CHANGES IN THE PHYSICO-CHEMICAL ATTRIBUTES OF AN URBAN STREAM IN JOS, NIGERIA

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Abstract

River Delimi originates from hills around old airport area in Jos. An important river which flows across Jos City in central Nigeria. It was chosen for study in order to investigate the spatial and temporal variations in the physico-chemistry of its water. Five different locations were selected to reflect sections of possible human activities that are capable of changing the quality of its water. Generally, the surface water of the river was characterized by high turbidity (6 92 FTU), high conductivity (142 - 1125μmhoscm^{-1}), moderate dissolved oxygen content (1.3 12mg/l), and high alkalinity (20 410mg/l). Nutrient elements, NO_3-N and PO_4-P recorded moderately high values of between 1.0 6.6mg/l and 0.6 2.9mg/l respectively. It was observed that significant variation exists in the habitat attributes and in the quality of the sampled waters with sampling periods. The pattern of variability observed in the study was largely affected by both the interplay of diffuse pollution from land based anthropogenic activities and from climate changes due to seasonal variation. Stream flow was correlated positively with turbidity ($p < 0.05$), depth ($p < 0.01$), width ($p < 0.01$), velocity ($p < 0.01$), and PO_4-P ($p < 0.01$) concentration in water. However, conductivity and alkalinity correlated negatively with flow, turbidity, velocity and phosphate. The study indicates that increased nutrients input from activities within the catchments and terrestrial runoff are major threats to Delimi River. With increasing population and urbanization, the water quality will continue to deteriorate.

Keywords: Urban effluents, physicochemical, River Delimi, Jos-Nigeria.

INTRODUCTION

Urban rivers and man made canals are increasingly contaminated by the free discharge of industrial effluents, runoff from houses and agricultural lands, especially in storm conditions after periods of dry weather. Disturbance like pollution produce changes in the chemistry of the receiving water and the physical nature of the substratum, which subsequently exerts a differential effect upon the biota.

While chemical water- quality alteration has received considerable attention in urban streams (Paul and Meyer, 2001), the studies are largely based on the experience in temperate urban or sub-urban streams where disturbance is primarily a human affair. Rivers and streams in temperate regions share relatively uniform soil, climate and topography allowing direct comparison. Rivers in the tropics, on the other hand, require more attention because of their close interaction and service to a greater number of people and the important role they play in the epidemiology of many tropical diseases (Thomas and Tait, 1984; Hug et al, 1988). Many rivers in Africa lack adequate waste collection, treatment and disposal facility (Vowels and Connel, 1980; FAO, 1991 and Adakole and Anunne, 2003).

River Dilimi, owing to the rainfall pattern of the Jos plateau, experienced a prevailing high run-off accompanied by large delivery of organic and inorganic particulate with associated absorbed contaminants due to scouring action. This study therefore reports on the spatio-temporal changes in the physico-chemical characteristics of the river contributing significantly to the understanding of tropical freshwater ecosystems and the aspect of anthropogenic activities as the river becomes progressively polluted.

MATERIALS AND METHODS

STUDY AREA

The Jos Plateau (822' 9 30'E: 8 50' 1010'N) is a highland area in north-central Nigeria, bounded mostly by steep slopes to the surrounding plains, often 300 to 600 metres or more below (Khan and Ejike, 1984). The landscape is predominated by plutonic and volcanic rocks with sediments of alluvium and other unconsolidated deposits (Morgan, 1979). Jos, because of its elevation, is characterized by lower temperatures (average daily temperatures of 21C) and serves as source of many streams and rivers one of which is Delimi River.

Two distinct climatic periods prevail in the area. A dry season (October to February) dominated by the northeast trade winds popularly called "Harmattan that is characterized by cool and dusty winds (Morgan, 1979).

STUDY SITE

Delimi River is the main drainage system of Jos and its surroundings. Beyond Jos, it descends to the northern plain via a steep gorge. It then flows in an approximately northeast direction for about 400km before it confluences with the Hadejia river which flows into Lake Chad (Anadu and Akpan, 1986). Apart from the spring sources arising from hills around the Jos old Airport area, the river receives effluents from Jos Abattoir, Liberty dam spillover, Local mine washings, Yan-Shanu Market, Naraguta leather works company and other sundry and domestic effluents while draining the metropolis (Anadu and Akpan, 1986).

SAMPLING SITES

The section under consideration extends from upland, headwater near the old airport, through a rocky steep-sided area to a wide sandy riverbed zone around Babale. Five sampling sites were chosen on the mainstream channel to reflect the clean, polluted and recovery sections of the river and based on their accessibility and suitability for survey. The location and details of the sites chosen for the present survey are as outlined (Table 1 and Fig. 1).

