium (mg/L)	49.0±7.6	27.8±5.1	87.6±4.6	68.8±4.4	130±9	65.7±7.1	92.7±5.3	90.3±1.9	<200	-
Magnesium (mg/L)	9.24±4.2	4.61±3.4	4.85±2.4	3.61±1.7	7.32±2.6	5.9±9.4	2.94±4.3	5.21±1.3	<150	0.20
Total solids (mg/L)	1040±606	1000±12	817±348	773±455	1430±389	1310±584	1450±201	725±282	<1500	-
TDS (mg/L)	813±519	916±64	676±423	426±389	1090±172	525±282	1040±133	191±26	<1000	500
DO (mg/L)	2.24±1.10	2.89±1.90	1.04±0.04	5.94±3.88	6.68±0.96	1.73±0.59	2.02±1.91	5.50±2.97	6.0	-
BOD (mg/L)	48.5±6.41	86.8±7.58	79.3±27.8	110±43	34.3±2.9	39.0±33	30.8±3.8	143±36	-	-
COD (mg/L)	166±81	292±7.6	191±101	271±88	72.8±17.6	112±45	181±80	277±7	-	-
Nitrate (mg/L)	10.6±1.10	20.0±0.7	2.63±0.15	23.1±1.6	10.8±1.0	1.30±0.22	55.1±0.8	4.95±0.28	50	50
Sulphate (mg/L)	12.9±10.7	22.7±7.9	10.2±8.0	27.4±21.6	20.7±4.3	7.55±1.23	5.05±0.67	1.09±0.03	500	100
Phosphate (mg/L)	0.12±0.06	0.01±0.0	0.03±0.0	0.04±0.01	0.10±0.01	0.01±0.01	0.04±0.02	0.07±0.01	-	-
Ammonia (mg/L)	3.05±1.66	7.15±0.23	4.87±3.07	14.6±17.5	5.83±3.12	2.38±0.38	3.43±0.57	2.60±0.05	<1.5	-
Lead (mg/L)	0.12±0.02	0.13±0.01	0.08±0.66	0.11±0.1	0.29±0.02	0.29±0.26	0.08±0.02	0.02±0.03	0.01	0.01
Cadmium (mg/L)	0.01±0.02	0.05±7.60	0.01±0.05	BDL	0.01±0.01	BDL	BDL	BDL	0.003	0.003
Chromium (mg/L)	0.03±0.02	0.01±0.01	0.02±0.00	0.01±0.01	0.03±0.01	0.02±0.02	0.01±0.00	0.01±0.01	0.05	0.05
Nickel (mg/L)	BDL	0.01±0.19	BDL	BDL	0.06±0.01	0.07±0.01	BDL	0.01±0.01	0.07	0.02
Cobalt (mg/L)	0.14±0.01	0.03±0.00	0.02±0.07	0.02±0.02	0.02±0.01	0.03±0.05	0.01±0.00	0.01±0.01	-	-
Copper (mg/L)	0.02±0.01	0.02±0.00	0.02±0.06	0.04±0.01	0.06±0.02	0.03±0.04	0.11±0.00	0.01±0.00	2.0	1.00

TDS: Total dissolved solids; DO: Dissolved oxygen; BOD: Biochemical oxygen demand; COD: Chemical oxygen demand; BDL: Below detection limit; <sup>a</sup>: WHO (2011); <sup>b</sup>: NIS-Nigeria industrial standard (2007)

7.21 while temperature varied between 27.0 and 33.7°C. Generally, the pH values in this study are indicative of a good water quality. The average pH values were within the acceptable range of the regulatory limits (NIS, 2007; WHO, 2011) except for Lagos lagoon which was slightly more acidic than regulated. The average temperature values for all water samples were <40°C depicting temperature range that is supportive of good surface water quality (NIS, 2007). The pH and temperature values for all rivers studied were comparable with previous studies done on some selected rivers in the south-western Nigeria (Akoteyon *et al.*, 2011; Osibanjo *et al.*, 2011; Adeogun *et al.*, 2012). The average alkalinity, total hardness, calcium and magnesium content of water samples showed no indication of anthropogenic input. The total hardness of Lagos lagoon, Ona, Ogunpa and Majidun rivers which were above 200 mg/L (WHO, 2011) could form scales on heating. The average values for Total Solids (TS) and Total Dissolved Solids (TDS) ranged from 723 to 1450 mg/L and 191 to 1140 mg/L respectively, with the lowest values for both TS and TSS recorded in water samples collected from Majidun River (Table 1). The amount of solids present in a water body can be used to estimate the pollution load as a result of both organic and inorganic contaminants present. Total Dissolved Solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic carbon that are dissolved in water. TDS in drinking

