Eth. J. Sci & Technol 4(2) ... - 46
© Bahir Dar University April ... ISSN 1816 - 3378

SPATIAL AND TEMPORAL VARIATIONS OF PHYSICO-CHEMICAL PROPERTIES OF IMO RIVER ESTUARY, SOUTH EASTERN NIGERIA

Akoma Osondu Christopher

Department of Biology, Bahir Dar University, Bahir Dar, Ethiopia
Email: sonduakoma@yahoo.com

Abstract: A study of the physical and chemical properties of the Imo River Estuary Southeastern Nigeria was carried out between April 2001 and June 2002. Water temperature ranged between 25-30°C; total dissolved solids 7.6-19,890mgl⁻¹; turbidity 1- 51FTU; color 0-288PtCo.U; pH 5.2-8.2; conductivity 15.3-39,780µScm⁻¹; alkalinity 12- 945mgl⁻¹; dissolved oxygen 4.6-10.2mgl⁻¹; salinity 0-22‰; nitrate 0.004- 4.32mgl⁻¹; sulphate 0.088-11.08mgl⁻¹; phosphate 0.01-2.01mgl⁻¹; silica 0.25-27mgl⁻¹. With the exception of dissolved oxygen, all other parameters were significantly different ($P<0.001$) in the study stations. Temperature, total dissolved solids, conductivity, alkalinity, dissolved oxygen; sulphate and phoshate were high during the dry season while turbidity, color, pH, nitrate, salinity and silica were high during the wet season. Hydrographic features (water input-output) influenced the pattern of seasonal variation of parameters investigated. Flood influx into the estuary during the wet season and tidal inflow of sea water during the dry season were the major factors that influenced the limnology of Imo river estuary.

Keywords: Physical, Chemical Properties, Variability, Estuary, South-East Nigeria

Introduction

Rivers are critical for human existence and survival as they serve various purposes like being the source of municipal water supply, fisheries and irrigation projects, transportation and animal husbandry; industrial and recreational uses. Water is one of the most essential constituents of the human environment and it is a limited resource. Surface water in rivers, streams and estuaries is an important source of water for various uses. As a result of the unabated exploitation of natural resources, urbanization and industrialization, there is pollution stress on the air, land and especially water. Therefore it has become necessary to conserve and protect the limited water resource in our environment.

Reports on the physical and chemical characteristics of rivers include those of Holden and Green (1960) on river Sokoto, John (1986) on the inland waters of West Africa, Egborge (1971, 1974 and 1979) on river Oshun and Lake Asejire, Adebisi (1981) on Ogun river, Khan and Ejike (1984) on Jos plateau lakes and Nwadiaro and Umeham (1985) on Oguta Lake. Other rivers are New Calabar river (Erondu and Chindah, 1991; Odukuma and Okpokwasili, 1993, Chikere and Okpokwasili 2002), Ikogosi Springs (Kadiri, 2000), Great Kwa river (Akpan *et al.*. 2002), and Okhuihe River (Kadiri and Omozusi, 2002).

Imo River is one of the major rivers in South Eastern Nigeria and takes its source from the Achi-Okigwe highlands in the southern elevation of the Udi Hills. The river flows through highland areas cutting deep gorges with steep valleys through the derived Savannah to a dense rainforest, where allochthonous inputs of organic matter from the surrounding vegetation are derived from run-offs. The estuary is located between latitudes 4°15', 4°59' N and longitudes 7°20', 7°45' East and stretches for a distance of about 45km to the mouth of the Atlantic ocean at the Bight of Benin. The estuary is characterised by fast current, semi-diurnal tides and sandy beaches. A dense vegetation of *Nypa fruticans* predominates most of the fringing vegetation.

The present study was undertaken to provide background data on the physical and chemical conditions in the river, obtain information on the river water quality of the estuary, establish baseline conditions and provide data for proper management for the river in the event of future environmental impact. It is also a contribution to our present knowledge of the inland water bodies in Nigeria.

Material and Methods

Water samples were collected from six sampling stations at monthly intervals from April 2001 to June 2002. The stations as indicated in Fig. 1 are Akwete, Obete, Kaloko, Ikot Abasi, Queenstown and Opobo South. Pre - washed two-liter plastic containers earlier rinsed with distilled water and the sample to be collected were used for sample collection.

