

Seasonal Variation of Physicochemical Parameters of Water and Sediments from Iko River, Nigeria

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Abstract :

The seasonal and locational variation of physicochemical parameters viz, p H, dissolved oxygen, biochemical oxygen demand, conductivity, salinity, chloride, sulphate, nitrate, ammonium ion, total nitrogen, total organic carbon, total hydrocarbon and exchangeable cations, in water and sediments of Iko River, South Eastern Nigeria were investigated. The import of this investigation is that Iko River, is in Iko Petroleum Belt of the Niger Delta that has suffered from years of intense petroleum exploitation, recent cases of oil bunkering in the area and moreso, its closeness to the Atlantic Ocean. In both dry and wet seasons considered, the variation of p H was not significant, and was within the WHO limit of 6.5 to 8.0 for an unpolluted streams and rivers, while the salinity, chloride and exchangeable cations, were above WHO limits, indicating a high degree of saline water intrusion and influence in the water chemistry of the river from the Atlantic Ocean. The sediment of the river had acidic characteristics and were predominantly of medium to fine grained sand (> 70 %) and less of silt (< 15 %) and clay (< 10 %), indicating that Iko River is not an important sink for heavy metal and organic pollutants, implying that in a case of accidental discharge of chemical pollutants, will stay in the water column a longer time, thus accessible to the biota. Interestingly, the total hydrocarbon content of the sediments were greater than 200 mg/kg, the levels set for an area that is heavily polluted with petroleum. Based on the physicochemical parameters of the water, the pollution index determined for the wet season gave a value of 0.97, which is less than a value of 1 for an unpolluted surface water body, but gave a pollution index of 1.34 during the dry season, which could be attributed to dilution from the surface runoff. The variation of the dissolved oxygen was not significant in both seasons and were higher than 5.0 mg/l WHO limit for surface waters, and indicated a highly oxidized environment. The phosphate content of the sediment of the river was lower in both seasons than average for soils, whereas, total nitrogen, total organic carbon and sulphur contents were higher than average for soils.

Keywords: Iko River, Sediments, Water, Physicochemical Parameters, Seasonal Variation, Pollution Index

1. Introduction

Iko River had been an area of intense petroleum extraction activities since 1973 by Shell Petroleum Development Company Nigeria Limited, in what was referred to as the Utapete Operational Zone (Ansa, 1998). Though, the oil exploration activities had been discontinued few years back, had created social, economic and environmental dislocations within the host communities and water bodies within the area.

One of the most negative activities in Iko is the phenomenon of acid rain. The resulting high levels of acidity in the environment manifest as severe corrosion of roof sheets on houses in Iko, skin irritation, poor agricultural soils, destruction and reduction of fish life and fisheries production of the waters, deterioration of the quality of surface and ground waters (Mobil, 1997; FIMSCO, 2002).

Iko River in Eastern Obolo Local Government Area, is located within the petroleum belt of the Niger Delta, thus rivers in this area are exposed to additional risk of pollution from petroleum and related sources. Iko River takes its rise from the Qua Iboe River catchment and drains directly into the Atlantic Ocean at the Bight of Bonny. The devastation in the area is also aggravated by the direct influence of seawater and the inward driving wind from the Atlantic Ocean due to its closeness.

There has been a reported case of diurnal and seasonal changes in water temperature, p H, dissolved oxygen and conductivity of the water system in Iko River (Ekpe et al, 1995). The river is of high economic and ecological importance, as it supports the livelihood of a large number of artisanal fishermen.

Iko River runs through both mangrove and fresh water swamps with adjoining creeks and tributaries, with communities settling all along the river. Therefore, whatever environmental changes taking place in the river will affect the hydrology of the surrounding creeks and tributaries (Imevbore, 1970; Egereonu et al, 2012).

In a study of the basic ecological features of the different sectors of the mangrove and fresh water swamp forest of Nigeria, it was shown that the ecological equilibrium is very delicate (Enyenihi et al, 1987). These effects are bound to influence the overall high productivity of the environment (The World Bank, 1995).

Of recent, there are reported cases of oil bunkering and establishment of local refineries in Iko area, with indiscriminate dumping of petroleum residues, seepages and spillages in Iko River. The deleterious effect of these activities in the ecosystem is enormous and calls for concern.

The need to protect the environment as a prerequisite for preserving the quality of life has been emphasized in 1984 by a report initiated by the South African Committee for Oceanographic Research which established water quality criteria (WQI, 1991). The report defined these as “a scientific yardsticks upon which a decision or judgement may be made concerning the ability of water of a given quality to support a designated beneficial use”. Beneficial uses include preservation of ecosystem, direct contact recreation, migration of aquatic life and mineral recovery.

In the general framework of the global environmental problems, and the large store of background data about the deteriorating environment, this study is initiated to monitor the spatial and seasonal distribution of petroleum hydrocarbon pollutants and interactive effects on water quality parameters in the water and sediments of Iko River. Therefore, the acquisition of accurate data on the concentration and distribution of pollutants in the coastal water and sediments of Iko River is essential in understanding the geochemical and biogeochemical cycles of the elements and to deduce the extent to which the equilibrium of the river ecosystem has been disturbed.

2. The Study Area

Iko River in Eastern Obolo Local Government Area of Akwa Ibom State, Nigeria, is located within the petroleum belt of the Niger Delta, Nigeria (Fig. 1). Iko River is located in the Eastern part of the Niger Delta between latitude $4^{\circ}30' N$ and $4^{\circ}45' N$ and longitude $7^{\circ}35' E$ and $7^{\circ}40' E$. The river has a shadow depth ranging from 1.0 metre to 7.0 metres at flood and ebb tide and an average width of 16 metres.

Iko River takes its rise from the Qua Iboe River catchment and drains directly into the Atlantic Ocean at the Bight of Bonny (Ekpe et al, 1995). Iko River has many adjoining tributaries and creeks, and part of it also drains into Imo River estuary, which opens into the Atlantic Ocean at the Bight of Bonny.

The shore line of Iko River is characterized by soft –dark mud flats, usually exposed during low tide, mangrove swamps with mangrove trees, shoals and sand bars. The river has semi-diurnal tides and has a length of more than 30 km.

