GLOBAL JOURNAL OF ENVIRONMENTAL SCIENCES VOL. 6, NO. 1, 2007: 1 - 13
 1SSN 1596 - 6194

ASSESSING THE ENVIRONMENTAL IMPACTS OF OIL EXPLORATION AND PRODUCTION ON THE WATER QUALITY OF OSSE RIVER, SOUTHERN NIGERIA

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(Received 13 April 2006; Revision Accepted 22 August, 2006)

ABSTRACT

The concentrations of some physico-chemical parameters of the Osse River were studied to assess the impacts of Dubri Oil Company operations. Samples were collected between July 2000 and June 2002 from five stations: Station 1 and 2 (upstream), Station 3 (Gelegele Port/Oil Company site) and Stations 4 and 5 (downstream). The concentrations of these parameters in the river ranged from 26.1 – 33.7°C for air temperature, 25.2 – 29.1°C (water temperature); 38.0 – 225cm (Transparency); 2.3 – 58NTU (Turbidity); 42.5 – 520.20mgl^{-1} (TDS); 14.66 – 210.04mgl^{-1} (TSS); 57.14 – 701.50mgl^{-1} (TS); 5.55 – 7.91 (pH); 4.40 – 11.60mgl^{-1} (DO), 0.80 – 5.60mgl^{-1} (BOD_5); 10.0 – 208µscm^{-1} (Conductivity); 17.50 – 100mg $CaCo_3^{-1}$ (Alkalinity); 7.02 – 34.50mgl^{-1} (Chloride); 0.02 – 0.43mgl^{-1} (Sulphate); 0.04 – 0.73mgl^{-1} (Nitrate); 0.28 – 3.52mgl^{-1} (Phosphate); 0.18 – 19.1mgl^{-1} (Sodium); 0.11 – 6.2mgl^{-1} (Potassium); 1.11 – 9.62mgl^{-1} (Calcium) and 0.20 – 7.78mgl^{-1} for magnesium. With the exception of air temperature, transparency, turbidity, suspended solid, dissolved solids, total solids, biochemical oxygen demand and nitrate which were significantly different ($P< 0.05$), all other parameters were not significantly different ($P> 0.05$) in the study stations. The impacts of the oil exploration and production operations of the Oil Company on the water quality was negligible as all parameters were relatively homogenous across the study stations, and were below the WHO guidelines for domestic usage. The environmental conditions studied have been discussed in relation to the general water quality standard.

KEY WORDS: Water quality, impact, Oil Company, Physico-chemical parameters, Osse River.

INTRODUCTION

The quality and quantity of water in any aquatic environment is reflected in the biotic communities, and a reduction in any of these can lead to considerable changes in the biota (Culp and Davies, 1982). The studies of the physical and chemical hydrology of most environmentally perturbed inland water bodies, both lotic and lentic in the Niger Delta region of Nigeria, have been documented (Ogbeibu and Egborge, 1995; Edokpayi *et al.*, 2000; Ogbeibu and Oribhabor, 2002). Unfortunately, no detailed baseline data on these rivers exist for comparison of pre-and post developmental activities for valid assessment of the overall impact of developmental activities on the water qualities of these rivers.

The Osse River has been subjected to domestic and industrial pollution by the oil exploration activities of Dubri Oil Company and the numerous communities on the bank of the river. The river is the major source of drinking water to the inhabitants of these communities, and yet no form of water quality assessment has been conducted on this river.

This paper is the second in a series documenting the impact of the exploration activities of Dubri Oil Company on the water quality of the Osse River, and gives baseline information on the status, temporal and spatial dynamics in the physical and chemical attributes of the Osse River.

THE STUDY AREA

The Osse River Originates in the Akpata hills in Ekiti State, Nigeria. It flows in a North-Southern directions through Ovia North-East Local Government area and empties into the Benin River which is one of the four major rivers that drains into the Atlantic Bight of Benin (Lat.5^0 – 5^0.40'N and Log. 5^0 – 6^0.30'E). Others being Ramos, Forcados and Escravos River (Fig 1). The climate has the unique features of the humid tropical wet and dry seasons governed mainly by rainfall. In the wet season, the river is characterized by increased flow rate, high turbidity and muddy water especially after heavy rainfall. The dry season on the other hand is characterized by moderate or slow flow rate and clearer water. Several streams and creeks drain into the river.

The river is located on the Benin formation described by Wilson and Bain (1928), and composed of coarse sand, interspersed with lignite and patches of laterite sand clay.

Water samples were taken from five stations which spread from upstream to downstream of the Dubril Oil location (Fig 1). Stations 1 and 2 were upstream of station 3 (the nucleus of activities at Gelegele), while stations 4 and 5 were downstream.

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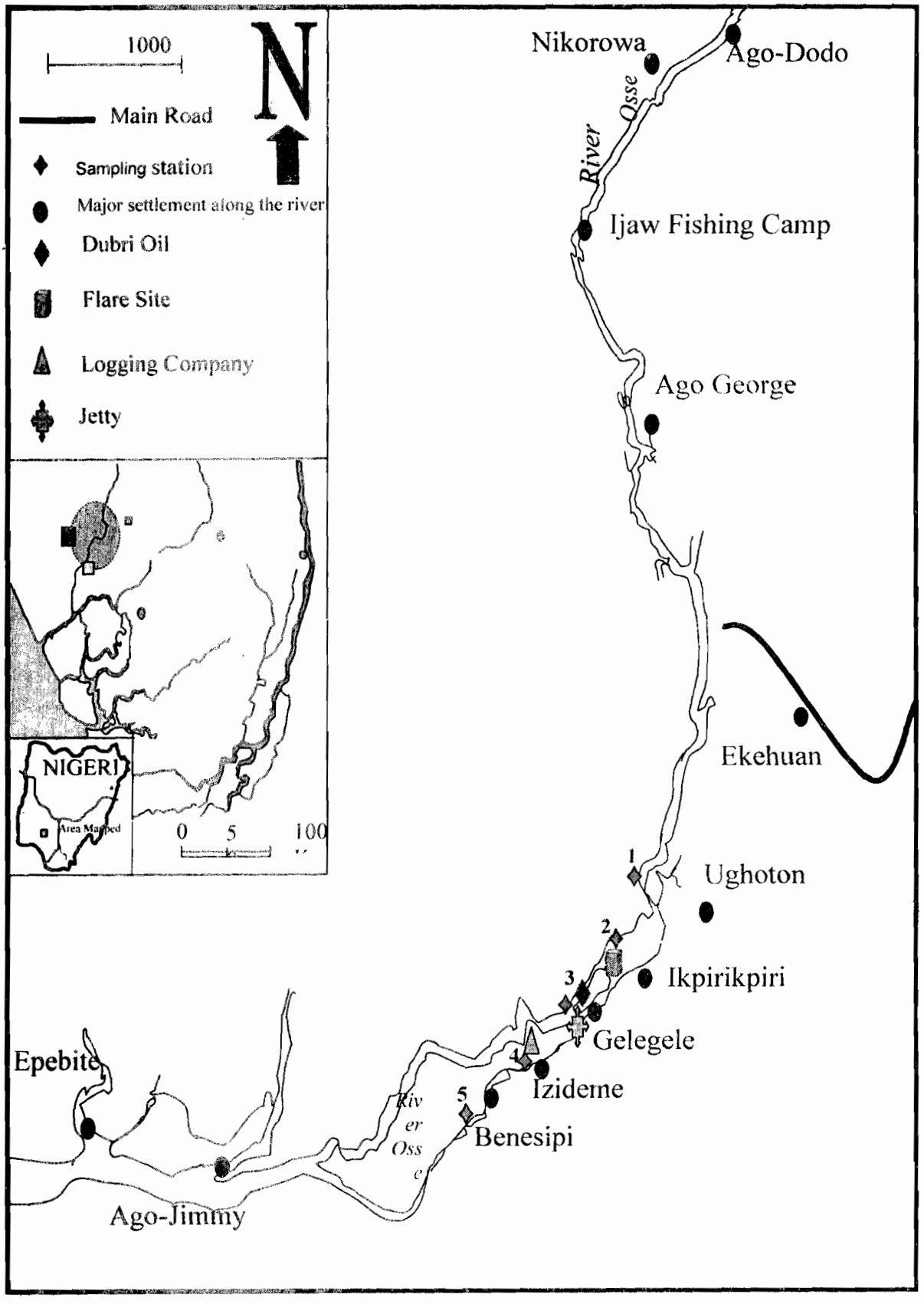