Site 1, (1.3 km from source) is located close to the headwater upstream before Jos Abattoir where the water flows in tiny shallow strings. The water is'clean' at this site. Site 2 (5.0 km from source) lies downstream of the entry of the tributary from Rikkos with its nutrient rich water coming from Yan - shanu (cattle Market). The water is turbid, dark-gray in colour with unpleasant putrid odour, containing large amount of suspended organic remnants and refuse. Site 3 (10.5 km from source) is located after the stream had received most of the municipal effluents, at the downstream edge of the city. Agricultural use of land in the watershed is extensive here. Sites 4 and 5 are located on the plain, further downstream (16.5 km and 23.5 km from the source respectively).The banks are vegetated and there is great deal of human interference as farms, fadamas (dry season farms) and rural settlements are found close to the stream. The water is much clearer due to self - purification.

METHODS

The sampling area at each site was a defined 10 m length of stream termed a reach, chosen to be reasonably typical of a particular stretch of water (Holmes and Whitton 1981). Water samples were collected monthly in acid - washed 21 polyethylene containers between April 2004 and May 2005.

Flow or discharge was calculated from the equation represented in USEPA (1997). Temperature was determined in-situ with a thermometer while pH and conductivity were determined using a portable pH meter (Corning) and conductivity meter (EL model MC-1-Mark V). Dissolved oxygen was determined by Winkler's titrimetric method while Nitrate-nitrogen and Phosphate-phosphorus were determined spectrophotometrically using Hach water kid (DREL/1a) according to APHA (1985).

Two-way analysis of variance (ANOVA) using Microsoft Excel was used to determine whether there is significant variation between the physico-chemical variables measured for sites and sampling periods. The analysis also was aimed at determining relationship between physico-chemical attributes by using correlation analysis,

RESULTS

Various chemical parameters during the study period are presented in Fig. 2.The result indicated varied degree of responses (Table 2) with sampling period and sampling sites. Generally the surface water of the river was characterized by high turbidity (6 92 FTU), high conductivity (> 142μScm-1), Moderate dissolved oxygen content (1.3 12mg/l), high alkalinity (20 410mg/l). Nutrients, NO_3-N and PO_4-P recorded moderately high values of 1.0mg/l and > 0.6mg/l respectively.

The most marked spatial changes (Table 2) is that values of measured parameters which include water temperature, pH, velocity, were lowest for upstream site 1 for all sampling months. These values however, showed consistent increase downstream (site 2 -5). pH values and dissolved oxygen contents were lowest in Site 2. On the contrary, mean depth, conductivity, and turbidity showed consistent decrease downstream of Site 2. As expected physical properties such as water temperature, depth, width, velocity and flow increased significantly and steadily downstream. Another notable observation is the fact that Sites 4 and 5 tend to be significantly low in conductivity, alkalinity, NO_3 - N, PO_4 - P and SO_4 compared to Sites 2 and 3, which did not differ among themselves in respect to the parameters.

The most marked temporal changes indicated (Table 3) that the dry season values showed decrease in width, depth, velocity, flow and turbidity over those of the wet season. Dissolved oxygen dropped at the onset of rains for all sites but increased gradually to measure up with values in the dry season. Increases in alkalinity, pH and conductivity values for all sites were recorded in the dry season over those of the rainy season. Other water quality parameters such as nitrate and sulphate showed no significant temporal change. Comparatively low temperatures and decrease in flow prevailed generally in the dry season periods (October to February) while higher temperatures and high flows were evident during the rainy season (May to September) when the storm run - off entered the river. With the exception of dissolved oxygen, nitrate nitrogen and sulphate concentrations, all other parameters differed significantly ($p < 0.01$) with sampling period.

Table 3 gives the relationship of various parameters during the study. Significant relationships were evident between many variables during the study. Stream flow was correlated positively with turbidity ($p < 0.05$), depth ($p < 0.01$), width ($p < 0.01$), velocity ($p < 0.01$), and PO_4-P ($p < 0.01$) concentration in water. However, conductivity and alkalinity correlated negatively with flow, turbidity, velocity and phosphate.

DISCUSSION

The significant variation in the different parameters observed could be attributed to flow variability and changes in watershed conditions. This agrees with the observations of Chukwu and Nwankwo (2003) and Akpan (1990) who reported that the high variability in water quality may be due to the impact of extrinsic factors (e.g. rainfall and surface runoff) and catchment's activities which prevailed during the rainy and dry season periods respectively. Adebisi (1981) and Chapman and Kramer (1981) have also reported that in tropical systems marked variation in temperature and rainfall between season influenced the physico-chemical characteristics of water bodies.