The climate of the area is characterized by distinct wet and dry seasons. The wet season begins in April and lasts till November, while the dry season begins in November till March. A short period of draught is usually experienced in July and August, while a period of harmattan characterized by cold dry winds and lower temperatures normally occurs between December and February (Moses, 1979; Enemugwem, 2009).

Iko area is characterized by a humid tropical climate with rainfall reaching about 3000 mm per annum. The mean annual daily evaporation of the area is 4.6 mm per day (Edet and Ntekim, 1996). The hydrology of Iko River is affected by tides, although seasonal influences which are related to the climatic regime, are evident. Iko River is directly influenced by processes in the Atlantic coastal waters (Ekpe et al, 1995).

Sediments in Iko River become well sorted, composed of mainly coarse quartz sand, shell debris, faecal pellets, silts and clay (Ekwere et al, 1992). This assortment of sediments when trapped within the luxuriant mangrove prop roots and impregnated with decaying mangrove leaves and branches constitutes mud flats, with characteristic feature of Iko River shorelines.

3. Materials and Methods.

Iko River was divided into ten sampling stations for water and sediment sampling. The sampling stations were so selected to be close to an abandoned oil well or close to an old oil pipeline (Fig. 1). At each sampling point, water sample was collected in polyethylene bottles at a depth of 30 cm below the surface, while sediment sample was taken by Van Veen grab sampler (Loring and Rantala, 1992).

The sampling were undertaken in dry season months of November and December, 2011, January and February, 2012 and wet season months of June, July, August and September, 2012.

Some parameters that deteriorate on storage were determined at the sampling locations like temperature, pH, dissolved oxygen, conductivity, salinity, redox potential using multicombi meter. Water and sediment samples were stored in iced coolers before being transported to the laboratory for the determination of other parameters.

Sediment samples were air dried and used for grain size analysis by the method of Fork (1994). Fresh sediment samples were used for the determination of pH, conductivity, salinity and redox potential of sediments in a 1:1 volume suspension in water.

Acidity and chloride content of the water samples were determined by appropriate titrimetric techniques (Egereonu et al, 2012), while dissolved oxygen and five-day biochemical oxygen demand (BOD_5) were determined electroanalytically by dissolved oxygen meter (Uzoukwu et al, 2005). Sulphate, nitrate and nitrite were determined spectrophotometrically by standard methods (APHA, AWWA, WPCF, 2005).

Chemical oxygen demand , total hydrocarbon , calcium , magnesium , sodium and potassium in water were determined by appropriate standard methods (APHA, AWWA WPCF, 2005).

Total carbon content of the sediments was determined on the finely ground sediment samples by Leco Elemental analyser (CHN 1000), with EDTA as the calibration standard. Total organic carbon was determined by the Walkey-Black method as adopted and modified (Rump and Krist, 1988). Total inorganic carbon was determined by the difference between total carbon and total organic carbon (Loring and Rantala, 1992).

Total hydrocarbon content of the sediments was determined by the methods of IOC , 1982 and ROMPE, 1983. The exchangeable bases Calcium , Magnesium ,sodium and potassium were determined in the sediments by the modified method of Rump and Krist (1988), while exchangeable acidity was determined by extraction with 1 M KCl solution and titrimetry with 0.01 M NaOH (APHA, AWWA, WPCF, 2005).

Effective cation exchange capacity (ECEC) of the sediments was determined by the summation of exchangeable bases and acidity (IITA, 1979), while base saturation was determined for the sediments by calculation ,

$\% \text{ Base Saturation} = \text{Exchangeable Bases} / \text{ECEC} * 100.$

4. Results and Discussion

The mean monthly variation of physicochemical parameters of water from Iko River is presented in Table 1, while the monthly variation of physicochemical parameters of sediments from Iko River is presented in Table 2. The mean seasonal variation in physicochemical parameters is presented in Table 3, while the mean seasonal variation of physicochemical variation in sediments is presented in Table 4.

Temperature of the water from Iko River gave mean values of 24.5 o C during the dry season and 24.08 o C during the wet season, as compared to the WHO limit of 25 o C for surface waters. (Table 6). Conductivity of the water gave values of 76.2 m S/cm and 57.5 m S/cm during the dry and wet seasons respectively, compared to the WHO limit of 50 m S/cm. p H of the water in both seasons were within the WHO limit of 6.5 – 8.5.

Dissolved oxygen of the water gave values of 7.98 mg/l and 6.01 mg/l for the dry and wet seasons respectively, compared to the WHO limit of 5 .0 mg/l for surface waters. Thus, the values indicated an oxidized environment. The total hydrocarbon gave values of 44.1 mg/l and 35.59 mg/l during the dry and wet seasons respectively, compared to WHO limit of 50 mg/l in surface waters (Fig. 6).

The mean concentration of Ca, Mg , Na and K were 15.21 mg/l, 885.5 mg/l, 1580 mg/l , and 294.7 mg/l during the dry season and 13.97 mg/l , 612.7 mg/l , 824.5 mg/l and 178.1 mg/l during the dry season (Table 6). The values for Ca, Mg and K , were higher than the WHO limit of 250 mg/l. The high values of magnesium and sodium could be attributed to contributions from the saline water from the Atlantic ocean. High sodium content in water causes active corrosion on metal substrates (Egereonu et al, 2012).

The concentrations of sulphate, nitrate, nitrite, chloride and ammonium ions in the water were 255.9 mg/l, 2.50 mg/l, 0.18 mg/l , 441.1 mg/l , 0.11 mg/l respectively during the dry season and 184.3 mg/l, 1.91 mg/l , 0.42 mg/l , 410.3 mg/l , 0.17 mg/l respectively during the wet season. Sulphate was higher than WHO limit of 250 mg/l during the dry season , while chloride was higher than WHO limit of 250 mg/l in both seasons (Table 6). The high chloride concentration in both seasons could be attributed to influence of saline water from the Atlantic ocean, with high salinity value.

Based on the physicochemical parameters of the water, the pollution index determined for the wet season gave a value of 0.97, which is less than a value of 1 for an unpolluted surface water body, but gave a pollution index of 1.34 during the dry season (Table 6). The polluted index of the water for dry season was more than 1 for an unpolluted surface water body. However, the lower polluted index for wet season could be attributed to dilution from the surface runoff.