Fig. 1: Study Area and Sampling Stations

Station 1 was located at Ughoton. The vegetations were mostly forest type. The river is flanked by Indian bamboo (*Bambusa* sp) which provides a canopy for the underlying vegetation. The water surface has a mat of floating macrophytes, *Salvinia* sp *Nymphaea* sp. *Lemna* sp and *Eicchornia crassipes* (water hyacinth). The substratum was mainly organic sticky mud.

Station 2: Located about 500m downstream from station 1. The vegetation consists mainly of secondary forest, made up of trees and tall grasses such as *Pennisetum purpureun*. The floating macrophytes include *Nymphaea lotus* and *E. crassipes*. The substratum was rich in organic matter and muddy.

Station 3 was about 500m downstream of station 2. On the left bank of the river is Dubri Oil Company which engages in oil exploratory activities. There were very few floating macrophytes. The river at this point is deep, a result of dredging to accommodate crude oil barges and tug boats usually anchored on the river. The substratum is a mixture of fine and coarse sand and gravels. The water at this point is almost always covered with a thin film of oil.

Station 4 was located about 500m downstream of station 3. The water surface has a mat of floating macrophytes which include *E crassipes, Salvinia* sp and *Nymphaea lotus*. The substratum is composed of decaying pieces of wood, coarse sand and silt.

Station 5 was located about 500m downstream of station 4. A dense mat of floating macrophytes covered the surface of the water, *E. crassipes, Nymphaea* sp and *ceratophyllium* sp. The substratum was made up of organic, rich sticky mud and fine silt.

MATERIALS AND METHODS

The sampling period spanned from July 2000 to June 2002. At each station, water samples were taken from the surface of the river in pre-washed and dried polyethylene bottles, preserved as appropriate (APHA, 1998) and then transported to the laboratory for analysis. Air and surface water temperatures were measured in the field with mercury - in - glass thermometer. Transparency was measured in-situ using a standard 20cm secchi disc, while total dissolved solids (TDS) conductivity and pH were determined using a HACH portable digital meter. Total suspended solids (TSS) were determined gravimetrically. Turbidity values in NTU (Nephelometric Turbidity Units) were read from the Spectronic 21D spectrophotometer (Milton Roy) at room temperature.

The Azide modification techniques of the Winkler's method (APHA, 1998) was used in determining the dissolved oxygen (DO), while water samples for the Biochemical oxygen demand (BOD_5) determination were collected in black 250ml reagent bottles and taken to the laboratory for a five-day incubation period before analysis using the Winkler's method. Total alkalinity was estimated by titration with 0.2N sulphuric acid (APHA, 1998), using phenolphthalein and methyl orange indicators. Chloride was determined by the argentometric method (APHA, 1998). Phosphate-phosphorous and nitrate-nitrogen were measured by the phenoldisulphonic acid and ascorbic acid methods respectively (APHA, 1998). Sulphate was measured using the turbidimetric method as described in APHA (1998). The cations, calcium and magnesium were determined titrimetrically using 0.1N solution of disodium salt of ethylene diaminetetra acetic acid (EDTA) using Eriochrome Black T and calcon as indicators. Sodium and potassium were determined using the conning flame photometer IV; Lithium being the reference filter. All analytical quality control requirements were strictly adhere to. Computation of means and other statistical analysis were performed using the SPSS 11.0 computer package.

RESULTS

The mean, values and range of the water quality parameters are summarized in Table 1.

