WATER QUALITY ASSESSMENT OF RIVER NIGER AT ASABA/ ONITSHA AXIS, NIGERIA

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The concentrations of heavy metals and selected water quality parameters of River Niger at Asaba/Onitsha axis were investigated during both dry and wet seasons in order to assess the water quality of the river. For the physicochemical properties of the water samples, the mean values ranged from 7.13 to 8.15 for pH, 227 to 749/cm for electrical conductivity, 132 to 430 mg/L for total dissolved solids and 12.3 to 13.9 mg/L for total suspended solids. The other physicochemical properties were in the ranges of (mg/L) 101 to 144, 0.06 to 0.20, 1.16 to 1.46, 6.79 to 8.48, 13.02 to 21.37 and 19.4 to 32.68 for chloride, nitrates suphate, dissolved oxygen, biochemical oxygen demand and chemical oxygen demand, respectively. The metal levels ranged from (mg/L) 6.15 to 7.69 for Fe, 0.73 to 1.15 for Zn, 0.12 to 0.22 for Cu, 0.15 to 0.02 for Mn, 0.16 to 0.22 for Ni, 0.04 to 0.06 for Cr, 0.17 to 0.26 for V, and 0.04 to 0.08 for Pb. The t-test analysis of the results revealed that there are significant variations in the values obtained for dry and wet seasons. The dry season values showed generally higher level of pollution loads. Some of the physicochemical parameters and almost all the metals investigated, showed values above Standard Organization of Nigeria (SON) and world Health Organization (WHO) permissible standard values. The extremely high values obtained for water quality index computation confirms that the River Niger water at Asaba/Onitsha axis is very unsuitable for drinking purposes.

Key words: Water quality, River Niger, heavy metals, physicochemical properties, Asaba/Onitsha axis.

INTRODUCTION

Aquatic ecosystem is a complex environment endowed with provision of water, fish, food and other important requirements (Abeh et al., 2007). Since natural water is utilized for irrigation, recreational activities, drinking and other domestic purposes, the contamination of aquatic environment in any form is viewed with great concern.

Water is said to be polluted when there is alteration in its natural composition rendering it unfit for usage (Egereonu et al., 2012). Pollutants generally enter into river from anthropogenic sources resulting from urbanization and industrialization. Industrial effluents usually contain toxic chemicals and heavy metals, and may cause changes in quality of the river. These changes lead to increased dissolved nutrients causing eutrophication and addition of toxic substances which may have adverse effect on aquatic organisms. Heavy metals can not be biodegraded, so they accumulate gradually to toxicity level and eventually enter food chain resulting to risk of human health (Sanders, 1997).

River Niger is the largest river in West Africa and third largest in Africa after River Nile and River Congo. It is a trans-African link running through Mali, Niger, Benin and enters the Atlantic ocean through Nigeria (Nwajei et al., 2011). Pollution studies on River Niger have attracted attention of some researchers in recent times. Oboh and Edema (2007) investigated heavy metal levels in water and fishes from the upper reaches of the River at Yelwa-Yauri. Wangboje and Ikhuabe (2015), also determined the metal contents in fish and water from the river at Agenebode, Edo State. Other similar studies currently carried out at the lower reaches of the river were also limited or restricted to heavy metal levels in fishes, water or sediments (Nwajei, 2011; Olatunji and Osibanjo, 2011).

The objectives of this study were to

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investigate the physicochemical properties as well as the trace metals levels in the River Niger water at Asaba /Onitsha axis and to apply water quality index to assess the present pollution status and water quality of the river.

MATERIALS AND METHODS

Description of study area

Asaba which is located at the west bank of the River Niger, lies approximately between latitude 6°40' and 6°15' N and longitude 6°40' and 6°45' E. It is the administrative headquarter of Oshimili South Local Government Area, and also the capital of Delta State and these have led to high urbanization and presence of some small and medium scale industries which ultimately result in high generation and discharge of anthropogenic wastes into the river. The Amilimocha River from the hinterland discharges its pollution loads into the River Niger at Asaba town.

Onitsha which is a river port and an economic centre for industry and education, is densely populated city located at the eastern bank of the River. Its geographical coordinates are latitude 6°41'N and longitude 6°80'E. It has the largest market in Nigeria which leads to high urbanization. Presence of small and medium scale industries coupled with high urbanization generates a lot of anthropogenic wastes which are discharged either directly or indirectly into the river.

In addition, the Anambra River which passes through some Enugu State towns and some agricultural towns of Nkwele, Nsugbe, Otuocha and others in Anambra State, enter the River Niger near Onitsha discharging all the pollution loads into the river. The Niger bridge which links the eastern states to many other states through Asaba, experiences a lot of traffic activities leading to vehicular emissions. It is the suspicion of the possible pollution of the river at this axis that informed the choice of the study area. The map of the study area indicating sampling locations is shown in Figure 1.