water originates from natural sources, sewage, urban runoff and industrial wastewater. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubilities of minerals. The results of total and dissolved solids presented in this study (Table 1) for all rivers were within accepted limits of 1500 and 1000 mg/L respectively, set by WHO (2011). The TDS and TS from the Ona River in this study were much higher than previously reported (Osibanjo *et al.*, 2011).

The average values for Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) ranged from 1.04 to 6.68, 30.8 to 143 and 72.8 to 292 mg/L, respectively. Ogunpa River showed highest average DO value of 6.68 mg/L and lowest average COD of 72.8 mg/L supportive of the established inverse proportionality of DO with COD of any water sample. Low DO and high BOD and COD of a greater percentage of the rivers investigated suggest gross organic pollution. The average BOD values of all the rivers exceeded the Recommended Maximum allowable Concentration (RMC) set by the European Union for good quality water for fisheries and other aquatic life which is 3.0-6.0 mg/L (Chapman, 1996). All the inorganic nutrients like NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup> and PO<sub>4</sub><sup>3-</sup> were within the regulatory limits (NIS, 2007; WHO, 2011) except ammonia that was higher in all samples than maximum limit of 1.5 mg/L. This indicates greater use of organic fertilizers for agricultural activities within the vicinity of the

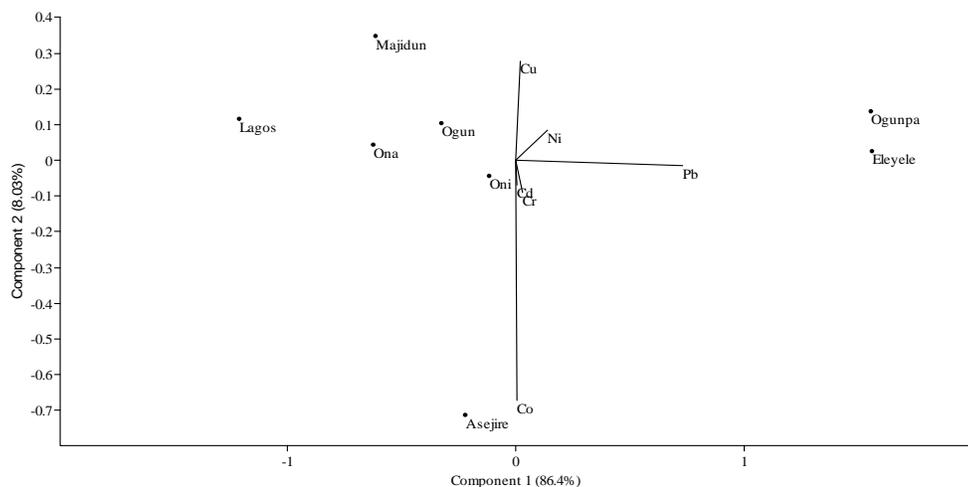


Fig. 1: Principal component analysis biplot of the surface water metal data set

Table 2: Quality of sediments (Mean±S.D.) in the rivers studied

Parameter	Asejire	Oni	Ona	Ogun	Ogunpa	Eleyele	Majidun	Lagos lagoon
pH	6.43±0.38	6.20±0.31	6.14±0.08	6.03±0.27	6.28±0.26	6.10±0.25	6.10±0.29	5.80±0.16
OC %	0.46±0.31	0.27±0.02	1.96±2.17	0.95±0.04	0.41±0.03	1.07±0.30	1.77±0.17	0.87±0.03
Sand	93.1±3.05	93.3±4.16	87.7±7.57	95.4±2.64	87.7±5.50	90.1±4.04	89.7±3.05	95.4±2.65
Silt	2.73±1.15	2.07±1.15	9.04±5.29	1.40±2.72	6.07±0.58	6.00±2.00	4.07±0.58	1.40±0.72
Clay	4.20±2.00	4.86±3.05	6.87±2.31	1.20±1.00	5.87±0.58	3.93±1.27	4.20±1.10	1.20±1.00
Pb mg/kg	8.33±0.95	6.83±3.15	5.67±5.26	19.4±5.5	20.2±6.80	25.2±15.7	5.67±3.33	6.33±4.96
Cd	0.39±0.05	2.60±0.08	3.58±1.12	6.17±0.35	6.39±0.13	0.31±0.08	0.08±0.14	0.41±0.29
Cr	7.92±3.11	8.50±2.14	10.3±2.13	7.04±4.10	7.14±3.20	6.94±3.63	9.83±4.88	5.18±1.77
Ni	1.88±1.23	2.85±1.23	0.60±0.56	3.73±0.42	4.73±0.33	8.30±9.15	1.46±1.27	1.14±0.19
Co	3.19±0.34	2.75±0.50	3.92±1.66	3.13±1.18	3.52±1.02	2.57±0.20	2.36±0.44	4.67±1.01
Cu	3.95±0.19	4.16±0.76	16.6±1.22	8.04±2.86	8.12±2.57	23.5±18.8	8.83±1.28	17.0±1.00

OC: Organic carbon