Table 1. Summary of Mean Values for Physical and Chemical Characteristics

PARAMETERS (n=20)	Station 1	Station 2	Station 3	Station 4	Station 5	Statistical Significance
	Min Max Mean ± SE	Min Max mean ± SE	Min Max mean ± SE	Min Max Mean ± SE	Min Max Mean ± SE	
Air Temperature	26.10 - 31.20 29.13 ± 0.34^{A}	26.00 - 31.20 29.18 ± 0.34^{A}	27.00 - 33.70 31.35 ± 0.38^{B}	26.80 - 31.30 29.28 ± 0.32^{A}	26.20 - 31.20 29.20 ± 0.30^{A}	P<0.05 *
Water Temperature	25.20 - 29.10 27.30 ± 0.26	25.30 - 29.00 26.29 ± 1.09	25.50 - 29.30 27.42 ± 0.25	25.70 - 29.10 27.27 ± 0.26	25.50 - 29.30 27.26 ± 0.26	P>0.05
Transparency	39.00 - 210.00 109.33 ± 11.24^{B}	50.00 - 225.00 105.79 ± 9.89^{B}	46.00 - 208.00 109.63 ± 9.01^{B}	38.00 - 143.00 74.33 ± 6.39^{A}	41.00 - 190.00 89.33 ± 9.03^{A}	P<0.05 *
Turbidity	3.48 - 40.05 20.73 ± 2.70^{A}	2.32 - 40.18 21.80 ± 2.65^{A}	4.46 - 42.11 22.68 ± 2.60^{A}	12.16 - 58.11 36.10 ± 3.14^{B}	9.86 - 48.17 29.42 ± 2.84^{B}	P<0.05 *
Dissolved Solids	54.60 - 310.45 138.53 ± 14.55^{A}	42.50 - 424.72 165.29 ± 16.70^{A}	48.50 - 398.78 175.41 ± 19.65^{A}	80.54 - 520.20 256.73 ± 24.52^{B}	75.00 - 456.00 230.23 ± 20.02^{B}	P<0.05 *
Suspended Solids	18.03 - 146.66 64.38 ± 8.43^{A}	14.66 158.08 70.62 ± 7.76^{A}	16.00 - 128.43 68.85 ± 7.24^{A}	30.36 - 210.04 128.75 ± 10.14^{B}	19.45 - 193.54 108.59 ± 11.12^{B}	P<0.05 *
Total Solids	73.80 - 457.11 200.41 ± 21.91^{A}	57.16 - 582.80 227.58 ± 23.51^{A}	64.50 - 517.60 246.08 ± 24.39^{A}	110.90 - 701.50 388.85 ± 33.43^{B}	97.17 - 607.03 338.41 ± 28.33^{B}	P<0.05 *
pH	5.76 - 7.91 6.96 ± 0.11	6.02 - 7.84 7.03 ± 0.11	5.80 - 7.83 7.01 ± 0.10	6.09 - 7.70 6.92 ± 0.08	5.55 - 7.73 6.83 ± 0.11	P>0.05
Dissolved Oxygen	4.40 - 7.80 6.43 ± 0.18	4.80 - 8.20 6.44 ± 0.17	5.40 - 8.80 6.39 ± 0.15	5.20 - 11.60 6.76 ± 0.28	5.40 - 7.80 6.50 ± 0.15	P>0.05
Biochemical Oxygen Demand	1.60 - 4.20 3.23 ± 0.15^{B}	1.60 4.10 2.83 ± 0.14^{B}	1.20 - 4.80 2.93 ± 0.13^{B}	0.80 - 4.80 2.65 ± 0.17^{A}	1.60 - 5.60 3.17 ± 0.18^{B}	P<0.05 *
Conductivity	11.00 - 123 33.48 ± 6.98	13.0 - 180.0 40.03 ± 7.33	16.00 - 208.0 50.92 ± 8.81	10.00 - 130.00 43.73 ± 7.03	14.00 - 110.00 48.86 ± 6.50	P>0.05
Alkalinity	20.00 - 75.0 50.65 ± 3.01	17.50 - 100.00 48.71 ± 3.79	21.00 - 90.00 49.96 ± 3.35	17.50 - 80.00 47.94 ± 3.85	19.20 - 95.00 45.92 ± 3.80	P>0.05
Chloride	9.36 - 25.90 19.16 ± 0.87	8.78 - 26.33 19.01 ± 0.89	8.78 - 24.62 18.85 ± 0.88	9.11 - 34.50 19.76 ± 1.11	7.02 - 25.56 18.59 ± 0.90	P>0.05
Suphate	0.05 - 0.43 0.13 ± 0.02	0.06 - 0.23 0.13 ± 0.01	0.02 - 0.29 0.14 ± 0.01	0.05 - 0.41 0.16 ± 0.02	0.03 - 0.34 0.14 ± 0.02	P>0.05
Nitrate	0.04 - 0.61 0.25 ± 0.03^{A}	0.09 - 0.73 0.31 ± 0.04^{B}	0.06 - 0.73 0.33 ± 0.04^{B}	0.06 - 0.69 0.34 ± 0.04^{B}	0.10 - 1.14 0.39 ± 0.05^{B}	P<0.05 *
Phosphate	0.28 - 2.88 1.61 ± 0.13	0.72 - 3.06 1.73 ± 0.12	0.15 - 2.60 1.66 ± 0.12	0.43 - 3.10 1.79 ± 0.13	0.40 - 3.52 1.73 ± 0.13	P>0.05
Sodium	0.47 - 10.56 3.40 ± 0.54	1.19 - 19.10 3.71 ± 0.74	0.89 - 15.40 3.50 ± 0.62	0.99 - 17.50 3.49 ± 0.70	0.18 - 14.16 3.29 ± 0.59	P>0.05
Potassium	0.11 - 3.20 1.50 ± 0.16	0.16 - 5.84 1.46 ± 0.22	0.20 6.35 1.74 ± 0.32	0.15 - 5.96 1.52 ± 0.24	0.15 - 6.24 1.42 ± 0.25	P>0.05
Calcium	1.23 - 9.62 3.14 ± 0.35	1.11 - 7.21 3.08 ± 0.28	1.53 6.41 3.04 ± 0.26	1.65 - 8.71 3.34 ± 0.34	1.18 - 5.82 2.89 ± 0.18	P>0.05
Magnesium	0.49 - 7.78 1.59 ± 0.29	0.20 - 3.89 1.47 ± 0.16	0.62 - 3.89 1.47 ± 0.15	0.60 - 4.86 1.70 ± 0.21	0.41 - 5.84 1.60 ± 0.23	P>0.05

*** Significantly different means (P<0.05); similar letters indicate means that are not significantly different using Duncan Multiple Range Test.**

The air temperature was highest in station 3 with a mean of 33.7°C and it was significantly higher ($P<0.05$) than the other stations. There was no significant difference ($P > 0.05$) between the mean surface water temperatures in the study stations. Temporal variation for both air and surface water temperature was quite distinct, and the pattern of fluctuation was similar in all the stations (Fig. 2a-b). Figures 2c -2g represent the temporal variations of transparency, turbidity, Total dissolved solids, Total suspended solids and Total solids, while figures 2h – 2t shows temporal variations of other physicochemical parameters as indicated in the figures.

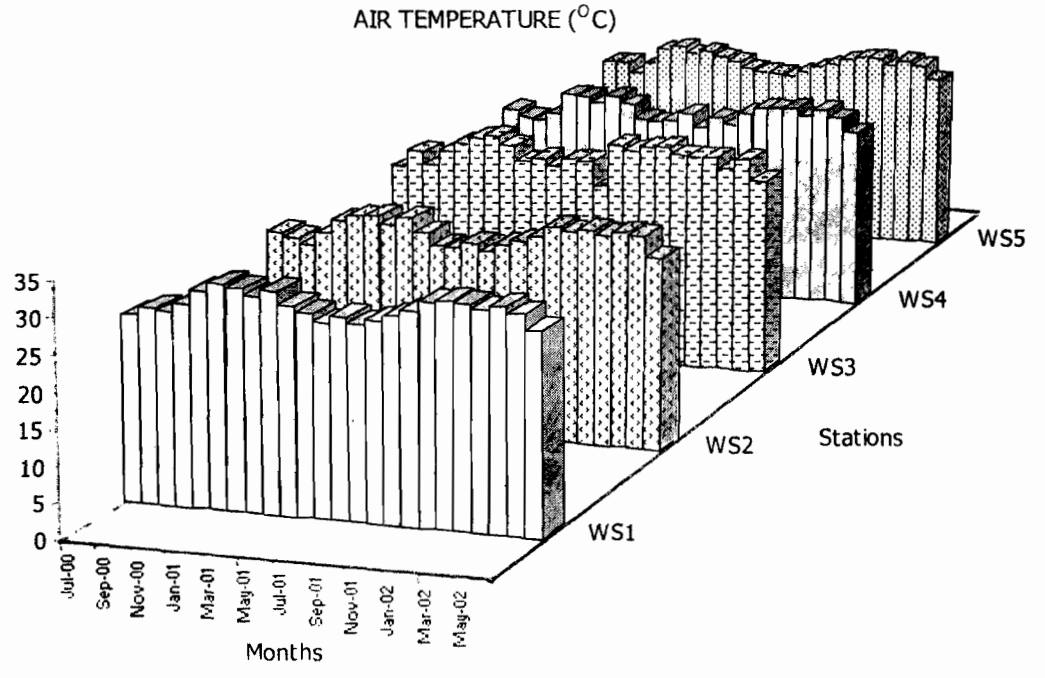

Fig. 2a: Temporal variation in the of Air Temperature (°C) at the study stations.