Water temperature was measured with mercury in glass thermometer. Total dissolved solids, conductivity, color and turbidity were recorded with a HACH DR2000 spectrophotometer. Dissolved oxygen was determined by the alkali-azide modification of Winkler's method. Salinity measurement was made with the aid of a HACH salinity meter CO150.

The salinity probe had limited sensitivity and therefore values near to zero could not be recorded in the freshwater station. Nitrate concentration was determined using the phenol disulphonic acid method; sulphate, turbidimetric method; phosphate, ascorbic acid method; silica, molybdosilicate method (APHA, 1998). Calcium, magnesium and alkalinity were also determined titrimetrically as outlined by APHA (1998). Mean and standard error for each of the parameters were determined. Single factor analysis of variance (ANOVA) was computed to test differences among the sampling stations.

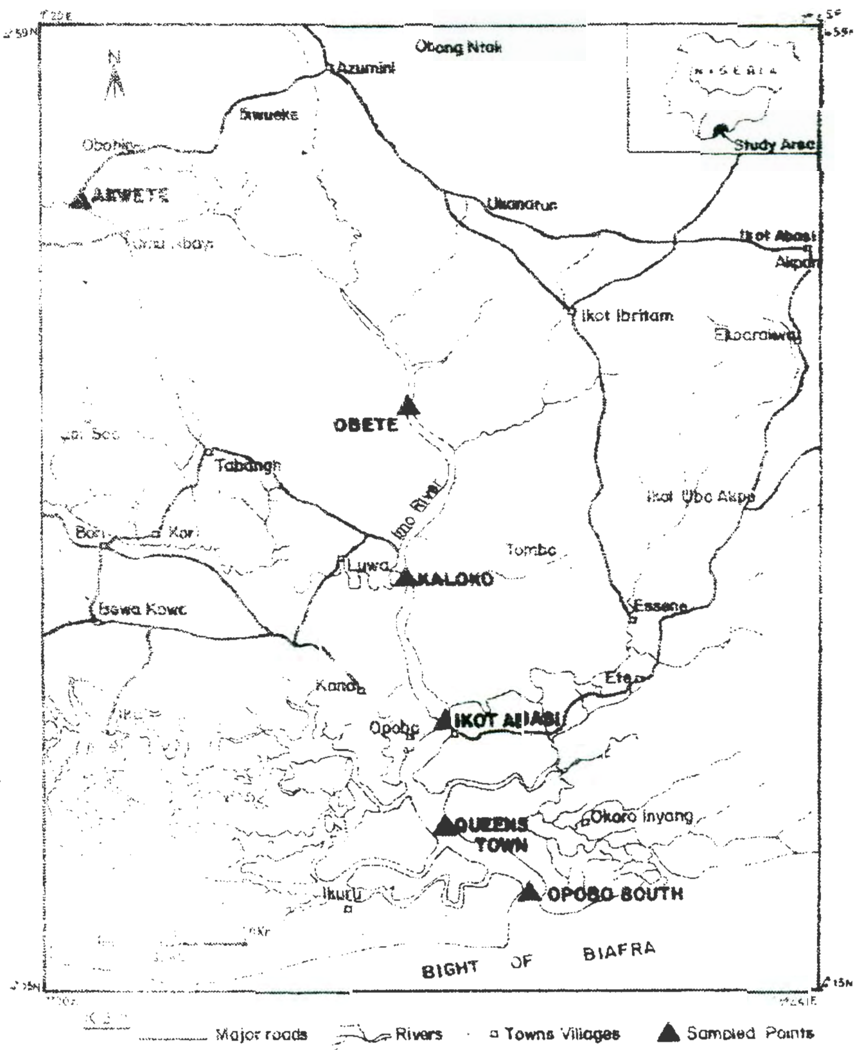

Figure 1: Map of Imo River Estuary showing sampling stations.