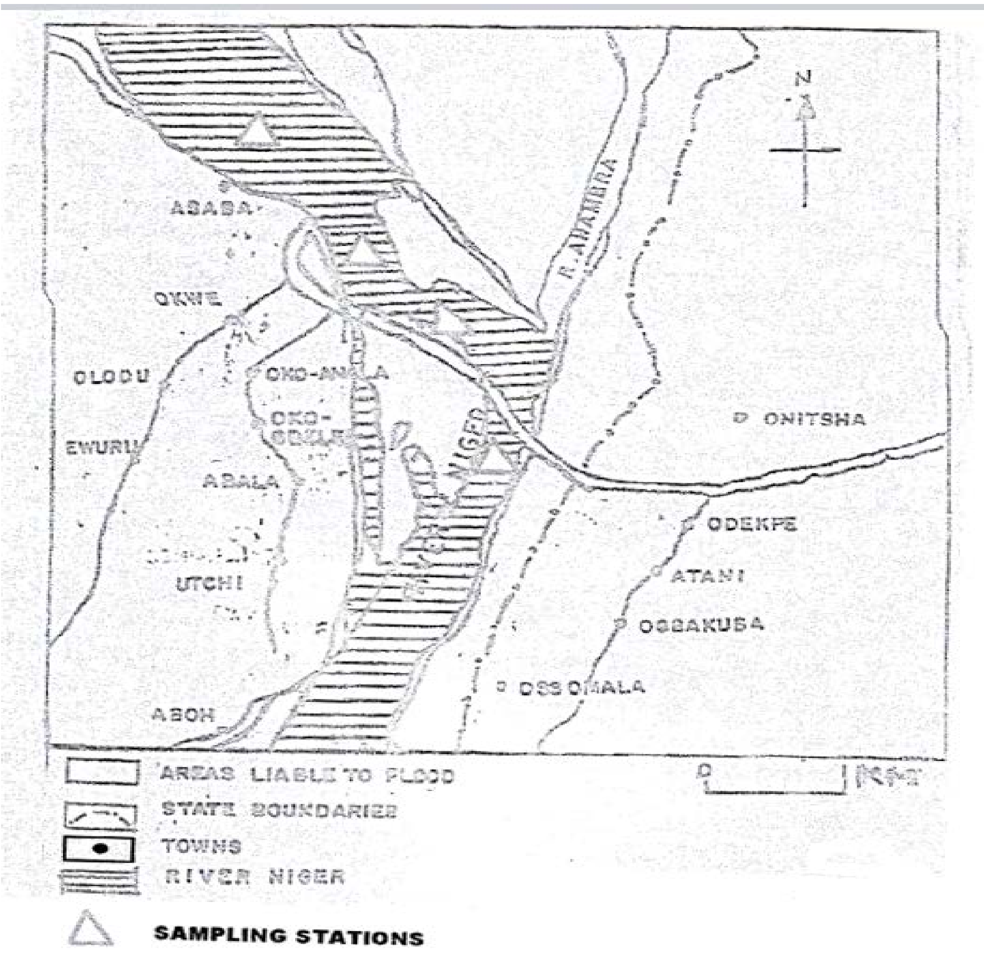

Figure 1. Map of the study area showing the sampling stations.

Sample collection and preparation

Water samples were collected into decontaminated 2 L plastic bottles with caps, from four different locations along the River Niger, two from Asaba axis and two from Onitsha axis, in November, December, January and in June, July, August, representing dry and wet seasons respectively. Control samples were also collected from Ilah at Asaba side and Nsugbe at Onitsha side. All the samples were stored in ice packed cooler for transportation to the laboratory where they were kept in a refrigerator preset at 4°C. For trace metal analysis, 100 cm^3 of each water sample was heated in a vacuum until the volume was reduced to 25 cm^3 before it was acidified with few drops of 2M HNO_3, and then kept for Atomic Absorption Spectroscopic analysis (Egereonu and Dike, 2007).

Sample analysis

Physicochemical parameters

Electrical conductivity and pH of the samples were determined at the collection sites prior to preservation. All the other physicochemical characteristics were determined in the laboratory using their specific standard methods (Franson, 1995; IITA, 1990; Vogel, 1989; Her Majesty's Stationery Office, 2000).

Trace metals

The trace metals were determined using Atomic Absorption Spectrophometer (Perkin Elmer Model A Analyst, 2002).

RESULTS AND DISCUSSION

The results of the physicochemical properties of the samples in both dry and wet seasons are presented in Tables 1 and 2 respectively, while their mean values for the entire study period are presented in Table 3.

The mean pH values of water samples during the study period ranged from 7.13 to 8.15. These values are in the same range with those reported by Krishnakumar et al. (2014). The range is within the pH value of 6.5 to 8.5 stipulated by the Standard Organization of Nigeria (SON) (2007) and World Health Organization (WHO) (2011). The range of the pH values of the water samples may be attributed to anthropogenic activities such as sewage disposal and discharge of some industrial effluents containing some alkaline compounds.

Table 1. Physicochemical properties of water samples during the dry season.