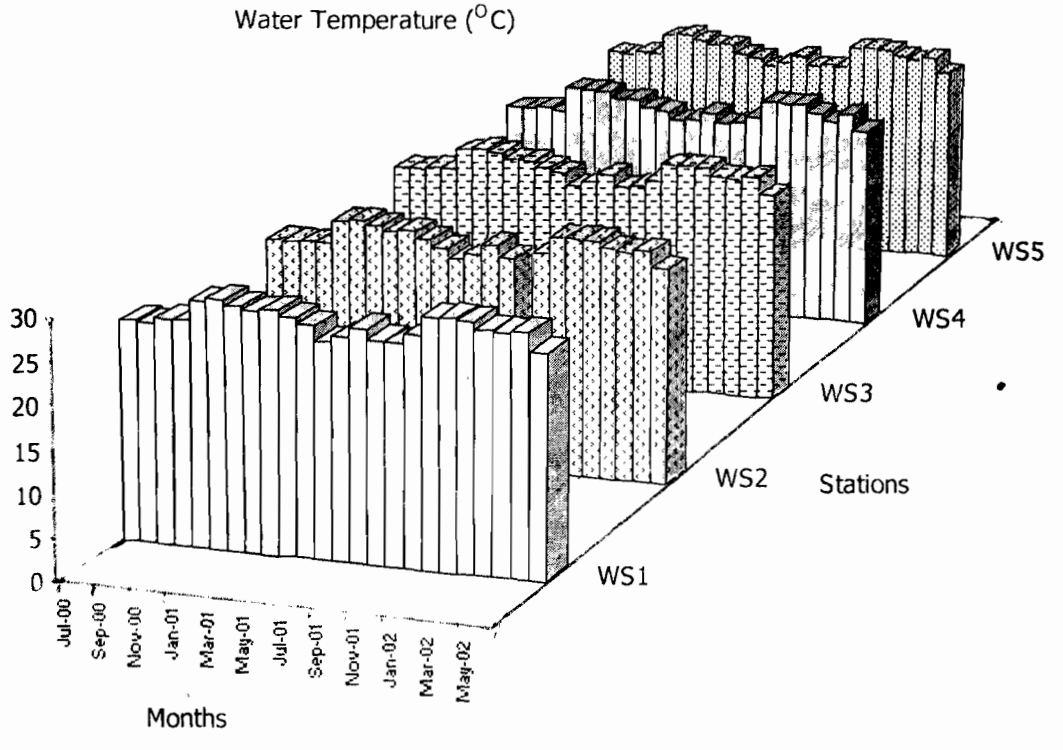

Fig.2b: Temporal variation in the of Water Temperature (°C) at the study stations.

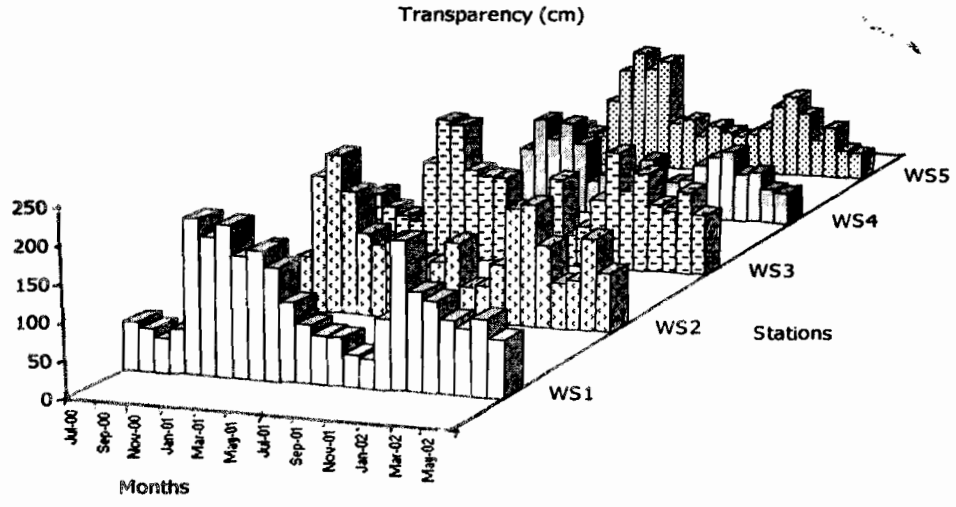

Fig. 2c Temporal variations of Transparency (cm) at the study stations

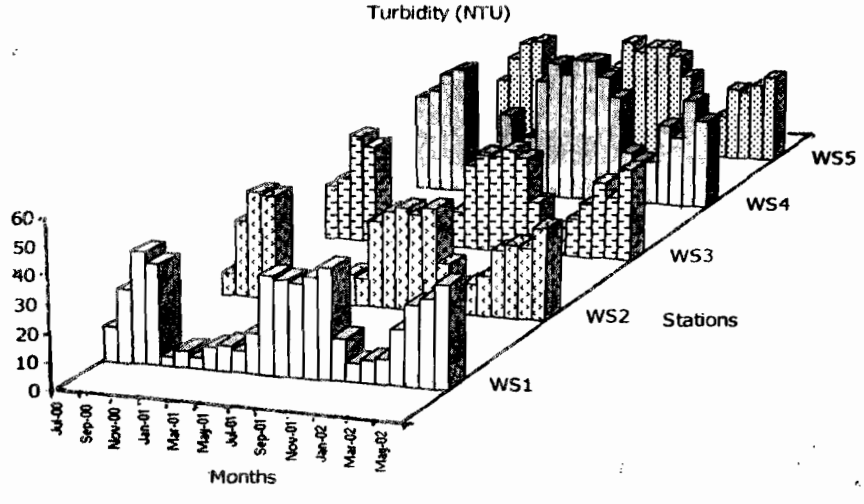

Fig. 2d: Temporal variations of Turbidity (NTU) at the study stations

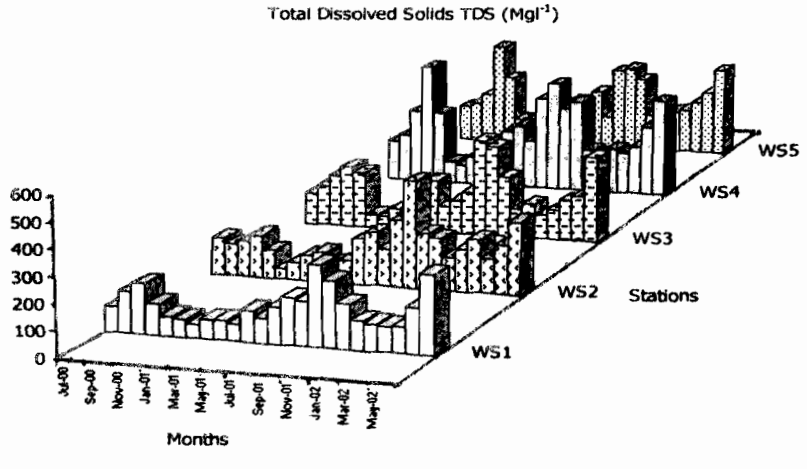

Fig. 2e: Temporal variation in the Total Dissolved Solids (Mgl^{-1}) at the study stations