The particle size distribution of the sediments of Iko River gave 78.22 % sand , 9.45 % clay and 12.32 % silt during the dry season , while the results gave 74.36 % sand, 10.46 % clay and 15.13 % silt during the wet season (Fig.11 and Table 7). The predominance of sand in the sediments is in agreement with the observation by Ekwere et al . (1992), that in the sediments of the Bight of Bonny , which is in the eastern flank of the Niger Delta, sand and sandy silt are predominant by the classification of Folk (1974). They observed that the strong tides and long shore drift tend to influence the distribution pattern of the sediment fractions.

The low content of clayey materials which are known to be good scavengers for metallic and organic contaminants indicates that Iko River sediments are not likely to be important sinks for metallic pollutants entering the water body. This implies that the absence of a sediment sink (low clay) will enhance the pollutants remaining mostly in suspension or in solution in the river. And of course, increasing the lifetime of the pollutants in the water column obviously increases their accessibility to the biota.

The total organic carbon content of the sediments in both seasons were higher than an optimum value of 1.3 % , indicating a relatively high content of organic matter in the sediments. This may be due to the diversified sources of organic matter in Iko River sediments , which are marine sediments and could have been derived from decomposition of marine organisms , terrestrial inputs from surface discharge and oil spillages from bunkering

activities (Demaison and More, 1980).

The mean total hydrocarbon content of the water from Iko River was 44.12 mg/l during the dry season and 35.59 mg/l during the wet season . The values were lower than a natural background value of 50 mg/l set by the WHO (Table 6) . The mean total hydrocarbon content of the sediments was 377.5 mg/kg during the dry season and 288.7 mg/kg during the wet season (Table 2). The values for both seasons were far above 200 mg/kg total hydrocarbon concentration set for moderately polluted areas in the bottom sediments of Arabian Gulf (Massoud et al. 1996). In comparison to this study, the natural background levels of total hydrocarbon in bottom sediments of the Arabian Gulf were found to be 10 to 50 mg/kg and the concentration above this level was attributed to inputs from anthropogenic sources such as oil spills , oil slicks and seepage (Literathy et al , 1989) .

5. Conclusion

In both seasons, the higher conductivity for water and sediments is attributed to salt water intrusion from the Atlantic Ocean, indicating that geochemical reactions which occur in the sediments and water column are largely influenced by the physico-chemical conditions in the sediment-water complex, in particular conductivity and redox potential.

Based on the average total hydrocarbon content of the sediments, Iko River sediments could be said to be heavily polluted , while the average total hydrocarbon of the water is still within acceptable limit.

The concentrations of the hydrocarbons obtained are close to those reported by other workers on marine sediments in Kuwait and Saudi Arabia (Literathy et al 1989; Michel et al, 1993) .

From the results obtained in this study, it was established that there were seasonal and locational variations in the mean levels of the physic-chemical parameters of the water and sediments of Iko River. The p H values of the water were within the recommended WHO limits for unpolluted streams and rivers (WHO, 1984 ; Prati et al, 1974). However, the principal cations in the river namely, calcium , sodium, magnesium and potassium were of high levels , far in excess of the WHO limits set for drinking waters and natural waters (WHO, 1984) .

The high levels of these cations point to the fact that Iko River is particularly vulnerable to the inputs of chemical pollutants. The unique chemistry suggests that the ecology of the river is very fragile and a slight shift in composition can potentially be disastrous to some component of the food chain.

The mean levels of salinity and salt content of the water indicate that the river water is brackish and there is much influence of saline water over runoff water from the coastline. Results from the grain-size distribution revealed that the sediments from the river predominantly consisted of sand and less of silt and clay. This implies that the sediments of Iko River are not likely to be important sinks for chemical pollutants, thus making pollutants available to biota in the water column.

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Table 1 : Mean Monthly Variation in Physicochemical Parameters in Water from Iko River

Parameter	Nov.2011	Dec.2011	Jan.2012	Feb.2012	June.2012	July.2012	Aug.2012	Sept.2012
Temp. o C	24.8	24.6	24.9	23.7	23.5	23.9	24.8	24.1
Conductivity (mS/cm)	66.9	72.2	82.1	83.6	67.6	60.9	55.8	45.7
p H	6.76	6.82	6.63	6.53	6.88	6.91	6.8	5.87
DO (mg/l)	7.8	7.7	8.42	7.81	6.31	7.11	5.6	7.21
BOD5 (mg/l)	2.75	3.2	3.42	3.05	3.57	3.18	3.74	4.17
COD (mg/l)	5.41	5.26	5.65	6.09	5.03	5.29	5.11	6.43
Total Hydrocarbon (mg/l)	49.2	44.06	39.34	43.89	38.39	36.43	34.63	40.91
Ca (mg/l)	10.99	14.42	17.69	17.74	15.79	13.28	14.08	12.83
Mg (mg/l)	768.3	857.4	981.4	934.9	683.4	590.2	624.3	553.1
Na (mg/l)	1796	1588	1573	1363	928	797.9	839.2	732.9
K (mg/l)	305.5	311.5	279.8	282.1	189.9	193.1	185.2	144
Acidity (mg/l)	2.69	2.58	2.85	2.58	2.61	1.89	2.04	1.88
Sulphate (mg/l)	270.3	270.6	243.4	239.5	208.3	183.7	174.5	170.8
Nitrate (mg/l)	2.41	2.62	2.78	2.24	2.26	1.85	1.86	1.68
Nitrite (mg/l)	0.11	0.19	0.26	0.17	0.22	0.38	0.47	0.62
Chloride (mg/l)	428.2	435.7	471.4	429.4	459.7	412.8	376.3	392.2
Ammonium (mg/l)	0.07	0.09	0.16	0.11	0.14	0.17	0.19	0.19
Salinity (‰)	0.77	0.79	0.85	0.78	0.83	0.74	0.68	0.71

Table 2 : Mean Monthly Variation in Physicochemical Parameters in Sediment from Iko River