The higher values of alkalinity, conductivity, turbidity and nutrient load coupled with reduced dissolved oxygen content in low flow months (December to March) are obviously due to the contribution of domestic effluents and wastewater, which usually dominates river contents within the city at these times. Similar increases in conductivity and nutrient load are found to be associated with increase in urbanization (May *et al*, 1997; Walsh *et al*, 2005 and Booth, 2005). The worsening of water quality in Sites 2 to 5 can be attributed to discharges from Yan-shanu (Cattle market) stream, a tributary that joins at Site 2 with complex mixture of animal waste in addition to other domestic and sundry wastewater along the way.

The pH level and dissolved oxygen for Site 2 is exceptionally low through out the study because of the high autochthonous input into the stream at this site. Akpata *et al*, (1993) and Chukwu and Nwankwo (2003) recorded a similar low dissolved oxygen concentration at organically polluted sites. From the results obtained however, it seems that the pollution load in site 2 may probably be directly or indirectly used as food resource in the downstream sections (sites 4 and 5) situated beyond the settlement. This is corroborated by the improvement in water quality (e.g. D.O and pH) in the sites. This is more so because Omoregie *et al*, (2002) worked on the same river and sampled downstream beyond (about 35kms from the source) and discovered that this portion of the river showed recovery from pollution.

The high surface conductivity from site 2 downward (20 410mg/l) is a pointer to the eutrophic status of the river. Adakole (2003) gave a similar report in a study on urban stream in Zaria, Nigeria.

Conclusively, it is clear that the pattern of variability observed in the study was largely affected by both the interplay of diffuse pollution from land based anthropogenic activities and from climate changes due to seasonal variation. It was observed that the stress to the river is aggravated during both the low flow periods and also the rainy season that is characterized by torrential rains due to existing topography leading to high input of inorganic and organic particulate with associated contaminants.

The ability of the river to purify itself after organic contamination has been demonstrated by improvement in water quality beyond the effluent receiving sites due to decomposition, dilution and sedimentation. However, with increasing population and urbanization the water quality of the river will continue to deteriorate. Reduction in nutrient loads into the river as well as provision of sanitation facilities to the riparian communities are needed to control further water degradation.