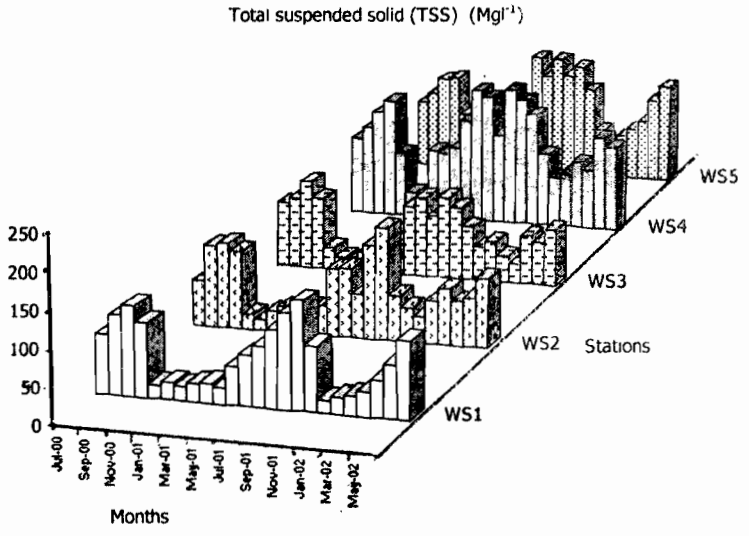

Fig. 2f: Temporal variations in the Total suspended solids (TSS) (Mgl^{-1}) at the study stations

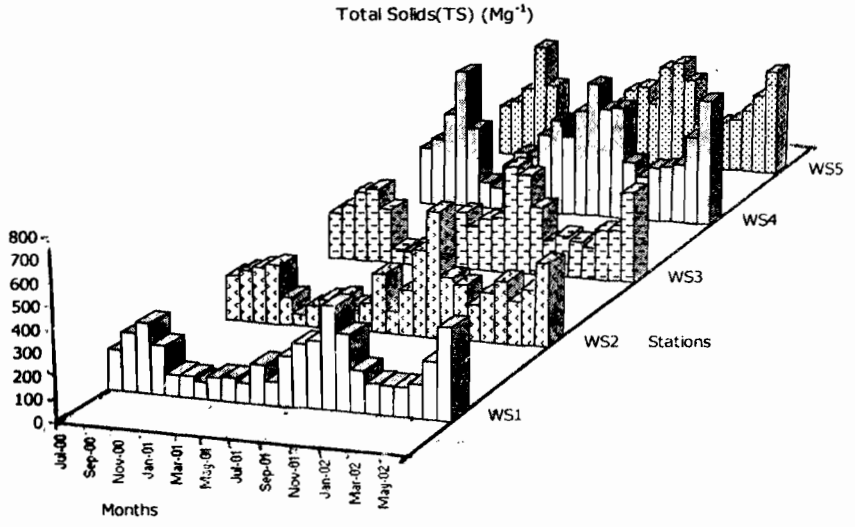

Fig. 2g: Temporal variation in the concentration of Total Solid (TS) (Mgl^{-1}) at the study ...

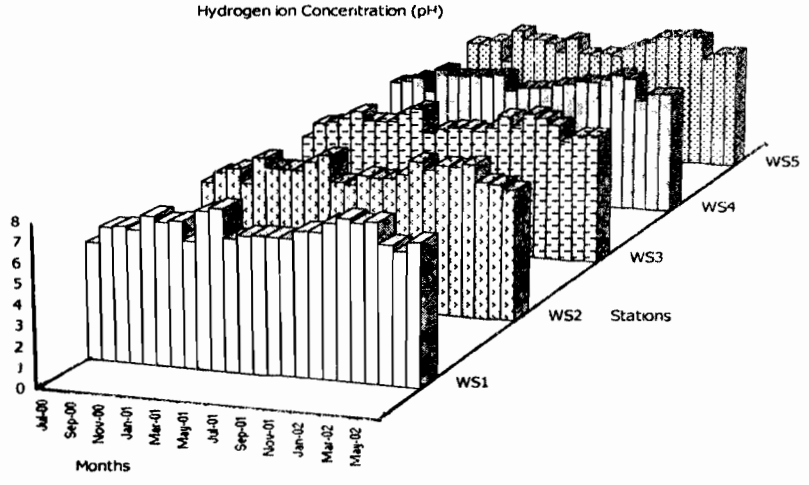

Fig.2h: Temporal variations in the Hydrogen ion concentration (pH) at the study stations

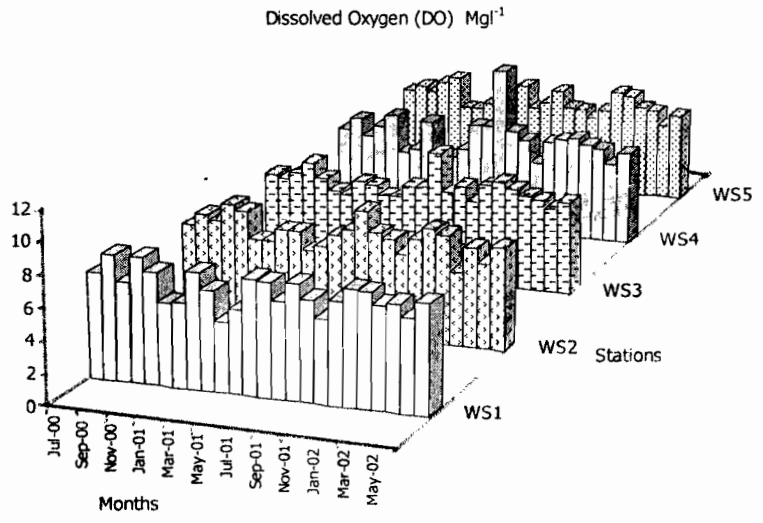

Fig. 2i: Temporal variations in the Dissolved Oxygen (DO) contents at the study stations

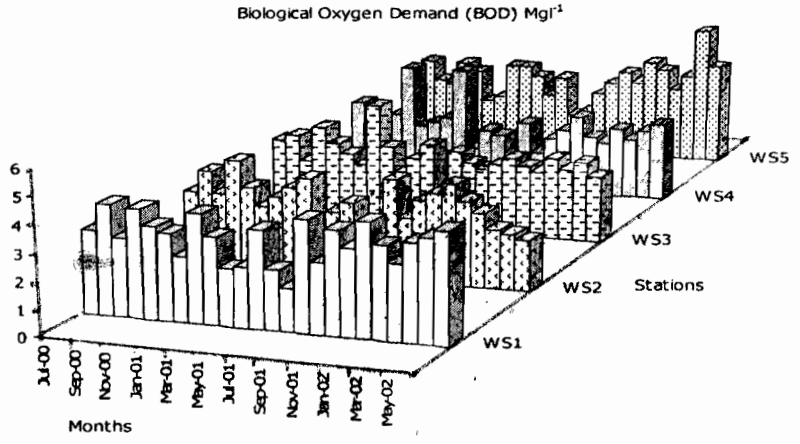

Fig. 2j: Temporal variation in the concentration of Biological Oxygen Demand (BOD) Mgl^{-1} at the study stations