Variable	I	II	III	IV	CRT
pH	7.63±0.21	8.23±1.27	7.57±0.06	7.33±0.29	5.60±0.10
EC(μ/cm)	357±35.6	237±34.8	736±189	1151±490	17.0±1.00
TDS(mg/L)	204±20.3	135±19.9	419±108	656±279	9.69±0.57
TSS (mg/L	8.57±1.85	7.78±0.48	7.80±1.85	8.54±0.96	1.40±0.17
TS (mg/L)	212±19.1	143±19.8	427±107	730±3.62	11.1±0.67
CL^- (mg/L)	36.7±41.0	60.3±41.0	36.7±41.0	74.3±16.7	42.0±0.00
NO_3 (mg/L)	0.18±0.03	0.22±0.12	0.07±0.02	0.09±0.05	2.08±0.14
SO_4 (mg/L)	0.93±0.05	0.96±0.17	0.98±0.01	1.08±0.10	0.57±0.08
Total hardness (mg/L)	69.7±1.43	75.4±1 8.4	59.5±1.67	65.3±4.76	2.27±0.23
Turbidity (NTU)	129±2.52	104±7.37	109±2.00	117±2.08	1.48±0.32
Ca (mg/L)	21.8±3.67	16.9±3.83	10.2±1.61	14.7±2.27	1.69±0.16
Mg (mg/L)	47.8±2.27	58.5±15.8	49.4±0.86	48.9±3.52	0.57±0.07
Na (mg/L)	6.45±1.16	4.72±0.14	3.86±0.34	3.96±0.24	2.82±0.30
K (mg/L)	5.80±0.55	5.21±0.57	5.65±0.71	7.22±2.02	1.13±0.06
P (mg/L)	3.00±0.44	5.15±4.58	2.93±0.21	3.95±1.47	4.41±0.48
DO (mgfL)	25.90±2.59	28.39±1.63	29.10±4.07	32.14±4.00	10.7±3.09
BOD (mg/L)	7.37±41.9	6.14±50,2	7.39±53.5	7.61±5.53	1.11±0.61
COD (mg/L)	11.57±6.58	9.65±3.88	11.61±4.80	11.94±2.68	3.99±0.91

EC Electrical Conductivity, TDS Total Dissolve Solid, TSS Total Suspended Solid, TS Total Solid, Cl^- Chloride, NO_3^- Nitrate, SO_4^{2-} Sulphate, Ca Calcium, Mg Magnesium, Na Sodium, K Potassium, DO Dissolved Oxygen, BOD Biochemical Oxygen Demand, COD Chemical Oxygen Demand.

Table 2. Physicochemical properties of water samples during the wet season.

Variable	I	II	III	IV	CRT
pH	7.37±0.15	807±1.33	7.30±0MG	&97±0.29	5.30±0.10
EC(∫/em)	232±53.4	218±33.4	155±19.5	347±273	13.0±1.00
TDS(mg/L)	119±3.04	129±19.6	91.3±11.5	204±161	25.4±30.7
TSS (mg/L	17.4±1.71	16.7±11	18.0±1.93	19.3±1.19	3.86±0.66
TS (mg/L)	136±1.40	141±12.6	10±9.62	224±160	4.54±5.85
CL$^-$ (mg/L)	166±41.0	213±0.00	166±41.0	213±0.00	1.35±0.08
NO_3 (mg/L)	0.11±0.02	0.17±0.11	0.04±0.01	0.05±0.04	0.02±0.00
SO_4 (mg/L)	1.73±0.22	1.96±0.32	1.35±0.06	1.36±0.15	0.89±0.07
Total hardness (mg/L)	50.5±4.80	61.8±13.9	4-4.0±1.96	47.6±3.31	1.28±0J2
Turbidity (NTU)	272±3.06	84±19.4	244±3.87	243±9.00	8.00±0.36
Ca (mg/L)	16.0±6.05	11.2±2.89	6.41±0.80	10.7±2.81	0.87±0.11
Mg (mg/L)	34.5±1.2	50.6±12.0	54.2±29.1	36.9±2.70	0.41±0.08
Na (mg/L)	1.89±2.11	3.82±0.13	3.16±0.62	3.32±0.38	1.54±0.15
K (mg/L)	5.43±0.49	4.61±0.44	4.42±1.06	6.14±2.30	0.73±0,10
P (mg/L)	0.96±0.36	2.76±167	0.66±0.09	0.92±0.78	12.6±0.54
DO (mg/L)	71 .68±4.55	69.49±9.72	75.86±10.85	68.99±5.21	2.20±0.21
BOD (mg/L)	23.98±3.24	19.8±8.16	34.78±3.97	35.14±2.82	5.54±0.42
COD (mg/L)	36.45±4.93	30.24±12.4	52.87±6.03	53 .41±42.9	6.48±1.36

Table 3. Mean physicochemical properties of water samples in comparison with regulatory standards.