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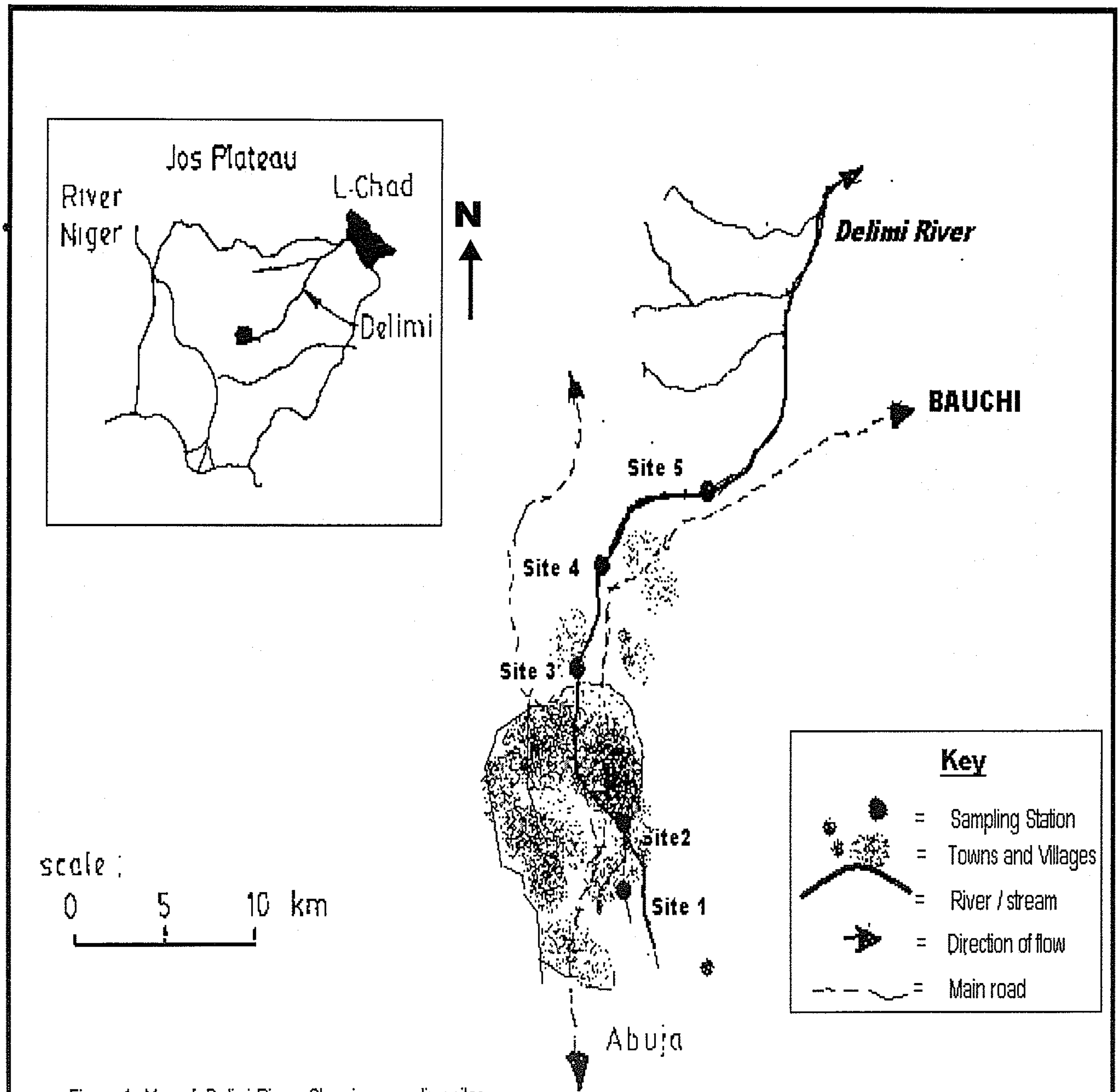
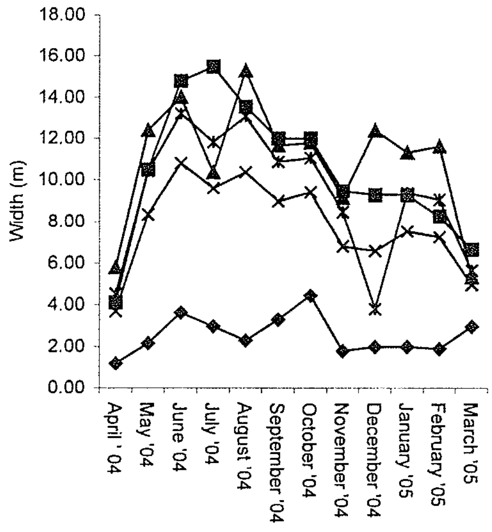
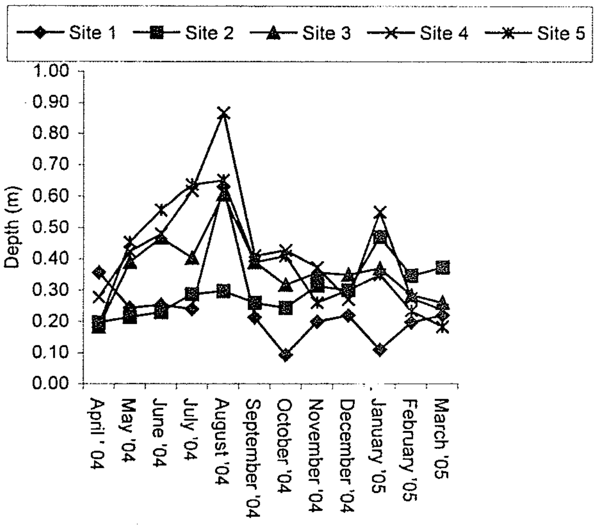


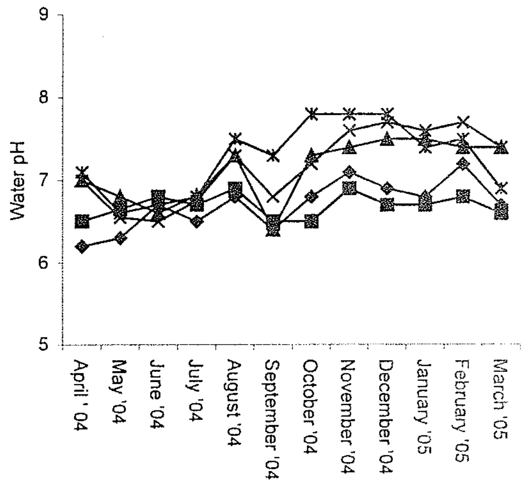
Figure 1: Map of Delimi River Showing sampling sites