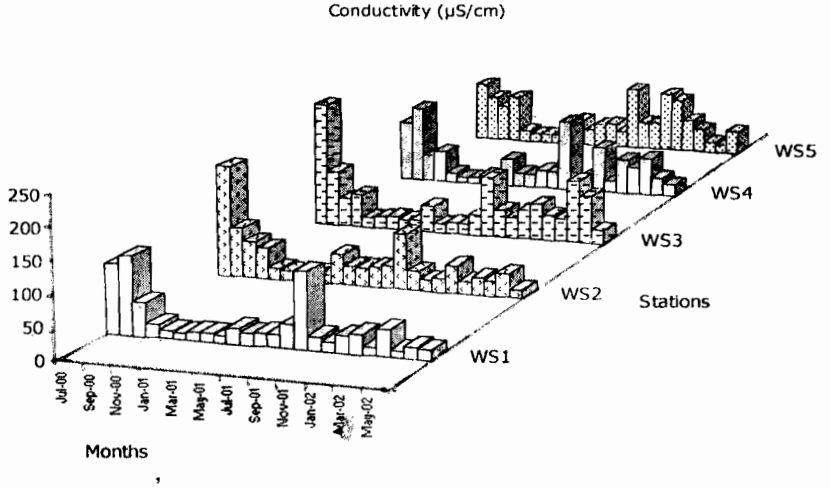

Fig. 2k: Temporal variations of Conductivity (µS/cm) at the study stations

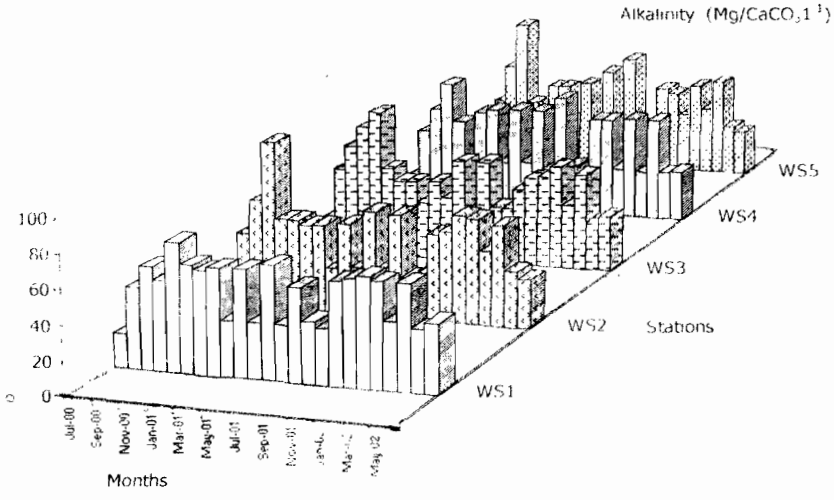

Fig. 2l: Temporal variation in the Alkalinity ($Mg/CaCO_3 l^{-1}$) at the study stations

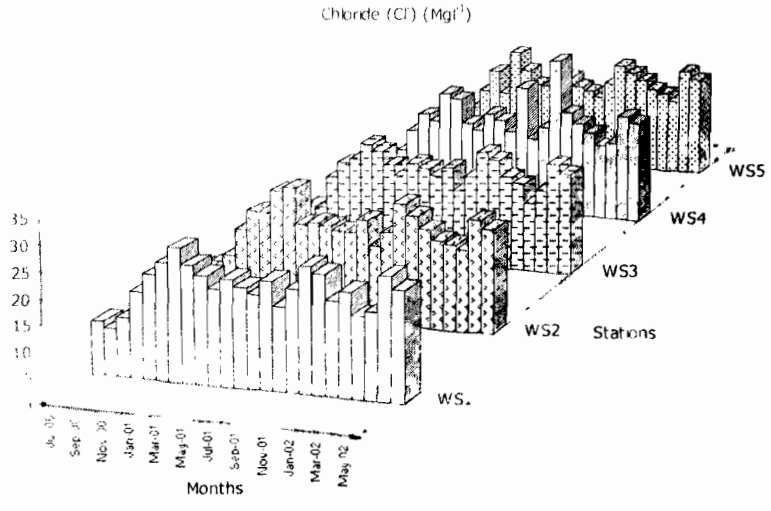

Fig. 2m: Temporal variation in the concentration of Chloride (Cl^-) (Mg^{-1}) at the study stations

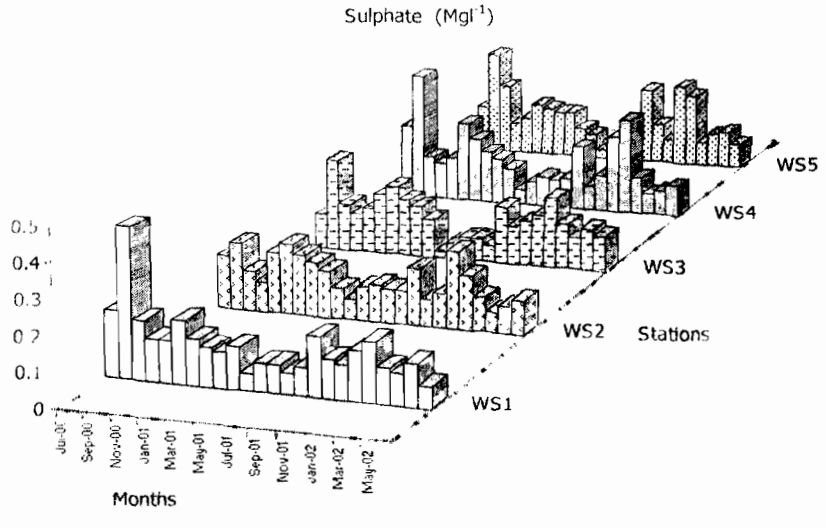

Fig. 2n: Temporal variation in the concentration of Sulphate (Mgl^{-1}) at the study stations

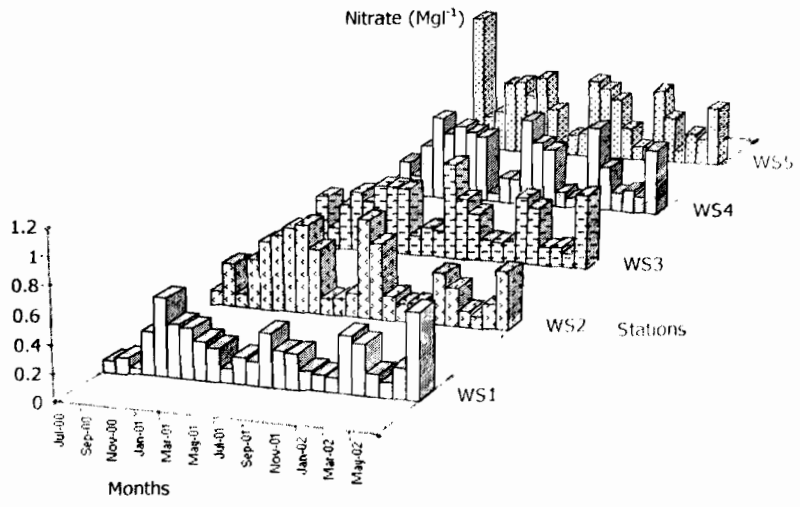

Fig. 2o: Temporal variation in the Nitrate (Mgl^{-1}) contents at the study stations

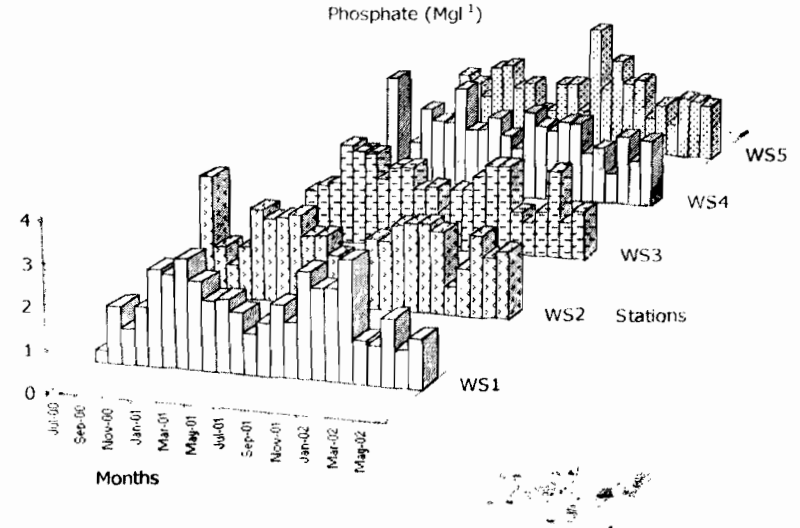

Fig. 2p: Temporal variation in the concentration of Phosphate (Mgl^{-1}) at the study stations.