Variable	I	II	III	IV	CRT	SON (2007)	WHO (2011)
pH	7.50±0.22	8.15±1.17	7.43±0.15	7.13±0.34	5.45±0.19	6.5-8.5	6.5-8.5
EC(μ/cm)	294±29.7	227±32.2	445±340	749±566	15.0±2.37	1000	1,500
TDS(mg/L)	(161±48.1	132±18.0	255±192	430±321	17.5±21.2	500	500
TSS (mg/L	13.0±5.10	12.3±4.96	13.9±5.80	13.9±5.94	2.63±1.42	-	5
TS (mg/L)	174±43.2	142±14.9	268±187	426±350	7.82±5.17	-	500
Cl$^-$ (mg/L)	101±79.6	137±87.6	101±79.6	144±76.7	21.7±22.3	250	200
NO_3^- (mg/L)	0.15±0.04	0.20±0.11	0.06±0.02	0.07±0.04	0.05±37.8	-	50
SO_4^{2-} (mg/L)	1.33±0.46	1.46±0.59	1.16±0.2 1	L22±0. 19	0.73±0.19	100	200
Total hardness (mg/L)	60.1±11.0	68.6±16.4	5f±8.66	56.5±10.3	1.77±0.56	150	150
Turbidity (NTU)	200±78.4	194±99.5	177±741	180±68.9	4.74±3.58	-	5
Ca (mg/L)	18.9±5.49	14.1±4.34	8.30±2.36	12.7±3.18	1.28±0.47	-	100
Mg (mg/L)	41.2±7.48	54.6±13.3	5 1.8±18.6	42.9±7. 13	0.49±0.11	-	50
Na (mg/L)	4.17±2.93	4.27±0.51	3.51±0.59	3.64±0.45	2.18±0.73	200	200
K (mg/L)	5.62±0.5 1	4.91±0.56	5.04±1.05	6.68±2.03	0.93±0.23	-	10
P (mg/L)	1.98±1.17	3.95±3.92	1.80±1.25	2.44±1.97	8.48±4.48	-	-
DO (mg/L)	6.79±2.53	7. 94±2.33	8.48±2.66	8. 17±2.06	18.0±17.4	-	6
BOD (mg/L)	15.68±3.39	13.02±5.26	21.09±1.52	21.37±1.51	5.83±0.56	-	-
COD (mg/L)	24.01±1.39	19.94±1.13	32.24±2.29	32.68±2.28	4.69±1.03	-	-

The mean electrical conductivity of the water samples ranged from 227 to 749 µS/cm. This is consistent with the range of values reported by Badejo et al. (2013) but lower than the range reported by Krishnakumar et al. (2015). The conductivity values obtained in this study are significantly higher than those reported in other similar studies (Egereonu and Dike, 2007; Emoyan et al., 2006; Kaizer and Osakwe, 2010). WHO (2011) standard is 1,500 µS/cm while that of SON is 1000 µS/cm. High electrical conductivity value indicates enrichment of dissolved ion content in the River and could lead to osmotic effect, specific ion toxicity and unfitness of the river for irrigation (Emoyan et al., 2006).

The mean total dissolved solids (TDS) ranged from 132 to 430 mg/L. This is below the permissible limit of 500 mg/L of SON (2007) and WHO (2011). The values obtained in this study are in the same range with those reported by Egboh and Emeshili (2007). The values are lower than those reported by Krishnakumar et al. (2015) but higher than those reported by Kaizer and Osakwe (2010) and Olatunji and Osinbajo (2012). Total dissolved solids lead to an increase in water hardness and also an elevation of electrical conductivity of water. High TDS could be attributed to the influence of anthropogenic sources such as domestic sewage and agricultural activities.

The mean total suspended solids (TSS) in the water samples ranged from 12.3 to 13.9 mg/L. The values are higher than 5.0 mg/L WHO (2011) limit. Significant seasonal variation ($P< 0.05$) was observed in the levels of TSS in the water samples. The TSS values during the wet season were higher than in the dry season. This might be as a result of run-offs and flooding during the wet season in which suspended wastes and materials are deposited into the river. The TSS values obtained in this study are higher than those reported by Kaizer and Osakwe (2010), but lower than those reported by Emoyan et al. (2006). These levels of TSS recorded in this study are indicative of high anthropogenic activities in the areas.

The mean chloride (Cl^-) concentrations in the samples ranged from 101 to 144 mg/L. These values are significantly higher than those reported by Egereonu and Dike (2007) and Egboh and Emeshili (2007), but lower than those reported by Krishnakumar et al. (2015). The WHO (2011) permissible limit for chloride is 250 mg/L while that of SON (2007) is 200 mg/L. Chloride ion in water may be from domestic and municipal effluents (Sarth Prasanth *et al.*, 2012).

Mean nitrate (NO_3^-) values in the water samples ranged from 0.06 to 0.20 mg/L. These values are lower than the values reported in another related study (Kaizer and Osakwe, 2010). The values are lower than WHO (2011) standard of 50 mg/L. Compounds of nitrogen are the highest widespread contaminants and they originate from multipoint agricultural source (Pang *et al.*, 2013). Sources of nitrate include combustion engines and some natural processes such as thunderstorms and lightening (Rim-Rukeh and Irerhievwe, 2012).

Sulphate ion (SO_4^{2-}) ranged from 1.16 to 1.46 mg/L which is below both the SON (2007) and WHO (2011) permissible limits of 100 mg/L and 200 mg/L respectively. These values are less than those reported by Krishnakumar et al. (2015) but higher than those reported by Kaizer and Osakwe (2010). Above the allowable limit, sulphate in presence of excess magnesium in water may cause laxative effect on human (Krishnakumar *et al.*, 2015).

Mean turbidity of the water samples ranged from 188 to 200 NTU. There was significant ($P>0.05$) seasonal variations in the turbidity of the water samples. The higher values during the wet season in relation to dry season could be attributed to high natural erosion and run offs from the surroundings during the wet season.

Mean Dissolved Oxygen (DO) values ranged from 6.79 to 8.48 mg/L. The range of values obtained in this study is in good agreement with those reported in similar studies (Emoyan et al., 2006; Egereonu et al., 2012; Olatunji and Osibanjo, 2012). Egboh and Emeshili (2007) reported lower range of DO values in their study on River Ethiope, Nigeria. WHO permissible level is 6.0 mg/L. The low DO values obtained in this study could be as a result of high organic matter and nutrients discharged into the river as industrial, domestic and sewage effluents.