Parameter	Nov.2011	Dec. 2011	Jan. 2012	Feb. 2012	June .2012	July. 2012	Aug. 2012	Sept. 2012
Conductivity (m S/cm)	15.06	13.72	13.08	12.76	11.85	12.14	11.4	11.82
p H	5.41	5.75	5.96	6.27	6.62	6.61	6.7	6.74
TOC (%)	1.71	1.68	1.55	1.59	1.54	1.52	1.58	1.37
Total Nitrogen (%)	0.28	0.32	0.37	0.43	0.39	0.45	0.41	0.39
Available P. (mg/kg)	2.75	2.18	1.89	1.86	1.66	1.61	1.43	1.46
Total Hydrocarbon (mg/kg)	403.7	396.3	351.5	358.3	308.2	290.9	274.5	281.5
Ca (meq/100 g)	9.38	9.31	7.98	7.01	4.52	3.59	3.21	2.85
Mg (meq/100 g)	7.78	6.46	5.01	4.91	4.59	4.04	3.18	2.63
Na (meq/100 g)	0.52	0.54	0.52	0.46	0.51	0.56	0.45	0.41
K (meq/100 g)	0.34	0.36	0.37	0.35	0.44	0.41	0.39	0.33
EA (meq/100 g)	1.81	1.56	1.53	1.58	1.66	1.47	1.52	1.42
ECEC (meq/100 g)	19.82	18.23	15.41	14.97	11.72	10.06	8.72	7.64
Base Saturation (%)	90.26	91.27	89.97	88.77	84.63	84.12	81.33	80.54
Total Carbon (%)	3.84	3.49	3.43	3.51	3.21	2.98	3.12	3.42
Sulphur (%)	1.46	1.27	1.21	1.23	1.21	1.13	1.19	1.27

Table 3: Mean, Range and Standard Deviation of Physicochemical Parameters in water samples from Iko River during Dry/wet Seasons

Parameter	Dry Season			Wet Season		
	Mean	Range	Std. dev.	Mean	Range	Std. dev.
Temp. o C	24.5	23.7 - 24.9	0.55	24.08	23.5 - 24.8	0.54
Conductivity (m S/cm)	76.2	66.9 - 83.6	8	57.5	45.7 - 67.6	9.23
p H	6.69	6.53 - 6.82	0.13	6.62	5.87 - 6.91	0.50
DO (mg/l)	7.93	7.7 - 8.42	0.33	6.01	5.00 - 7.1	0.91
BOD5 (mg/l)	3.11	2.75 - 3.42	0.28	3.39	3.07 - 3.74	0.32
COD (mg/l)	5.35	5.09 - 5.65	0.24	5.31	5.03 - 5.80	0.35
Total Hydrocarbon (mg/l)	44.12	39.34 - 49.20	4.03	35.59	32.90 - 38.39	2.36
Ca (mg/l)	15.21	10.99 - 17.74	3.21	13.97	12.72 - 15.79	1.34
Mg (mg/l)	885.5	768.3 - 981.4	93.39	612.7	553.1 - 683.4	55.39
Na (mg/l)	1580	1363 - 1800	176.7	824.5	732.9 - 928.1	81.7
K (mg/l)	294.7	279.8 - 311.5	16.12	178.1	144.1 - 193.0	22.93
Acidity (mg/l)	2.68	2.58 - 2.85	0.13	2.11	1.88 - 2.61	0.34
Sulphate (mg/l)	255.9	239.5 - 270.6	16.82	184.3	174.5 - 208.0	16.74
Nitrate (mg/l)	2.5	2.20 - 2.78	0.25	1.91	1.68 - 2.26	0.25
Nitrite (mg/l)	0.18	0.11 - 0.26	0.06	0.42	0.22 - 0.62	0.17
Chloride (mg/l)	441.1	428.1 - 471.4	20.46	410.3	376.3 - 459.7	36.19
Ammonium (mg/l)	0.11	0.07 - 0.16	0.04	0.17	0.14 - 0.19	0.02
Salinity (‰)	0.8	0.77 - 0.85	0.04	0.74	0.68 - 0.83	0.07

Table 4: Mean, Range and Standard Deviation of Physicochemical Parameters in sediments from Iko River during Dry/wet Seasons

Parameter	Dry Season			Wet Season		
	Mean	Range	Std. dev.	Mean	Range	Std. dev.
p H	5.85	5.41 - 6.27	0.36	6.67	6.61 - 6.74	0.06
Conductivity (m S/cm)	13.66	12.76 - 15.06	1.02	11.8	11.40 - 12.14	0.3
TOC (%)	1.63	1.55 - 1.71	0.08	1.56	1.52 - 1.58	0.03
Total Nitrogen (%)	0.35	0.28 - 0.43	0.06	0.41	0.39 - 0.45	0.03
P- Phosphate (mg/kg)	2.17	1.86 - 2.75	0.41	1.54	1.43 - 1.66	0.11
Ca (meq/100 g)	8.42	7.01 - 9.38	1.14	3.54	2.85 - 4.52	0.72
Mg (meq/100 g)	6.04	4.91 - 7.78	1.36	3.61	2.63 - 4.59	0.87
Na (meq/100 g)	0.51	0.46 - 0.54	0.03	0.48	0.41 - 0.56	0.07
K (meq/100 g)	0.36	0.34 - 0.37	0.01	0.39	0.33 - 0.44	0.05
E A (meq/100 g)	1.62	1.53 - 1.81	0.13	1.51	1.42 - 1.66	0.1
ECEC (meq/100 g)	17.06	14.79 - 19.82	2.37	9.54	7.64 - 11.72	1.76
Base saturation (%)	90.07	88.77 - 91.27	1.03	82.66	80.54 - 84.63	2.02
THC (mg/kg)	377.5	351.5 - 403.7	26.36	288.7	274.5 - 308.2	14.59
Total carbon (%)	3.48	3.43 - 3.51	0.03	3.18	2.98 - 3.42	0.18
Sulphur (%)	1.29	1.21 - 1.46	0.11	1.20	1.13 - 1.27	0.06

Table 5: Mean Monthly Variation of exchangeable cations in sediment from Iko River