rivers as commonly practiced. This supports the high demand for oxygen as indicated by low DO and high BOD and COD. High content of ammonia in a water body is an indicator of possible bacterial, sewage and animal waste pollution, which have organic origin.

All metals showed varying degrees of contamination across all rivers and the Lagos lagoon (Table 1). Lead level was higher than maximum permissible limit of 0.01 mg/L set by WHO (2011) and NIS (2007) in all water samples collected. This is indicative that Pb is ubiquitous in our environment with diverse pollution sources. A greater percentage of all metals were higher than the permissible limit, but the pollution rating was not alarming as almost all values were barely higher than the permissible limits. Lead level (0.0002-0.046 mg/L) of Ogunpa and Ona rivers determined in 1977-1978 (Mombeshora *et al.*, 1983), 34 years ago compared with present study (0.08-0.29 mg/L) showed significant increase of more than 6 folds. This clearly reflects the influence of the growing population and advancement in industrialization. Analysis of variance of metals in surface water for all rivers showed no significant differences ( $p>0.05$ ). The principal component biplot (Fig. 1) showed that Ogunpa and Eleyele rivers had higher levels of metals (Pb, Ni and Cu) accounting for 86.4% of the overall metal load in surface water in this study (Component 1; Right Hand Side) compared to 8.03% for Majidun, Lagos lagoon, Ogun, Ona, Oni and Asejire rivers

(Component 2; Left Hand Side). This indicates that the highest levels of metal contamination may be found within the waters of the Ogunpa and Eleyele. The cumulative metal contamination is in the order of Ogunpa>Eleyele>Asejire>Oni>Majidun> Ogun>Ona> Lagos lagoon, with the metal pollution index order of Pb>Cu>Co>Ni>Cr>Cd.

**Sediment quality assessment:** The pH values of sediments samples collected from all rivers ranged from 5.80 to 6.43, indicative of available  $H^+$  for exchange with any metals. The Lagos lagoon recorded the lowest pH value of 5.80 while Asijire river recorded the highest average pH value of 6.43 (Table 2). The organic carbon load in sediment samples collected was relatively low with the highest amount (1.96%) recorded at Ona river and lowest amount (0.27%) recorded at Oni river (Table 2). The sediment characteristics across all rivers exhibited a greater percentage of sand (87.7-95.4%), low silt (1.40-9.04%) and low clay (1.20-6.87), respectively. Sediment samples with these mechanical characteristics always acts as reservoirs for high solids that can easily be redistributed to surface water bodies. This might have contributed to the high total solids depicted by surface water samples collected from all rivers (Table 1).