Biochemical Oxygen Demand (BOD) mean values ranged from 13.02 to 21.37 mg/L. Similar range of values was reported by Emoyan *et al.* (2006). The BOD values imply high concentration of biodegradable organic substances which might have resulted from unregulated industrial and domestic effluents discharged into the river. Mean values of Chemical Oxygen Demand (COD) ranged form 19.94 to 32.68 mg/L. This range of values is in conformity with that reported by Olatunji and Osibanjo (2012). The COD levels indicate that pollutant loads from runoffs and discharges contain high levels of both oxidizable organic and inorganic pollutants.

The mean values of calcium and magnesium ranged from (mg/L) 8.30 to 18.90 and 41.20 to 50.60 respectively. The WHO permissible values are 100 mg/L for calcium and 50 mg/L for magnesium. These metals are associated with hardness of water and they exist as bicarbonates, suphates or chlorides. High concentration of calcium in water causes encrustation and scaling rendering the water unfit for domestic purposes.

The mean values of sodium ranged from (mg/L) 3.51 to 4.27 while those of potassium ranged from 4.91 to 6.68. These values are lower than the WHO permissible values of 200mg/L for Na and 10 mg/L for K. Sodium has been reported to be present in most silicate weathering or dissolution of stored soil salts resulting form evaporation influences, anthropogenic activities and poor drainage system (Krishnakumar et al., 2015).

alcium, sodium and potassium mean values are below WHO permissible values which implies that their quantities in water are acceptable.

Concentrations of heavy metals in water samples

The concentrations of metals in water in both dry and wet seasons are presented in Tables 4 and 5 respectively while their mean concentration for the entire study period are presented in Table 6.

Table 4. Heavy metal concentrations (mg/L) in a water samples during the dry season.

Site	I	II	III	IV	CTR
Fe	9.03±0.99 (7.89-9.66)	8.21±0.59 (7.86-8.89)	7.10±0.50 (6.78-7.67)	7.36±1,02 (6.73-8.54)	1.24±0.07 (1.17-1.30)
Zn	2.25±0.22 (2.04-2.48)	1.83±0.15 (1.68-1.98)	1.84±0.26 (1.59-2.10)	1.43±0,29 (1.18-1.74)	0.57±0.10 (0.47-0.66)
Cu	0.29±0.02 (0.27-0.31)	0.27±0.06 (0.23-0.33)	0.15±0.02 (0.13-0.17)	0.24±0.03 (0.21-0.27)	0.05±0.01 (0.04-0.05)
Mn	0.20±0.03 (0.18-0.23)	0.25±0.05 (0.21-0.31)	0.21±0.02 (0.19-0.22)	0.19±0.02 (0.17-0.21)	0.02±0.00 (0.02-0.02)
Ni	0.30±0.05 (0.26-0.35)	0.30±0.08 (0.24-0.39)	0.26±0.03 (0.23-0.29)	0.22±0.04 (0.17-0.21)	0.01±0.01 (0.01-0.02)
Cr	0.07±0.01 (0.06-0.08)	0.05±0.02 (0.04-0.07)	0.07±0.01 (0.06-0.08)	0.05±0.01 (0.04-0.05)	ND ND
V	0.26±0.04 (0.22-0. 29)	0.24±0.01 (0.23 -0.25)	0.20±0.01 (0.19-0.21)	0.18±0.01 (0.17-0.19)	ND ND
Pb	0.04±0.01 (0.03 -0. 05)	0.08±0.04 (0.05-0.12)	0.05±0.01 (0 05-0.06)	0.04±0.01 (0.04-0.05)	ND ND

The mean concentrations of Fe ranged from 6.15 mg/L to 7.69 mg/L. The concentrations of Fe observed in this study were higher than the permissible values of 0.3 and 0.03mg/L set by SON (2007) and WHO (2011) respectively. The concentrations of Fe obtained in this study are greater than those reported in some other similar studies (Owamah, 2013; Hong *et al.,* 2014). High levels of iron could be attributed to seapage of iron from ferratic soil into the river and also through run offs.

Zinc (Zn)

The mean concentrations of Zn in the water samples ranged from 0.73 to 1.15mg/L in all locations. These values are similar to those reported for River Ethiope (Kaizer and Osakwe, 2010) and River Benue at Yola (Hong et al., 2014), but higher than those reported by Farombi et al. (2014) for River Osun and Onojake et al. (2015) for Bonny/New Calabar Rivers. Higher concentrations of Zn in water from different rivers have also been reported in literatures. The concentrations of Zn obtained in this study are below the standard values of 3.0 and 5.0mg/L set by SON (2007) and WHO (2011) respectively. Zinc is a component of paint and during the wet seasons, rain usually

Table 5. Heavy metal concentrations (mg/L) in a water samples during the wet season.