Parameter	Nov.2011	Dec.2011	Jan.2012	Feb.2012	June.2012	July.2012	Aug.2012	Sept.2012
Ca (meq/100 g)	9.38	9.31	7.98	7.01	4.52	3.59	3.21	2.85
Mg (meq/100 g)	7.78	6.46	5.01	4.91	4.59	4.04	3.18	2.63
Na (meq/100 g)	0.52	0.54	0.52	0.46	0.51	0.56	0.45	0.41
K (meq/100 g)	0.34	0.36	0.37	0.35	0.44	0.41	0.39	0.33
EA (meq/100 g)	1.81	1.56	1.53	1.58	1.66	1.47	1.52	1.42
ECEC (meq/100 g)	19.82	18.23	15.41	14.97	11.72	10.06	8.72	7.64

Table 6 : Pollution index of Iko River water for dry / wet seasons

Parameter	Dry Season			Wet Season		
	Mean	WHO Limits	Pollution index	Mean	WHO Limits	Pollution index
Temp. o C	24.5	25	0.98	24.08	25	0.96
Conductivity (m S/cm)	76.2	50	1.52	57.5	50	1.15
p H	6.69	6.5 - 8.5	1.03	6.62	6.5 - 8.5	1.02
DO (mg/l)	7.93	5	1.59	6.01	5	1.2
BOD5 (mg/l)	3.11	6	0.52	3.39	6	0.57
COD (mg/l)	5.35	10	0.54	5.31	10	0.53
Total Hydrocarbon (mg/l)	44.12	50	0.88	35.59	50	0.71
Ca (mg/l)	15.21	50	0.31	13.97	50	0.28
Mg (mg/l)	885.5	250	3.54	612.7	250	2.45
Na (mg/l)	1580	250	6.32	824.5	250	3.3
K (mg/l)	294.7	250	1.18	178.1	250	0.71
Acidity (mg/l)	2.68			2.11		
Sulphate (mg/l)	255.9	250	1.02	184.3	250	0.74
Nitrate (mg/l)	2.5	45	0.06	1.91	45	0.04
Nitrite (mg/l)	0.18	5	0.04	0.42	5	0.08
Chloride (mg/l)	441.1	250	1.76	410.3	250	1.64
Ammonium (mg/l)	0.11	< 1.0	0.11	0.17	< 1.0	0.17
Salinity (‰)	0.8			0.74		

Table 7 : Particle Size distribution of sediments from Iko River

Particle size	Mean for Dry Season	Mean for Wet Season
Sand (%)	78.22	74.36
Clay (%)	9.45	10.46
Silt (%)	12.32	15.13

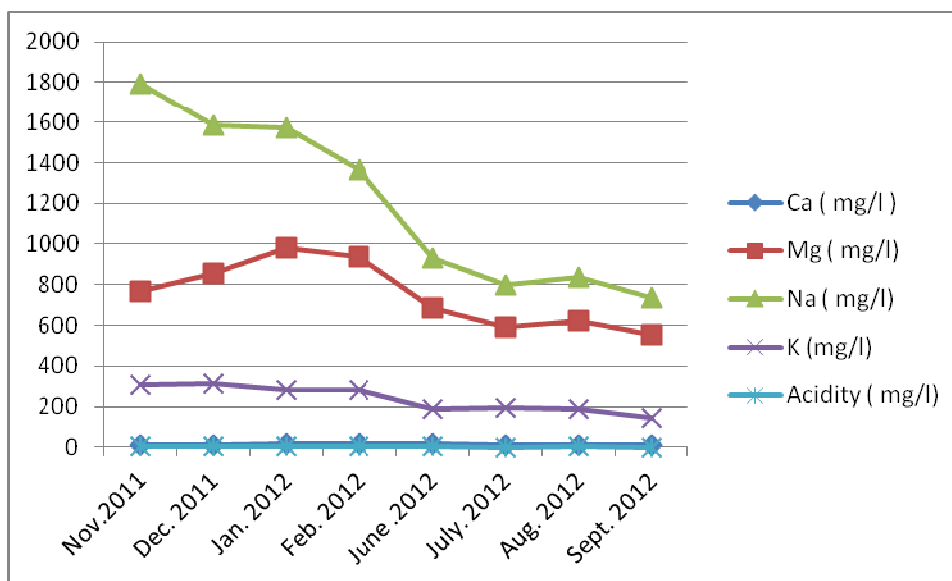


Fig. 2 : Mean monthly Acidity and Exchangeable cations in water from Iko River

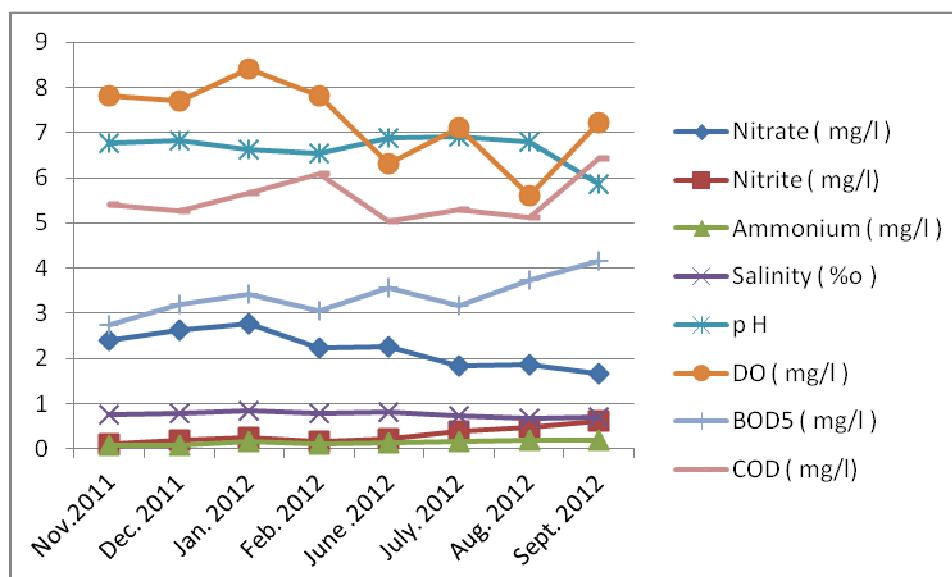


Fig. 3 : Mean monthly variation of salinity, nutrients, pH , DO, BOD5 and COD in water