Results and Discussion

Table 1 shows the range, mean and the levels of significance of some physico-chemical parameters in the Imo River estuary. The physical properties investigated include temperature, total dissolved solids, turbidity and color. Water temperature variation in the Imo River estuary (range 25-30°C; mean 28 ± 0.13) followed a seasonal pattern of high dry season and low wet season values characteristic of tropical water bodies (Talling, 1986).

Table 1: Physico-Chemical Properties of Imo River Estuary.

Parameters	Range	Mean ± S.E.	Probability
Temperature °C	25-30	28 ± 0.13	$P<0.05$
TDS mgl^{-1}	7.6-19,890	2953.13 ± 443.27	$P<0.001$
Turbidity (FTU)	1-51	11.16 ± 1.0	$P<0.001$
Colour (PtCo.U)	0-288	27.16 ± 5.09	$P<0.05$
pH	5.2-8.2	6.60 ± 0.08	$P<0.05$
Conductivity (μScm^{-1})	15.3-39,780	6,993.85 ± 996.04	$P<0.001$
Alkalinity (mgl^{-1})	12-945	38.77 ± 7.89	$P<0.001$
D. O. (mgl^{-1})	4.6-10.2	7.26 ± 0.11	$P>0.05$
Salinity (‰)	0-22%	4.28 ± 0.65	$P<0.001$
Nitrate (mgl^{-1})	0.004-4.32	0.80 ± 0.11	$P<0.001$
Sulphate (mgl^{-1})	0.088-11.08	3.29 ± 0.39	$P<0.001$
Phosphate (mgl^{-1})	0.01-2.01	0.37 ± 0.048	$P<0.05$
Silica (mgl^{-1})	0.25-27	6.85 ± 0.84	$P<0.001$
Calcium (mgl^{-1})	6.741-322.36	[illegible]9.26	$P<0.001$
Magnesium (mgl^{-1})	0.92-625.82	171.23±21.55	$P<0.001$

Total dissolved solids (TDS), turbidity and colour showed a similar trend of spatial variability during the study period. TDS values ranged from 7.6 to 19,890mgl^{-1}, mean 2,953.13 ± 443.27mgl^{-1} and turbidity 1 to 51FTU, mean 11.16 ± 1.0FTU. The results revealed spatially distinguishable freshwater zone with high turbidity and brackish water zone with low turbidity, and distinct significant difference (P<0.001) among the stations. Flocculation of colloidal suspension gave rise to low turbidity at the brackish water zone of the estuary. Colour variation (range 0-288PtCo.U; mean

27.16 ± 5.09PtCo.U) among the stations in the Imo river estuary was also significantly different ($P<0.05$) and showed the same pattern of spatial variability as turbidity. This is attributable to runoff water of clay and silt origin entering the river during the rains. Temperature and TDS were higher in the dry than wet season while the reverse was the case with turbidity and colour.

The weak acidic to neutral nature of the waters as shown by the pH result is an indication of a balanced acidic/basic interaction of mineral and organic components in the estuary. The pH (5.2-8.2, mean 6.0 ± 0.08) contrasts with the circum-neutral pH of 7.1-7.9 recorded in river Niger (Kadiri, 1999) and 8-8.8 reported for river Nile (Mohammed *et al.*, 1986). However the pH is comparable with those of Bonny River 5.9-9.7 (Chindah and Pudo, 1991), Warri/Forcados estuary 5.8-7.1 (Opute, 2000) and Eleme River 5.32-7.37 (Chikere and Okpokwasili 2002). Generally, pH values fluctuated among the stations and all-through the period of study, with no definite pattern. Varying pH conditions are dependent on the nature of rivers flowing into it, which in turn depends on the terrain the river has flowed through and indicative of the biological activities in the river.

The values ranged from 15.3 to 39,780µScm^{-1}. The conductivity of the estuary was higher in the dry season; mean 9618 ± 2020.9µScm^{-1} than in the wet season; mean 5479.83 ± 1009.1µScm^{-1} (Table 2). The brackish waters of the Niger Delta have been reported to have conductivity values in this range as corroborated by 12.0 to 46,000µScm^{-1} for Bony River (Chindah and Pudo, 1991). The ionic/solute concentration was predominately higher in the brackish water zone of the estuary than in the freshwater stations. This is attributable to the mixing of seawater and freshwater within the estuary and the low wet season values being a consequence of dilution by runoff.