Site	I	II	III	IV	CTR
Fe	6.36±0.40 (5.95-6.74)	5.94±0.07 (5.90-6.02)	5.36±0.45 (4.97-5.86)	4.94±0.15 (4.78-5.08)	0.58±0.05 (0.54-0.64)
Zn	0.05±0.02 (0.04-0.07)	0.05±0.01 (0.04-0.06)	0.06±0.02 (0.05-0.08)	0.04±0.01 (0.03-0.05)	0.18±0.03 (0.15-0.21)
Cu	0.15±0.04 (0.11-0.18)	0.14±0.06 (0.11-0.21)	0.09±0.02 (0.07-0.10)	0.09±0.01 (0.08-0.09)	0.02±0.01 (0.01-0.02)
Mn	0.12±0.01 (0.11-0.12)	0.14±0.03 (0.12-0.18)	0.12±0.01 (0.11-0.12)	0.11±0.01 (0.10-0.12)	ND ND
Ni	0.14±0.05 (0.1-0.19)	0.15±0.04 (0.11-0.18)	0.13±0.02 (0.11-0.14)	0.10±0.02 (0.08-0.12)	ND ND
Cr	0.04±0.01 (0.03-0.05)	0.03±0.01 (0.03-0.04)	0.04±0.01 (0.03-0.04)	0.03±0.01 (0.02-0.03)	ND ND
V	0.03±0.01 (0.02-0.04)	0.07±0.03 (0.04-0.10)	0.04±0.01 (0.03-0.04)	0.03±0.01 (0.03-0.04)	ND ND
Pb	0.25±0.03 (0.22-0.28)	0.23±0.03 (0.20-0.25)	0.18±0.01 (0.17-0.19)	0.16±0.01 (0.15-0.17)	ND ND

Table 6. Mean concentrations of metals (mg/L) water samples compared with standard va1ues.

Site	I	II	III	IV	CTR	SON (2007)	WHO (2011)
Fe	7.69±1.61 (5.95-9.66)	7.08±130 (5.90-8.89)	6.23±1.04 (4.97-T67)	6.15±148 (4.78-8.54)	0.91±0.37 (0.54-L30)	0.3	0.03
Zn	1.15±1.21 (0.04-2.48)	0.94±0.98 (0.04-1.98)	0.95±0.99 (0.05-2.10)	0.73±0.78 (0.03-1.74)	0.38±022 (0.15-0.66)	3.0	5.0
Cu	0.22±0.08 (0.11-0.31)	0.21±0.08 (0.11-0.33)	0.12±0.04 (0.07-0.17)	0.17±0.09 (0.08-0.27)	0.03±0.02 (0.01-0.05)	1.0	0.05
Mn	0.16±0.05 (0.11-0.23)	0.20±0.07 (0.12-0.31)	0.16±0.05 (0.11-0.22)	0.15±0.04 (0.10-0.21)	0.02±0.00 (0.02-0.02)	0.2	0.05
Ni	0.22±0.10 (0.10-0.35)	0.22±0.10 (0.11-0.39)	0.20±0.08 (0.11-0.29)	0.16±0.07 (0.08-0.25)	0.01±0.01 (0.01-0.02)	0.02	0.05
Cr	0.06±0.02 (0.38-0.08)	0.04±0.02 (0.03 -0.07)	0.05±0.02 (0.03-0.08)	0.04±0.01 (0.02-0.05)	ND ND	0.05	0.05
V	0.26±0.03 (0.22-0.09)	0.24±0.02 (0.20-0.25)	0.19±0.02 (0.17-0.21)	0.17±0.02 (0.15-0.19)	ND ND	0.01	0.01
Pb	0.04±0.01 (0.02-0.05)	0.08±0.03 (004-0. 12)	0.05±0.01 (0.03-0.06)	0.04±0.01 (0.03-0.05)	ND ND	-	-

washes away some paints from buildings and other painted structures, and they are discharged through runoffs into the river.

Copper (Cu)
The mean concentrations of Cu in the water samples in all locations ranged from 0.12 to 0.22 mg/L. The observed mean values of Cu in this study are similar to those reported by Wagbonje and Ikhuabe (2015) but lower than those reported by Olatunji and Osinbajo (2012), Owamah (2013), Akaahan et al. (2015) and Onojake et al. (2015). Lower concentrations of Cu have also been reported in literature (Farombi et al., 2014). The concentrations of Cu in this study are below the SON (2007) standard value of 1.0 mg/L but above WHO (2011) standard value of 0.005mg/L in water. Waste oil and electrical components such as wires disposed into the river could be source of copper in the river.

Manganese (Mn)
The mean concentrations of Mn in the water samples ranged from 0.15 to 0.20 mg/L. These values are greater than those reported by Kaizer and Osakwe (2010) for different rivers but lower than those reported by Olatunji and Osibanjo (2012). The concentrations of Mn in these samples are comparable to the SON (2007) standard values of 0.20mg/L but are however higher than the WHO (2011) standard value of 0.05 mg/L.

Nickel (Ni)
The mean concentrations of Ni in the water samples ranged from 0.16 to 0.22mg/L. These concentrations are similar to others reported in literature (Akaahan et al., 2015; Onojake et al., 2015). However, Farombi et al. (2014) reported lower concentrations of Ni while Olatunji and Osibanjo (2012) and Owamah (2013) reported higher concentrations of Cu in river waters. The SON (2007) and WHO (2011) standard values for Ni in water are 0.02 and 0.05 mg/L respectively. The mean concentrations of Ni obtained in these water samples are greater than the SON (2007) and WHO (2011) standard values. Nickel level could be due to emissions from fossil fuel, and also industrial effluents.