Average Pb level was higher in sediment samples collected from Ogun, Ogunpa and Eleyele rivers, while Cu level was highest at Eleyele river. Cadmium,

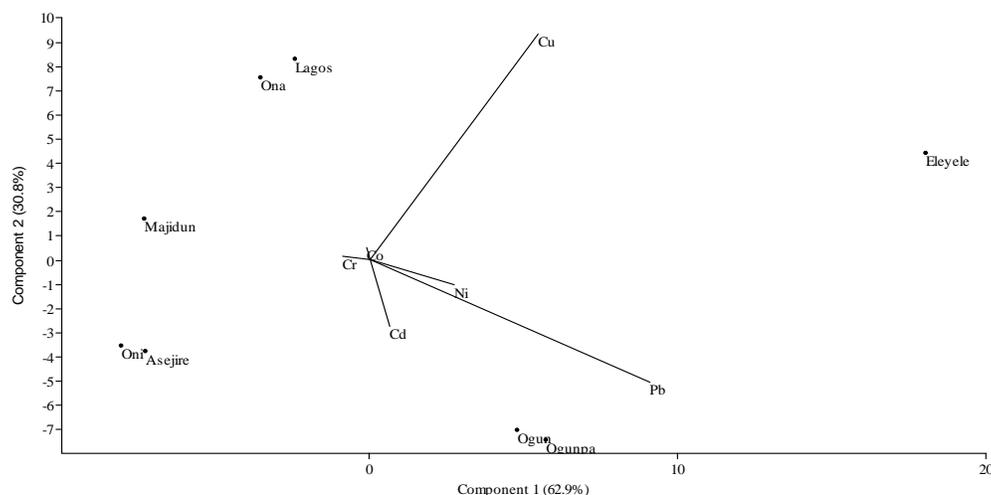


Fig. 2: Principal component analysis biplot of the sediment metal data set

Table 3: Average metal (mg/kg) levels of tilapia fish collected from the rivers

Parameter	Asejire	Ona	Ogun	Ogunpa	Eleyele	Majidun	Lagos lagoon
Pb	BDL	BDL	4.80±1.77	BDL	5.00±0.50	0.82±0.71	8.21±0.75
Cd	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cr	0.15±0.02	0.09±0.01	0.49±0.01	BDL	0.58±0.20	0.31±0.26	0.39±0.01
Ni	BDL	BDL	BDL	BDL	BDL	BDL	1.30±0.06
Co	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	2.53±0.10	1.93±0.07	3.27±0.95	BDL	1.77±0.04	3.14±0.44	1.46±0.22

n = 3

Table 4: Pearson's correlation coefficient (95% confidence limit) of metal levels

	Pb	Cd	Cr	Ni	Co	Cu
Surface water/sediment						
Pb	0.82*					
Cd	0.28	0.11				
Cr	-0.15	0.25	0.02			
Ni	0.87*	-0.11	0.23	0.86*		
Co	-0.40	-0.19	0.07	-0.16	-0.11	
Cu	0.17	-0.49	-0.08	0.46	-0.41	-0.22
Surface water/fish						
Pb	0.22	-0.62*	-0.28	0.33	-0.44	-0.02
Cr		-0.72*	-0.25	-0.00	-0.53	0.29
Cu			0.59	-0.16	0.05	0.18

chromium, nickel and Cobalt showed comparable levels in all rivers studied. Average Cd level in sediments samples collected from Oni, Ona, Ogun and Ogunpa rivers was above the Canadian interim Sediment Quality Guidelines (ISQG) for the protection of aquatic life of 0.6 mg/kg (CCME, 2007). Analysis of variance of metals in sediment samples from all rivers showed no significant differences ( $p > 0.05$ ). The principal component analysis biplot (Fig. 2) showed that metal levels were higher in sediments found within Eleyele, Ogun and Ogunpa rivers accounting for 62.9% of the total metal load (Component 1; Right Hand Side). Metal levels at the Lagos lagoon, Ona, Majidun, Oni and Asejire sediments accounted for 30.8% of the overall metal load (Component 2; Left Hand Side). The PCA further confirmed that the sediment within the Eleyele, Ogunpa and Ogun rivers recorded higher levels of Pb and Cu.