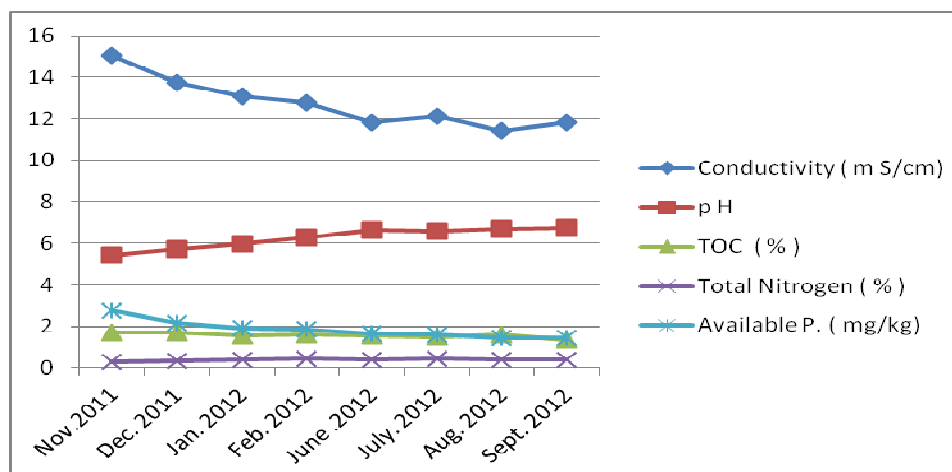


Fig. 4 : Mean monthly Total N, Cond., pH , TOC , Avail. P in sediments from Iko River.

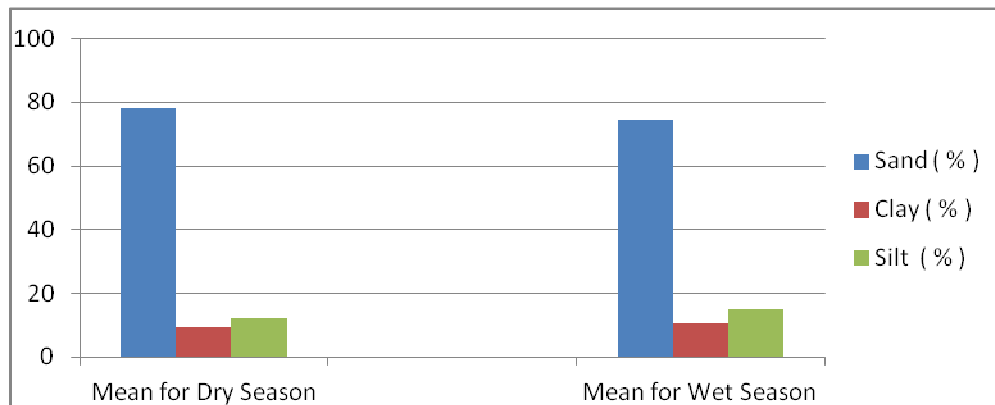


Fig. 11 : Particle size distribution of Iko River for Dry/Wet Seasons

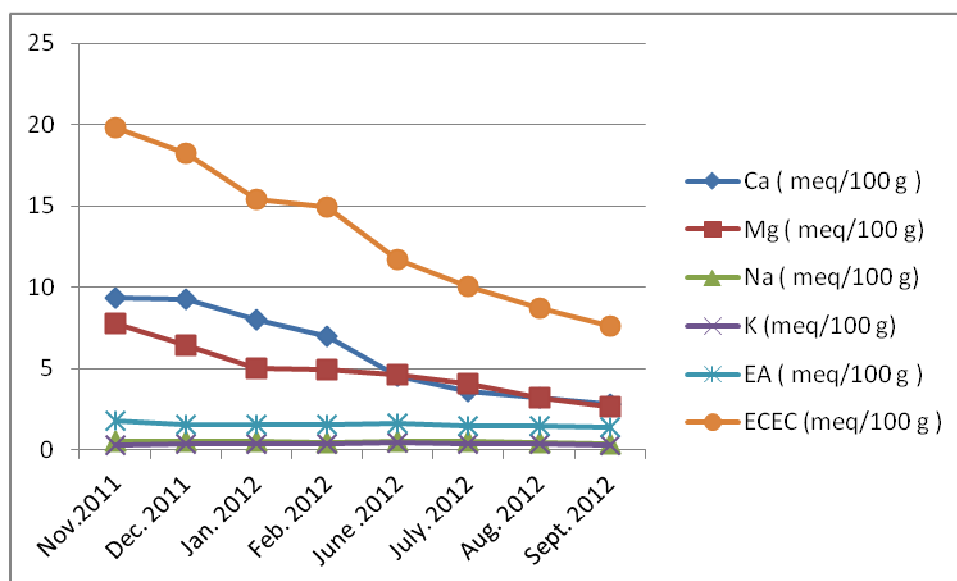


Fig. 5 : Mean monthly variation of exchangeable cations, exchangeable acidity and ECEC in sediment from Iko River