Chromium (Cr)
The mean concentrations of Cr in these water samples ranged from 0.04 to 0.06 mg/L. Similar concentrations were reported by Hong et al. (2014) while lower concentrations were reported by Kaizer and Osakwe (2010). Higher concentrations of Cr in water from rivers have also been reported (Olatunji and Osibajno, 2012; Owamah, 2013; Akaahan et al., 2015; Onojake et al., 2015). The concentrations of Cr observed at location IV was higher than the SON (2007) and WHO (2011) permissible value of 0.05 mg/L. Possible sources of Cr in the river are water erosion of rocks, power plants, liquid fuel as well as industrial and municipal wastes discharged into the river directly or indirectly.

Vanadium (V)
The mean concentrations of V in the water samples in this study ranged from 0.17 to 0.26

Lead (Pb)
The concentrations of Pb in the water samples ranged from 0.04 to 0.08 mg/L. These are in agreement with values reported by others in literature (Hong et al., 2014). Owamah (2013) and Onojake et al. (2015) reported higher concentrations of Pb in river waters than those obtained in this study. However, these concentrations are higher than those reported by Kaizer and Osakwe (2010), Olatunji and Osinbajo (2012) and Wagboje and Ikhuabe (2015). The permissible value of Pb in water is 0.01 mg/L (SON, 2007 and WHO 2011). Vehicular emissions from outboard engines and motor vehicles are possible sources of Pb in the river.

T-test analysis of the results of the physicochemical and metal levels of the water samples
The values of the physicochemical properties and metal levels of water in both dry and wet seasons were compared using the t-test statistical tool and the summaries of the analysis are presented on Tables 7, and 8 respectively. The t-test analysis showed that there are significant seasonal variations in the levels of all the parameters studied. These significant differences may be attributed to decrease in water volume as a result of evaporation during the dry season or as a result of dilution due to increase in water volume during the wet season.

Table 7. Summary of t-test analysis of physicochemical properties in the water samples.

Parameter	Mean dry season	Mean wet season	t-cat	t- crit	P-value	Decision
pH	7.69	7.41	5.745	2.35	0.010477	Significant
EC(μ/cm)	620	238	2.054	2.35	0.006123	Significant
TDS(mg/L)	353	135	2.096	235	0.003495	Significant
TSS (mg/L	8.17	17.8	21.17	235	0.000115	Significant
TS (mg/L)	377	153	1.95	2.35	0.003028	Significant
CL^- (mg/L)	52	189	24.54	2.35	0.000074	Significant
NO_3 (mg/L)	0.14	0.09	6.13	2.35	0.004352	Significant
SO_4 (mg/L)	0.99	1.60	3.55	2.35	0.018980	Significant
Total hardness (mg/L)	67.5	51.0	13.71	2.35	0.000420	Significant
Turbidity (NTU)	115	261	12.23	2.35	0.000589	Significant
Ca (mg/L)	15.9	11.1	9.07	2.35	0.001413	Significant
Mg (mg/L)	51.2	441	1.72	2.35	0.002338	Significant
Na (mg/L)	4.75	3.04	1.78	2.35	0.006242	Significant
K (mg/L)	5.97	5.15	4,05	2.35	0.013552	Significant
P (mg/L)	3.76	1.32	11.39	2.35	0.000726	Significant
DO (mgfL)	28.88	71.50	18.62	2,35	0.000169	Significant
BOD (mg/L)	7.13	28.45	5.93	2.35	0.004781	Significant
COD (mg/	11.19	43.24	5.88	2.35	0.004900	Significant

Table 8. Summary of t-test analysis of metals in the water samples.

Metals (mg/L)	Mean dry season	Mean wet season	t-cal	t-crit	p-value	Decision
Fe	7.93	5.65	11.45	2.35	0.000716	Significant
Zn	1.84	0.05	10.86	2.35	0.000836	Significant
Cu	0.24	0.12	5.91	2.35	0.004860	Significant
Mn	0.21	0.12	11.47	2.35	0.000712	Significant
Ni	0.27	0.13	13.55	2.35	0.000435	Significant
Cr	0.06	0.03	7.52	2.35	0.002438	Significant
V	0.22	0.04	9.70	2.35	0.001163	Significant
Pb	0.06	0.20	6.70	2.35	0.003387	Significant

Analysis of variance (ANOVA)

The results obtained for both the physicochemical properties and metal levels were also subjected to analysis of variance, and they are presented on Tables 9, 10, 11 and 12. The analysis of variance shows that there was no significant difference in the parameters studied in the four locations. This may be due to the similar anthropogenic activities taking place in the locations studied.

Table 9. ANOVA results for physicochemical properties of water during the dry season.

Source of variation	Sum of squares	Degree of freedom	Mean of squares	F	p-value	f-Crit
Between groups	2658033	3	88601			
Within groups	35182387	76	4629261	0.19139	0.90195	2.72494
Total	35448190	79	-			

Table 10. ANOVA results for physicochemical properties of water during the wet season.

Source of variation	Sum of squares	Degree of freedom	Mean of squares	F	p-value	f-Crit
Between groups	647536.1	3	215845.4			
Within groups	2.68E+08	76		0.061176	0.980051	2.724944
Total	2.69E+08	79	3528266			

Table11. ANOVA result for metal concentrations in water during the dry season.

Source of variation	Sum of squares	Degree of freedom	Mean of squares	F	p-value	f-Crit
Between groups	0.613437	3	0.204479	0.027365	0.99375	2.946685
Within groups	209.2261	28	7.472362			
Total	209.8396	31				

Table 12. ANOVA result for metal concentrations in water during the wet season.