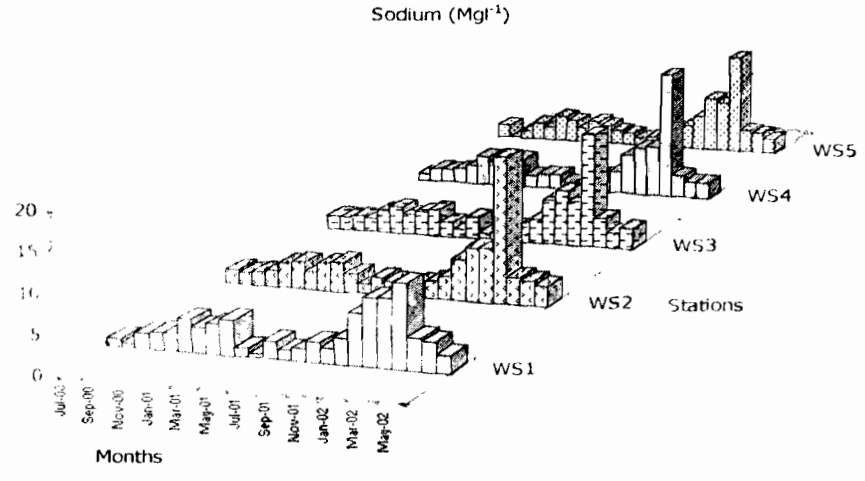

Fig. 2q: Temporal variations in the concentration of Sodium (Mgl^{-1}) at the study stations

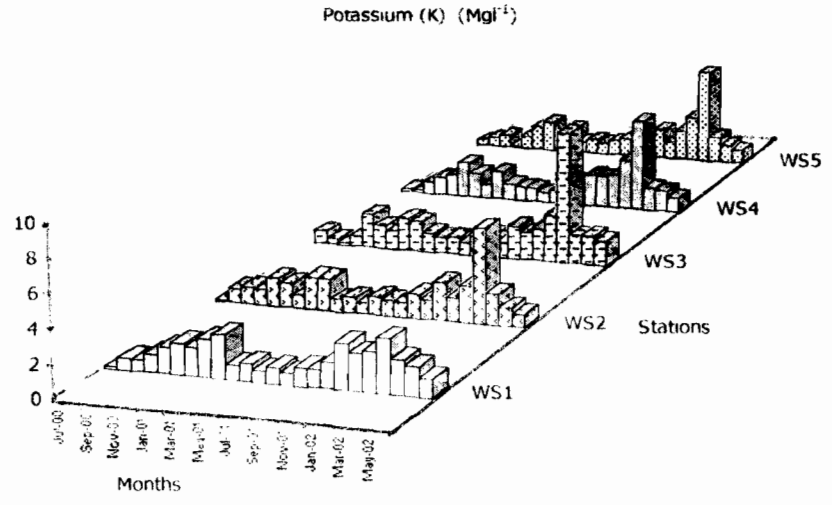

Fig. 2r Temporal variation in the concentration of Potassium (K) (Mgl^{-1}) at the study stations

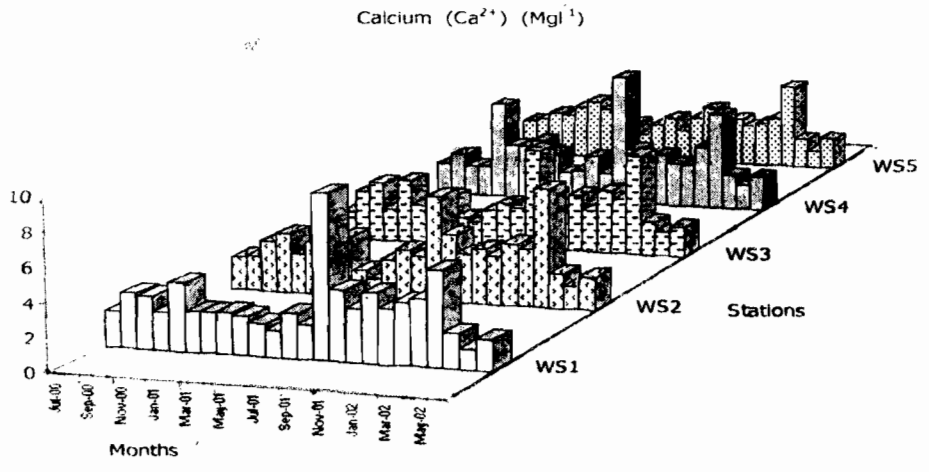

Fig. 2s Temporal variation in the concentration of Calcium (Ca^{2+}) (Mgl^{-1}) at the study stations

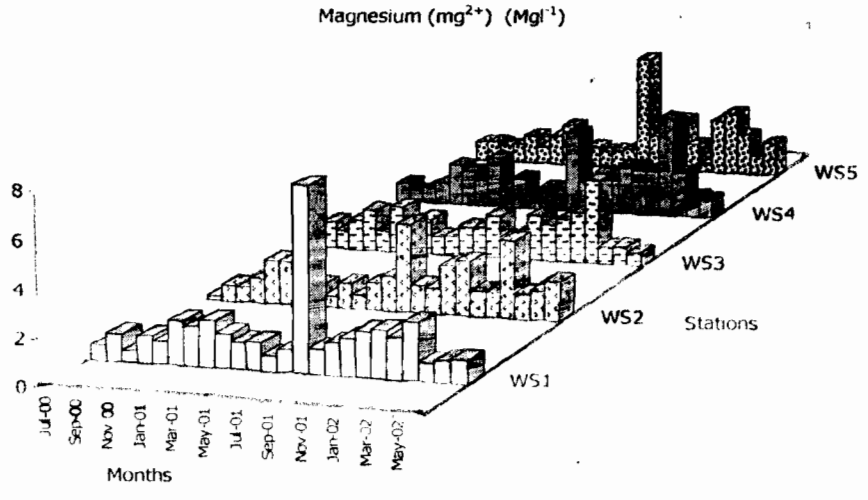

Fig. 2t: Temporal variation in the concentration of Magnesium (mg^{2+}) (Mgl^{-1}) at the study stations

Total dissolved solids (TDS), total suspended solids (TDS) and the total solids (TS) ranged from 138.53mgl^{-1} to 256.73mgl^{-1}; 64.38mgl^{-1} to 128.75mgl^{-1} and 200.40mgl^{-1} to 388.85mgl^{-1} respectively. The solids in stations 4 and 5 were significantly different (P< 0.05) from those of stations 1, 2 and 3. The trend of temporal variations in these parameters was similar, distinct seasonality was observed in the study stations, with an increase in solids during the rainy seasons and considerable decrease in the dry season months.