**Fish quality assessment:** The result of metal analysis on tilapia fish (*Oreochromis niloticuss*) collected from selected rivers is depicted in Table 3. *Oreochromis niloticuss* was used as a bio-indicator to assess the level of pollution from the river ecosystems. All metals investigated were Below Detection Limit (BDL) in fish collected from Ogunpa River. Also, Cd and Co were not detected in fish collected from all rivers. Lagos lagoon showed average metal levels in fish in descending order as follows: Pb (8.21 mg/kg dw) > Cu (1.46 mg/kg dw) > Ni (1.30 mg/kg dw) > Cr (0.39 mg/kg dw). Highest level of Cr (0.58 mg/kg dw) was witnessed in Fish collected from Eleyele river, while fish collected from Ogun river showed highest level of Cu (3.27 mg/kg dw). Fish samples from Lagos lagoon were most polluted probably because the lagoon acts as a reservoir that receives all other smaller rivers and streams with all kinds of pollutants in various forms.

**Correlation studies:** The result of Pearson's correlation coefficient studies conducted between surface water/sediment and surface water/fish is shown in Table 4. Lead showed strong positive correlation (0.82) between surface water and sediment and also a strong correlation (0.87) with Ni between the two media implying common source of Pb and Ni. Adversely, there was a strong negative correlation of Pb/Cd (-0.62) and Cr/Cd (-0.72) between fish/surface water. This suggests that there is lesser uptake of Cd in the presence of Pb and Cr or vice versa.

The average percentage recoveries were: Pb - 97.4±7.32%, Cr -95.8±3.25%, Cd -99.3.1±3.2%, Co - 96.4±6.4%, Cu -97.1±3.9% and Ni -79.6±4.8%.

### CONCLUSION

From the studies, surface water was found to be grossly polluted with organics as evident in high COD and BOB and low DO values. Lead was found to be present in all surface water samples at levels higher than permissible limits set by WHO (2011) and NIS (2007). Cadmium also was found in higher amount than permissible limits in sediments from Asejire, Oni, Ona, Ogun, Ogunpa, Eleyele and Majidun rivers. Fish from Lagos lagoon were the most polluted with metals. The implications of these findings may be that people dependent on this river waters for domestic use including cooking, bathing, washing and even drinking or for agricultural uses like fishing and farming may be exposed to public health risks. Proper treatment is imperative for the river to be appropriate for potable, domestic and industrial purposes.