Source of variation	Sum of squares	Degree of freedom	Mean of squares	F	p-value	f-Crit
Between groups	0.203109	3	0.067703			
Within groups	108.9305	28	3.890373	0.017403	0.996799	2.946685
Total	109.13368	31	-			

Table 13. Water quality index categorization.

Range	Types of water
< 50	Excellent water
50-100	Good water
100-200	Poor water
200-300	Very poor water
> 300	Water unsuitable for drinking

Source: WHO (2011).

Water quality index (WQI) of the water samples

WQI is very important for evaluating the water quality and its suitability for drinking purposes (SubbaRao, 2006; Magesh et al., 2013). It is a device for rating the influence of individual water quality parameters on the overall water quality (Mitra and ASABE member, 1998). The WQI of the water samples was evaluated using the equation as defined by WHO (2011).

$$WQI = \frac{\sum Q_i W_i}{\sum W_i}$$

Where:

Q_i = Quality rating of each parameter =

$$\frac{V_{actual} - V_{ideal}}{V_{standard} - V_{ideal}} \times 100$$

V_{actual} = Actual value of the water quality parameter obtained from laboratory analysis

V_{ideal} = Ideal value of that water quality parameter and it can be obtained from the standard Table.

Videal for pH = 7 and for other parameter, it is equal to zero

$V_{standard}$ = Recommended WHO standard of the water quality parameters

Wi = Unit weight – $^1/S_i$

Si = Standard permissible value for nth parameter

Qi = Quality rating of n^{th} parameters for n water quality parameters.

WQI values were classified into five categories as shown in Table 13.

The WQI of the study using the average values of the four locations are presented in Tables 14 and 15 respectively. The WQI values of the water samples from the study areas during the dry and wet seasons were 4515 and 3209 respectively. These values are far above the water quality index category of 300 indicating that the River Niger water at Asaba/Onitsha axis is very unsuitable for drinking.

CONCLUSION

The results from this study show that for physicochemical properties, the values were generally higher during the dry season than during the wet season. All the metal concentrations were also higher in the dry season than during the wet season except for Pb. The higher level of Pb in the wet season implies inputs from runoffs. These results generally revealed that the dry season months recorded higher levels of pollution loads. Almost all the metal levels are above the WHO and SON guideline values except for Zn and Cr. Some physicochemical parameters values exceeded the

Table 14. Water quality index of water samples during the dry season.

Variable	Observed values	Standard values (Sn)	Unit Weight (Wn)	Quality rating (Qn)	WuQu
pH	7.7	8.5	0.1176	46.1	5.42
EC	620.0	250	0.004	248	0.99
TDS	353.4	500	0.002	70.7	0.14
TSS	82	5	0.2	163.45	32.69
TS	377.9	500	0.002	75.59	0.15
Cl	52.0	200	0.005	26	0.13
NO_3	0.1	50	0.02	0.28	0.01
SO_4	10	200	0.005	0.49	0.00
Total hardness	67.5	150	0.0067	44.98	0.30
Turbidity	114.7	5	0.2	2293.33	458.67
Ca	15.9	100	0.01	1591	0.16
Mg	5L2	50	0.02	102.31	2.05
Na	4.7	200	0.005	2.37	0.01
K	6.0	10	0.1	59.72	5.97
Fe	7926	0.03	33.3	26419	880648
Zn	1.8375	5	0.2	36.75	7.35
Cu	0.2375	0,05	20	475	9500
Mn	0.2125	0.05	20	425	8500
Ni	0.27	0.05	20	540	10800
Cr	0.06	0,05	20	120	2400
Pb	0.055	0.01	100	550	55000

Wn =214; WnQn = 967363; WQI=4515.

Table 15. Water quality index of water samples during the wet season.

Variable	Observed values	Standard values (Sn)	Unit weight (Wn)	Quality rating (Qn)	WuQu
pH	7.42	8.5	0.1176	27.8	3.27
EC	237.75	250	0.004	95.1	0.38
TDS	135.72	500	0.002	27.1	0.05
TSS	17.83	5	0.2	356.65	71.33
TS	152.63	500	0.002	30.53	0.06
Cl	189.33	200	0.005	94.7	0.47
NO_3	0.09	50	0.02	0.19	0.00
SO_4	1.60	200	0.005	0.80	0.00
Total hardness	50.99	150	0.0067	33.99	0.23
Turbidity	260.56	5	0.2	5211	1042
Ca	11.09	100	0.01	11.09	0.11
Mg	44.05	50	0.02	88.10	1.76
Na	3.04	200	0.005	1.52	0.01
K	5.15	10	0.1	51.50	5.15
Fe	5.651	0.03	33.3	18836	627870
Zn	0.05	5	0.2	1	0.20
Cu	0.12	0.05	20	232	4633
Mn	0.121	0.05	20	242	4833
Ni	0.13	0.05	20	258	5167
Cr	0.034	0.05	20	68	1367
Pb	0.0425	0.01	100	425	42500

Wn = 214; WnQn= 687497; WQI =3209.

recommended guideline values while some others showed compliance. On the whole, the extremely high values of Water Quality Index for both seasons confirm that the River Niger water at Asaba/Onitsha axis is very unsuitable for drinking purposes.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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