The alkalinity result obtained in this study (12 - 945mgl^{-1}) is indicative of high concentration of bicarbonate and carbonate ions and therefore a high buffering capacity of the estuarine water (especially in the brackish water stations). The result contrasts with 28-39mgl^{-1} reported for river Niger by Kadiri (1999) and 4-22mgl^{-1} for the Warri/Forcados estuary (Opute, 2000). Comparison of the dry and wet season alkalinity values revealed a higher alkalinity range during the dry season months than the wet season months.

Dissolved oxygen result indicated no significant difference in the stations ($P>0.05$). The dissolved oxygen values (4.6-10.2mgl^{-1}) are comparable to those of tropical water bodies. However, lower values have been reported for various rivers in Nigeria. Examples include 3.5-7.2mgl^{-1} for Bonny river by Chindah and Pudo (1991), 3.0-6.0mgl^{-1} for the Lagos lagoon (Nwankwo, 1994), 3.0-4.3mgl^{-1} for the Warri/Forcados estuary (Opute, 2000) and 4.0-8.33mgl^{-1} for Great Kwa river (Akpan *et al.*, 2000).

Low primary production caused by low transparency and nutrient load has been implicated in low oxygen content of water. The high dissolved oxygen values obtained in the present study are indicative of the well-mixed waters of the estuary and possible input due to primary productivity by phytoplankton species, especially diatoms.

Table 2: Seasonal Variation of Physico-Chemical Properties of Imo River Estuary

Parameter	Wet Season	Dry Season
	Mean ± S.E	Mean ± S.E
Temperature(^{0}C)	27.75 ± 0.17	28.40 ± 0.19
TDS (mgl^{-1})	2262 ± 934.05	4146.06 ± 920
Turbidity (FTU)	13.36 ± 1.45	7.33 ± 0.72
Color (Pt.Co.U)	36.40 ± 7.70	12.53 ± 2.20
P^H	6.69 ± 0.096	6.45 ± 0.13
Conductivity (µS cm^{-1})	5479.83 ± 1009.1	9618.14 ± 2020 .9
Alkalinity (mgl^{-1})	37.03 ± 2.49	41.80 ± 2.72
D.O (mgl^{-1})	6.62 ± 0.15	8.02 ± 0.19
Salinity ($^0/_{00}$)	5.10 ± 0.85	4.0 ± 1.06
Nitrate (mgl^{-1})	0.96 ± 0.16	0.75 ± 0.15
Sulphate (mgl^{-1})	2.95 ± 0.50	3.84 ± 0.62
Phosphate (mgl^{-1})	0.32 ± 0.06	0.50 ± 0.08
Silicate (mgl^{-1})	8.25 ± 1.18	4.47 ± 0.9

A distinct salinity gradient was observed during the study from the freshwater to the brackish water stations. The salt content of the estuary (0.0-22‰) compares with 1.7-29.2‰ reported at the Lagos Lagoon by Nwankwo (1994). Chindah and Pudo (1991) reported a range of 7-14‰ for Bonny river. Akpan *et al.* (2000) also reported a wet season range of 0.01-0.52‰ and dry season range of 0.29-0.8‰ in the Great Kwa River; and similar trend of high dry and low wet season result was observed in the Imo River estuary. Stations 1 to 3 are exclusively freshwater and at no time during the sampling period experienced incursion of sea water despite observed tidal amplitudes (especially at the onset of the wet season). High dry season values are attributable to the inland thrust of greater mass of seawater upstream as a result of the absence of floodwaters and runoff. Unlike in the Warri/Forcados estuary where the entire estuary becomes freshwater at the peak of the wet season (Opute 2000), the Imo River estuary presents a marked salinity zone at all times, owing to its high downstream current and minimal tidal action by the adjacent sea.