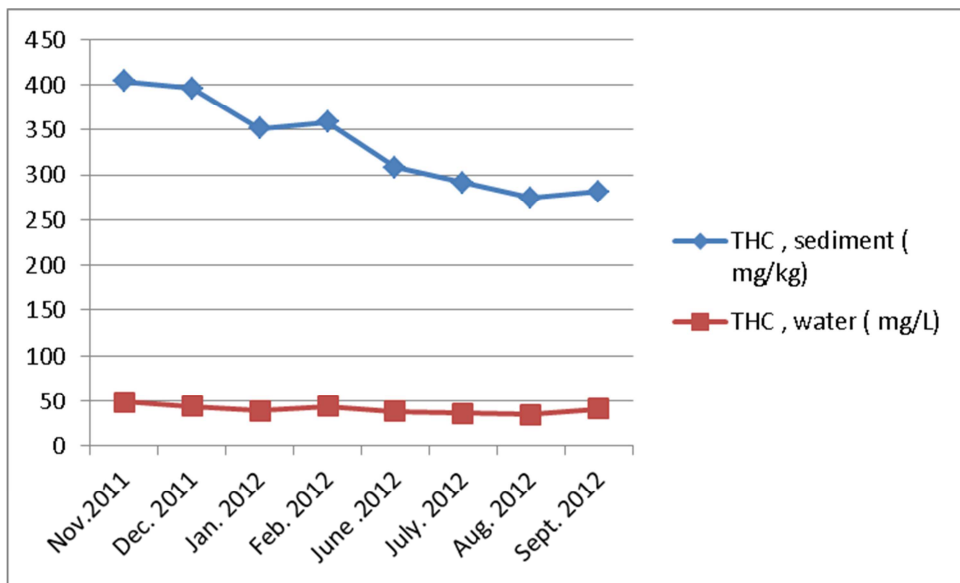


Fig. 6 : Mean monthly THC in water and sediment from Iko River

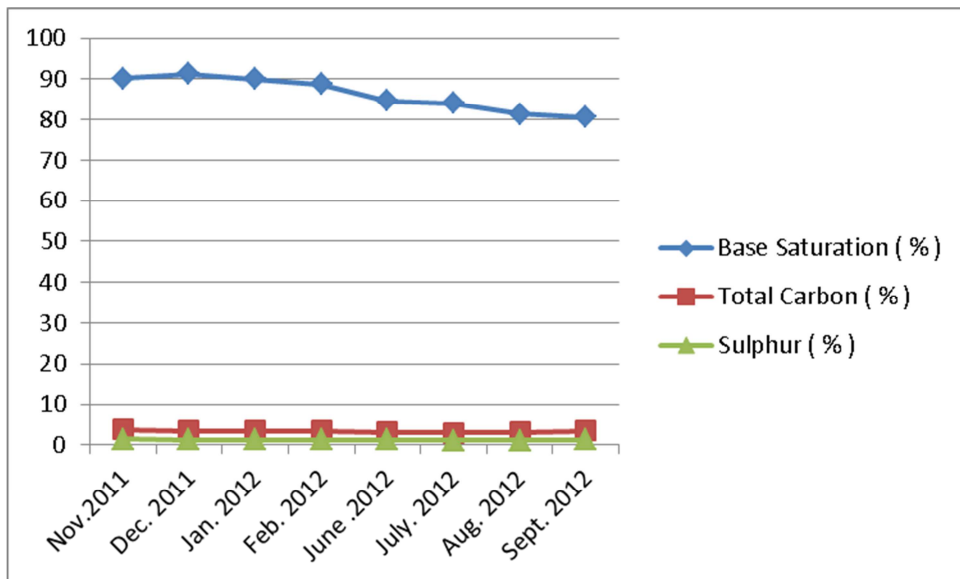


Fig. 7 : Mean monthly variation of Base saturation, Total carbon and sulphur in sediments from Iko River

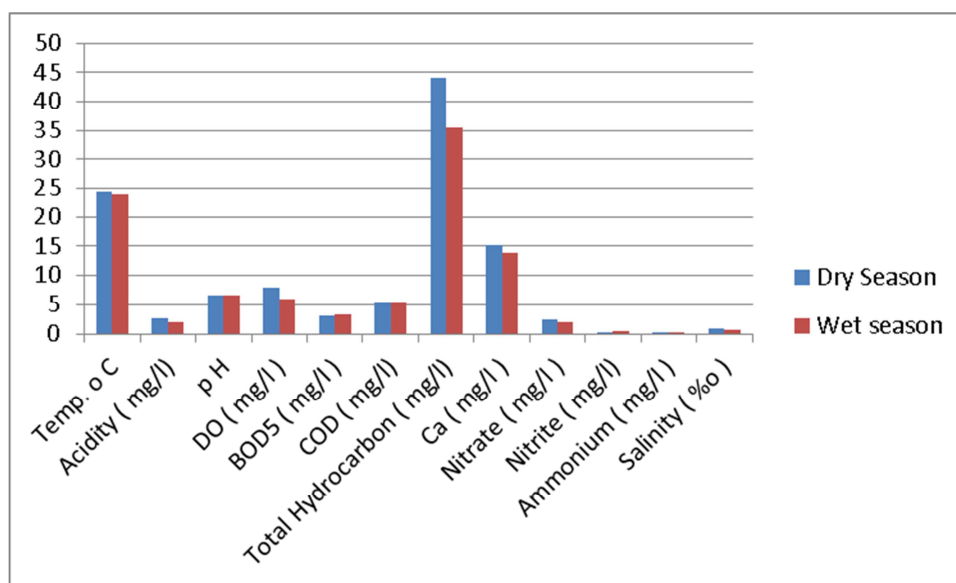


Fig. 8 : Mean monthly Physicochemical parameters in water from Iko River during dry /wet seasons

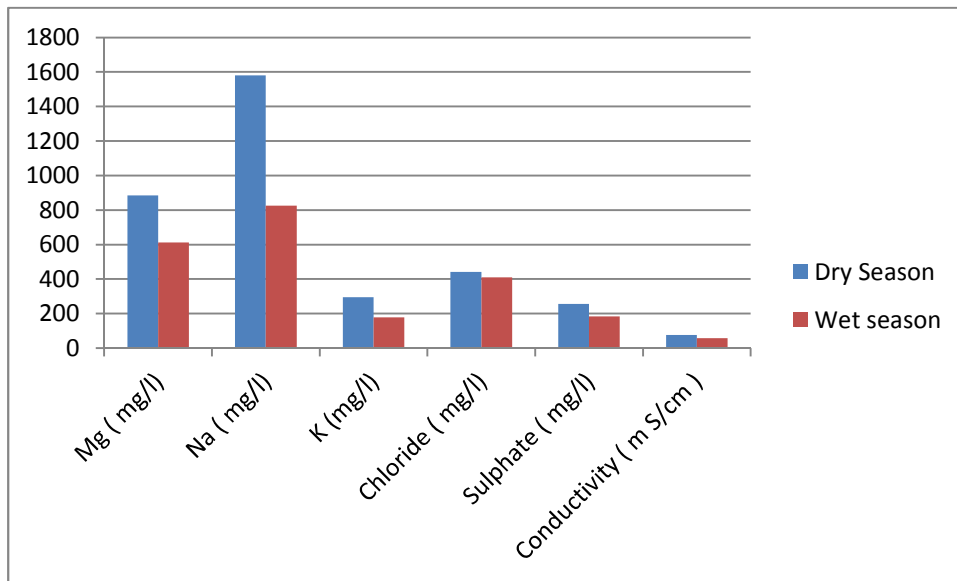


Fig. 9 : Mean monthly Mg, Na, K, Cl, Sulphate, Cond. Of water from Iko River during the dry/wet seasons