### REFERENCES

- Abida, B. and Harikrishna, 2008. Study on the quality of water in some streams of Cauvery River. *E J. Chem.*, 5(2): 377-384.
- Adeogun, A.O., T.A. Babatunde and A.V. Chukwuka, 2012. Spatial and temporal variations in water and sediment quality of Ona river, Ibadan, Southwest Nigeria. *Eur. J. Scient. Res.*, 74(2): 186-204.
- Ajayi, S.O. and O. Osibanjo, 1981. Pollution studies on Nigerian rivers, II: Water quality of some Nigerian rivers. *Environ. Pollut. Series B Chem. Phys.*, 2(2): 87-95.
- Akoteyon, I.S., A.O. Omotayo, O. Soladoye and H.O. Olaoye, 2011. Determination of water quality index and suitability of urban river for municipal water supply in Lagos-Nigeria. *Eur. J. Scient. Res.*, 54(2): 263-271.
- Anderson, A., 1976. On the determination of ecologically significant fractions of heavy metals in soils. *Swed. J. Agr. Res.*, 6: 19-25.
- APHA-AWWA-WPCF, 1985. Standard Methods for the Examination of Water and Waste Water. American Public Health Association, Washington, DC, pp: 93-538.
- Bouyoucos, G.H., 1951. A recalibration of the hydrometer for making mechanical analysis of soils. *Agron. J.*, 43: 434-438.
- Bricker, O.P. and B.F. Jones, 1995. Main Factors Affecting the Composition of Natural Waters. In: Salbu, B. and E. Steinnes (Eds.), Trace Elements in Natural Waters. CRC Press, Boca Raton, FL, pp: 1-5.
- CCME (Canadian Council of Ministers of the Environment), 2007. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life-Interim Sediment Quality Guidelines (ISQGs). Canadian Council of Ministers of the Environment, Winnipeg, pp: 1-6.
- Chapman, D., 1996. Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring. 2nd Edn., Chapman and Hall, London, UK.
- Dan'Azumi, S. and M.H. Bichi, 2010. Industrial pollution and heavy metals profile of Challawa River in Kano, Nigeria. *J. Appl. Sci. Environ. Sanitation*, 5(1): 23-29.
- Gabriel, O., O. Rita, A. Clifford, O. Cynthia, N. Harrison and O. Kennedy, 2006. Heavy metal pollution of fish of qua-Iboe river estuary: Possible implications for neurotoxicity. *Inte. J. Toxicol.*, 3(1): 42-56.
- Hsua, M.J., K. Selvarajb and G. Agoramoorthy, 2006. Taiwan's industrial heavy metal pollution threatens terrestrial biota. *Environ. Pollut.*, 143(2): 327-334.
- IITA (International Institute of Tropical Agriculture), 2001. Selected methods for soil and plant analysis. Manual Series No. 1, Ibadan, IITA, pp: 3-10.
- Ipeaiyeda, A.R. and P.C. Onianwa, 2009. Impact of brewery effluent on the water quality of Olosun River in Ibadan, Nigeria. *Chem. Ecol.*, 27(3): 189-204.
- Mombeshora, C., O. Osibanjo and S.O. Ajayi, 1983. Pollution studies on Nigerian rivers: The onset of lead pollution of surface waters in Ibadan. *Environ. Inter.*, 9(2): 81-84.
- NIS (Nigerian Industrial Standard), 2007. Nigerian Standard for Drinking Water Quality. NIS 554: 2007, ICS 13.060.20, Approved by the Standard Organization of Nigeria (SON) Governing Council, pp: 14-18.
- Okoronkwo, N. and O. Odeyemi, 1985. Effects of a sewage lagoon effluent on the water quality of receiving stream. *Environ. Pollut. Series A.*, 37: 71-86.
- Olatunji, A.S. and A.F. Abimbola, 2010. Geochemical evaluation of the Lagos lagoon sediments and water. *World Appl. Sci. J.*, 9(2): 178-193.
- Osibanjo, O., A.P. Daso and A.M. Gbadebo, 2011. The impact of industries on surface water quality of river Ona and river Alaro in Oluyole industrial estate, Ibadan, Nigeria. *Afr. J. Biotechnol.*, 10(4): 696-702.

- Peter, A.T. and T.B. Rodney, 2007. Pollution of a Tasmanian river by mine effluent I: Chemical evidence. *Inter. Rev. Hydrol.*, 58(6): 873-883.
- Shiklomanov, I.A. and J.C. Rodda, 2003. *World Water Resources at the Beginning of the 21st Century*. Cambridge University Press, United Kingdom.
- Shrestha, S. and F. Kazama, 2007. Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji River basin, Japan. *Environ. Model. Softw.*, 22: 464-475.
- Singh, K.P., A. Malik, D. Mohan and S. Sinha, 2004. Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India): A case study. *Water Res.*, 38: 3980-3992.
- Society for Analytical Chemistry, 1973. *Official Standardised and Recommended Methods of Analysis*. Analytical Methods Committee of the Society for Analytical Chemistry, London, pp: 327-409.
- Vega, M., R. Pardo, E. Barrado and L. Deban, 1998. Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis. *Water Res.*, 32: 3581-3592.
- Walkley, A. and I.A. Black, 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci.*, 37: 29-38.
- WHO (World Health Organization), 2011. *Guidelines for Drinking-Water Quality*. 4th Edn., NLM Classification: WA 675, World Health Organization, Geneva, Switzerland, pp: 307-433, ISBN: 978 924 1548151.
- World Bank, 1993. *World Development Report: Investment in Health*. Oxford University Press, New York.