There is a general trend of low nitrate concentration associated with African waters (Lund, 1965), and the values reported in this study reflect such trend. The nitrate content of Imo River estuary ranges between 0.004-4.32mgl^{-1} and varied both spatially and temporally. It contrasts with 0.18-0.62mgl^{-1} (Kadiri, 1999) for River Niger, 0.2-0.8mgl^{-1} for the Ikogosi springs (Kadiri, 2000) and 29-557µgl^{-1} for the New Calabar River (Odukuma and Okpokwasili, 1993). In this study, wet season nitrate content was higher than during dry season. Seasonal changes are associated with inflow from land drainage during the rains (Imevbore, 1970). The uncontrolled use of nitrogenous fertilizers by farmers in the drainage basin of the river leads to high nitrate concentration (Odukuma and Okpokwasili, 1993). Tidal influence could also be implicated for high brackish water nitrate content. At high-tide the fringing swampy vegetation is inundated and the decaying plant and animal materials are potential sources of nitrate enrichment (John, 1986).

The sulphate content of the river showed both spatial and temporal variability. The range of values obtained (0.88-11.08 mg1^{-1}) is at variance with 0.0-0.13 mg 1^{-1} - River Niger (Kadiri, 1999) and 5-186mg1^{-1} - New Calabar River (Odukuma and Okpokwasili (1993). Sulphate content of the river was significantly different ($P<0.001$) among the stations with higher values recorded during the dry season. Sulphate and phosphate were both higher in dry season while the reverse was true for nitrate. The major sources of sulphate in natural waters are usually from mineralization of parent rock materials (especially through pyrite oxidation) and from land drainage during the rains (Wetzel and Likens, 1995).

Phosphate content of the Imo River estuary varied both spatially and temporally and the values ranged from 0.01 to 2.01 $mg1^{-1}$. Phosphate is an important nutrient in water, and dissolved phosphate is the most widely available form of inorganic phosphate for phytoplankton growth, and along with nitrate is a limiting nutrient (Reynolds, 1984). The values indicate low phosphate content. The result is in agreement with 0.1-0.7$mg1^{-1}$ reported for the Ikogosi spring water (Kadiri, 2000) and 0.27 ± 0.11 $mg1^{-1}$ for Okhuaihe River (Kadiri and Omozusi, 2002). Higher values of 10-60$mg1^{-1}$ have been reported in River Niger (Kadiri 1999). Phosphate, unlike nitrate exhibited a trend of high dry season concentration and low wet season values. Dry season utilization for phytoplankton growth possibly depleted phosphate in water. Nevertheless, commensurate phosphate fluctuations are possible due to series of biological processes and transformation in water, seasonal variations through input from inflowing rivers, use of phosphorus-rich fertilizers by farmers and discharge of urban and industrial wastes into water. Loss from water column to sediment is another factor responsible for phosphate depletion in water (Egborge, 1981).

Phytoplankton require small amount of silica for protein and carbohydrate synthesis. Among the chrysophytes (diatoms in particular), which obligately strengthen their cell walls with amorphous silica polymers, the requirement becomes ecologically important (Talling, 1986; Reynold and Descy, 1996). The silica content of the estuary exhibited clear spatial and temporal variation with a mean silica value of 6.85 ± 0.04 mgl^{-1}. This value is higher and contrasts with the mean value of $3.14 \pm 0.16$$mgl^{-1}$ reported for Okhuaihe River by Kadiri and Omozusi (2002). The silica content of the river was significantly different in the stations ($P<0.001$), with the freshwater stations recording higher values than the brackish water stations. Silica concentration normally increases from the coast inland and the major sources of silica in inland waters are through runoffs and channelled urban drainage systems that find their way into surface waters of rivers and streams during the wet season flood. Silica is sufficiently depleted downstream owing to phytoplankton utilization (especially by diatoms). It is important to note that silica is a limiting nutrient for diatom growth (Edward and Ayyakkanu, 1991).

Results of this study revealed marked seasonal variations and differences among the stations with respect to the physico-chemical parameters investigated. The Imo River, unlike the other rivers within the interconnected creek system of the Niger Delta, is relatively pristine. There is limited industrial activity in its catchment area, suggesting allochthonous input during the wet season as the major source of nutrient enrichment. Baseline information on the physico-chemical conditions of the estuary is hereby provided, and water from the brackish water stations may not be suitable for potable and industrial uses without treatment, whereas it could be used for fisheries and other aquacultural practices.

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