Transparency ranged from 74.33cm to 109.63cm and stations 1 and 3 were significantly difference (P<0.05) from all other stations. Turbidity values ranged from 20.73NTU to 36.10NTU, and stations 4 and 5 were significantly higher (P<0.05) than stations 1, 2 and 3. Temporally, there was a distinct seasonal pattern in the variation of both transparency and turbidity. While transparency values were highest in the dry season months, the reverse was the case for turbidity.

Hydrogen ion concentration (pH) values ranged from 5.55 – 7.91. There was no significant difference (P>0.05) in the pH values and temporal variation was minimal throughout the sampling period. The mean Dissolved Oxygen (DO) values 6.39mgl^{-1} to 6.76mgl^{-1}, and there was no significant different (P>0.05) among the study stations. The Biochemical oxygen demand (BOD) mean values ranged from 2.65mgl^{-1} to 3.23mgl^{-1}, and a significant difference (P<0.05) in station 4 was observed. Temporal variations were observed to be irregular for both DO and BOD in the study stations.

The conductivity, total Alkalinity and chloride values ranged from 33.48µs cm^{-1} to 50.92µs cm^{-1}; 45.92mgCaCo$_3$l^{-1} to 50.65mgCaCo$_3$l^{-1} and 18.59mgl^{-1} to 19.74mgl^{-1} respectively. There was no significant difference (P>0.05) in the mean values of these parameters in the study stations. Temporal variations were observed to be irregular. The values for sulphate ranged from 0.13mgl^{-1} to 0.16mgl^{-1}, while the values for phosphate ranged from 1.61mgl^{-1} to1.74mgl^{-1}. There was no significant difference (P>0.05) in the mean concentrations of sulphate and phosphate in the study stations. The concentrations of nitrate values vary from 0.25mgl^{-1} to 0.39mgl^{-1}, and the mean value at station 1 was significantly different (P<0.05) from other stations. Temporal variations in these parameters showed similar trends, with higher concentrations observed in the rainy season.

The cations sodium and potassium values ranged from 3.29mgl^{-1} to 3.71mgl^{-1} and 1.42mgl^{-1} to 1.74mgl^{-1} respectively. The mean values of these cations were not significantly different (P>0.05) among the study stations. Temporal variations pattern was similar with higher values observed in the dry season. The alkaline earth metals calcium and magnesium values ranged from 2.89mgl^{-1} to 3.34mgl^{-1} and 1.47mgl^{-1} to 1.70mgl^{-1} respectively. The mean values of both parameters were not significantly different (P>0.05) among the study stations. Temporal variations in these alkaline earth metals were minimal as no discernible seasonality was observed.

DISCUSSION

The variations in the water quality parameters of Osse River show that, like most tropical rivers, it is governed by external factors as well as interactions between the various facets of its hydrology and biology. The air temperature which ranged from 26.1^{0}C to 33.7^{0}C had the highest value recorded at station 3 (Gelegele), indicating heat radiation from the gas flare. The environmental impact of gas flaring includes retardation of plant growth, depletion of aquatic animals and effect on the health of the inhabitants of the area (Opafunso, 2005). The surface water temperature values ranged from 25.2^{0}C to 29.1^{0}C. The impact of the oil Company activities on the surface water temperature was negligible. This could be explained by the fact that water has great specific heat capacity and studies on Nigerian rivers indicate homiothermy along the length of all rivers for distances of up to 25km (Egborge *et al.*, 1986).

The solids in water are categorized into Total, Dissolved and Suspended solids with values that ranged from 138.53mgl^{-1} to 256.73mgl^{-1}(TDS) 64.38mgl^{-1} to 128.75mgl^{-1}(TSS) and 200.40mgl^{-1} to 388.85mgl^{-1} for total solids. Although there was no discernible environmental impact at station 3, the high values observed at stations 4 and 5 can be attributed to the result of the activities of the Logging Company located on the river bank at station 4. Also, high concentrations of solids can also be due to the allochthonous material from the various creek and run-off into the river. Transparency values ranged from 38.0cm to 225cm, and were highest at stations 1 and 3. The high domestic activities such as laundering and production of local gin at station 2 and the activities of the Logging Company at station 4 explains the low values observed at these stations. Distinct seasonal variations, a trend consistent with reports from other Nigeria waters (Imoobe and Oboh, 2003) was observed.

The pH range for the river (5.55 – 7.91) falls within the slightly acidic condition, typical of tropical forest river. The values recorded in this study are similar to those recorded in many Nigerian water bodies (Nwadiaro and Umeham, 1985; Imoobe and Oboh, 2003, Ogbeibu and Anagboso, 2004; Olomukoro and Egborge, 2004). The dissolved oxygen (DO) concentration of the river (6.39mgl^{-1} to 6.76mgl^{-1}) indicated a well aerated system irrespective of season and station. This is expected as it is running water where dissolved oxygen is usually not a limiting factor due to the direct diffusion at the surface and various forms of surface water agitation, such as wave actions and turbulence. The BOD values ranged between 0.80 – 5.60mgl^{-1} in this study. These were below values indicative of little organic pollution. The biochemical oxygen demand is widely used to determine the pollution strength of waste waters and the quality of receiving surface waters (Radojevic and Bashkin, 1999).

The mean conductivity range of 33.48µscm^{-1} – 50.92µscm^{-1} and chloride values of 18.59 mgl^{-1} 19.74 mgl^{-1} showed the water to be fresh in all the study stations. These values are indicative of the negligible impact of the Oil Company activities on the water quality of the river.

The value of sulphate in Osse River is low and similar to that of Utor River (0.20 – 0.23mgl^{-1}) reported by Ogbeibu and Anagboso (2004) and (0.08 – 0.4mgl^{-1}) reported for Ikpoba River by Ogbeibu and Edutie, (2002). The mean concentration range of nitrate was 0.25 – 0.39mgl^{-1} while that of phosphate was 0.15 to 3.52mgl^{-1}. These values were lower than current WHO guideline (50mgNO$_3$l^{-1}) for drinking water. Together with the nitrate levels, the phosphate levels points to the oligotrophic status of the Osse River, although a tendency towards eutrophic status was observed.

The alkali metals and alkali earth metals which constituted the major cations showed homogeneity across the study stations. The important cations in the river was in the other Na > Ca > K > Mg, similar to the observation of Nwadiaro and Umeham, (1985) for the Oguta Lake; Na > Ca > K > Mg for Utor River (Ogbeibu and Anagboso, 2004). The pattern of temporal variations was similar in all the stations; the effect of dilution in the rainy season was clearly observed.

The concentrations of the water quality parameters in the water of Osse River were lower than the WHO allowable limits for drinking water. It is concluded that environmental impact of the oil exploration and production activities of Dubri Oil Company on the water quality of Osse River was insignificant, and this may be corroborating the view of Wake (2005) that the discharge from oil refineries has reduced in quantity and toxicity over recent decades, allowing many impacted environment in the estuaries and coasts to make substantial recovery.

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