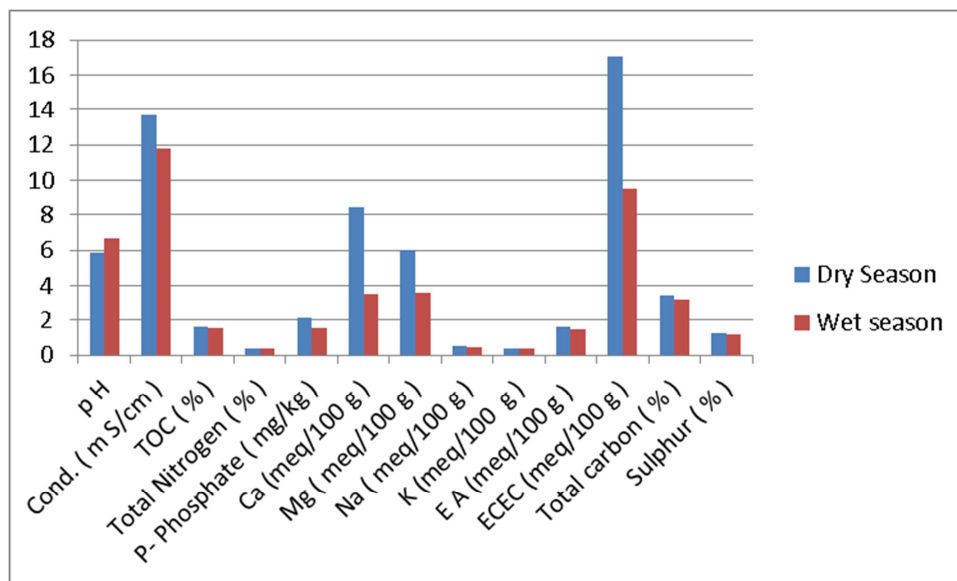


Fig.10 : Mean Physicochemical parameters in sediment from Iko River during

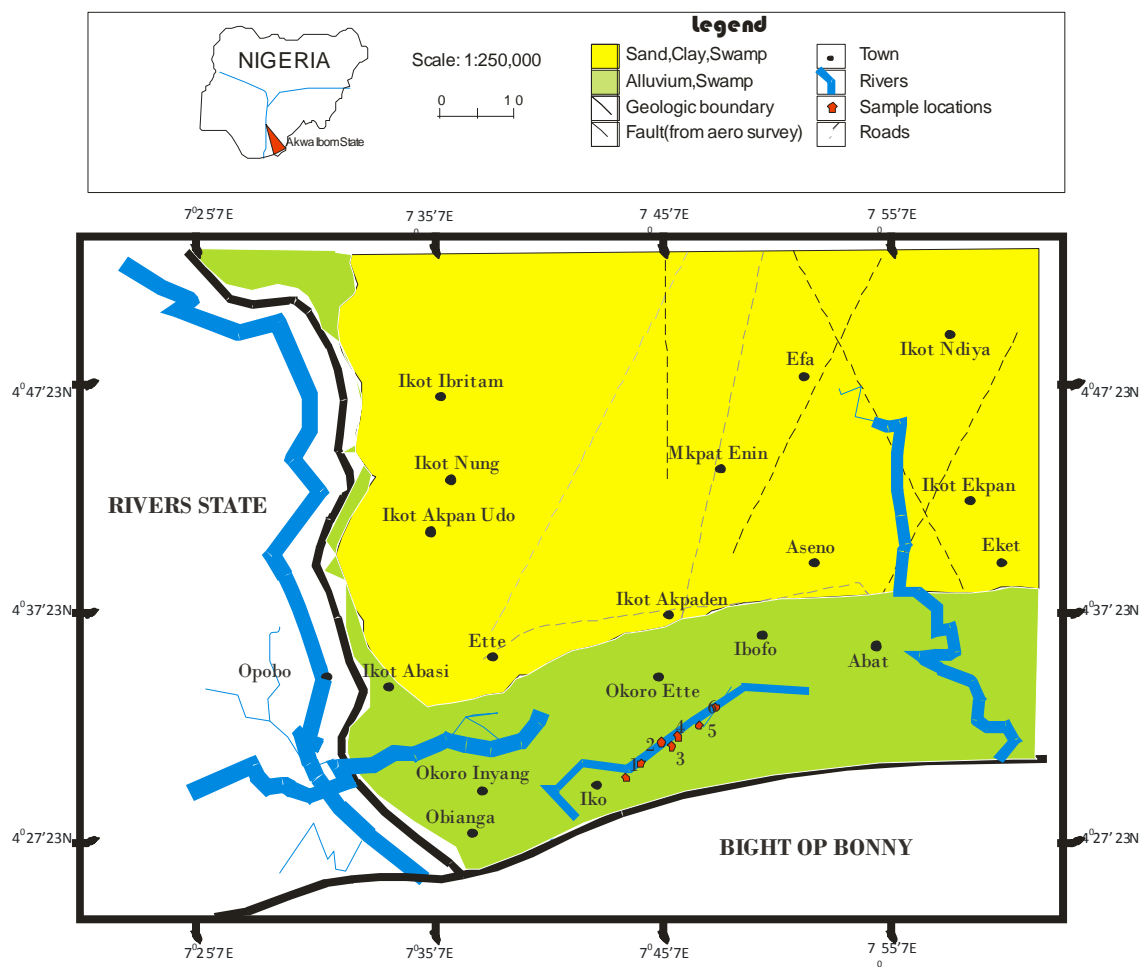


Fig.1: Map of the study area showing Sample locations

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