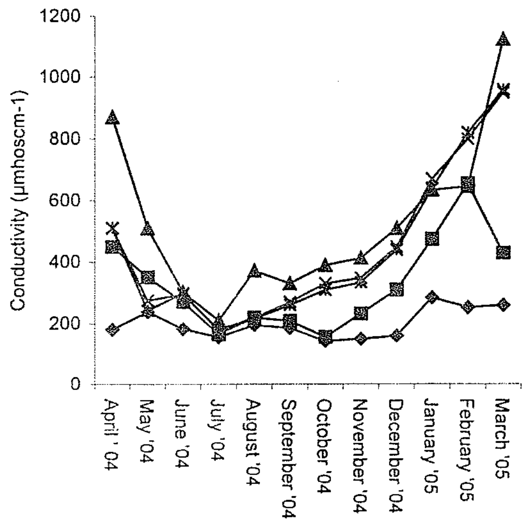
Table. 1. Background information on the study sites.

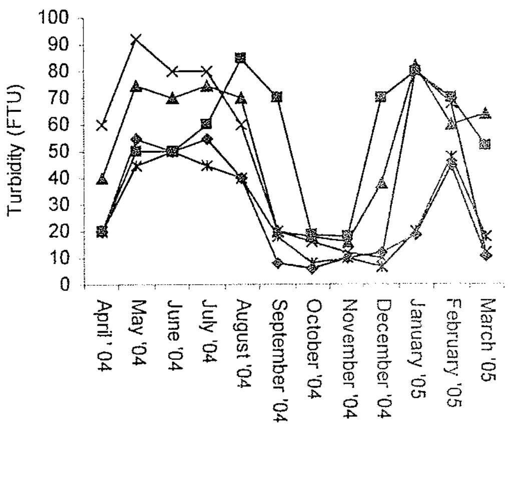
SITE	DISTANCE FROM SOURCE (Km)	LOCATION	ALTITUDE (M)	GRID REFERENCE LAT.	GRID REFERENCE LONG.
1	1.3	Near Jos Abattoir.Jos.	1230	8^{0} 54^{1} E	9^{0} 54^{1} N
2	5.0	Nasarawa Bridge, Delimi street, Jos.	1160	8^{0} 54^{1} E	9^{0} 55^{1} N
3	10.5	Student village Bridge, Farin-Gada road, Jos.	1090	8^{0} 53^{1} E	9^{0} 58^{1} N
4	16.5	Beyond Naraguta Village, off Bauchi- Jos road, Jos	1040	8^{0} 54^{1} E	10^{0} 00^{1} N
5	23.2	Behind Barikin Babale, off Bauchi- Jos Road, Jos	890	8^{0} 57^{1} E	10^{0} 54^{1} N

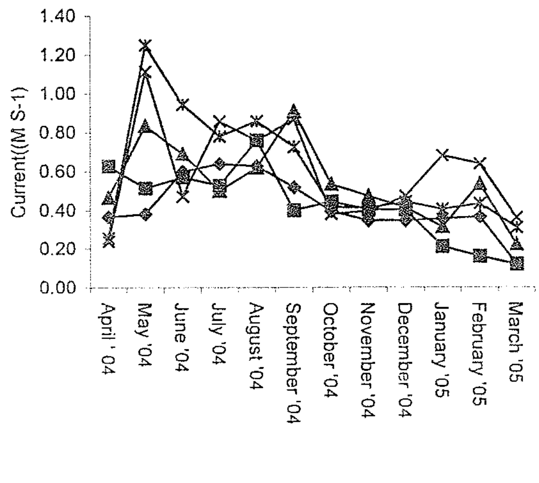

Width (m)
April ' 04
May '04
June '04
July '04
August '04
September '04
October '04
November '04
December '04
January '05
February '05
March '05


Site 1
Site 2
Site 3
Site 4
Site 5
Depth (m)
April ' 04
May '04
June '04
July '04
August '04
September '04
October '04
November '04
December '04
January '05
February '05
March '05


Water pH
April ' 04
May '04
June '04
July '04
August '04
September '04
October '04
November '04
December '04
January '05
February '05
March '05


Conductivity (µmhoscm-1)
April ' 04
May '04
June '04
July '04
August '04
September '04
October '04
November '04
December '04
January '05
February '05
March '05


Turbidity (FTU)
April ' 04
May '04
June '04
July '04
August '04
September '04
October '04
November '04
December '04
January '05
February '05
March '05


Current((M S-1)
April ' 04
May '04
June '04
July '04
August '04
September '04
October '04
November '04
December '04
January '05
February '05
March '05

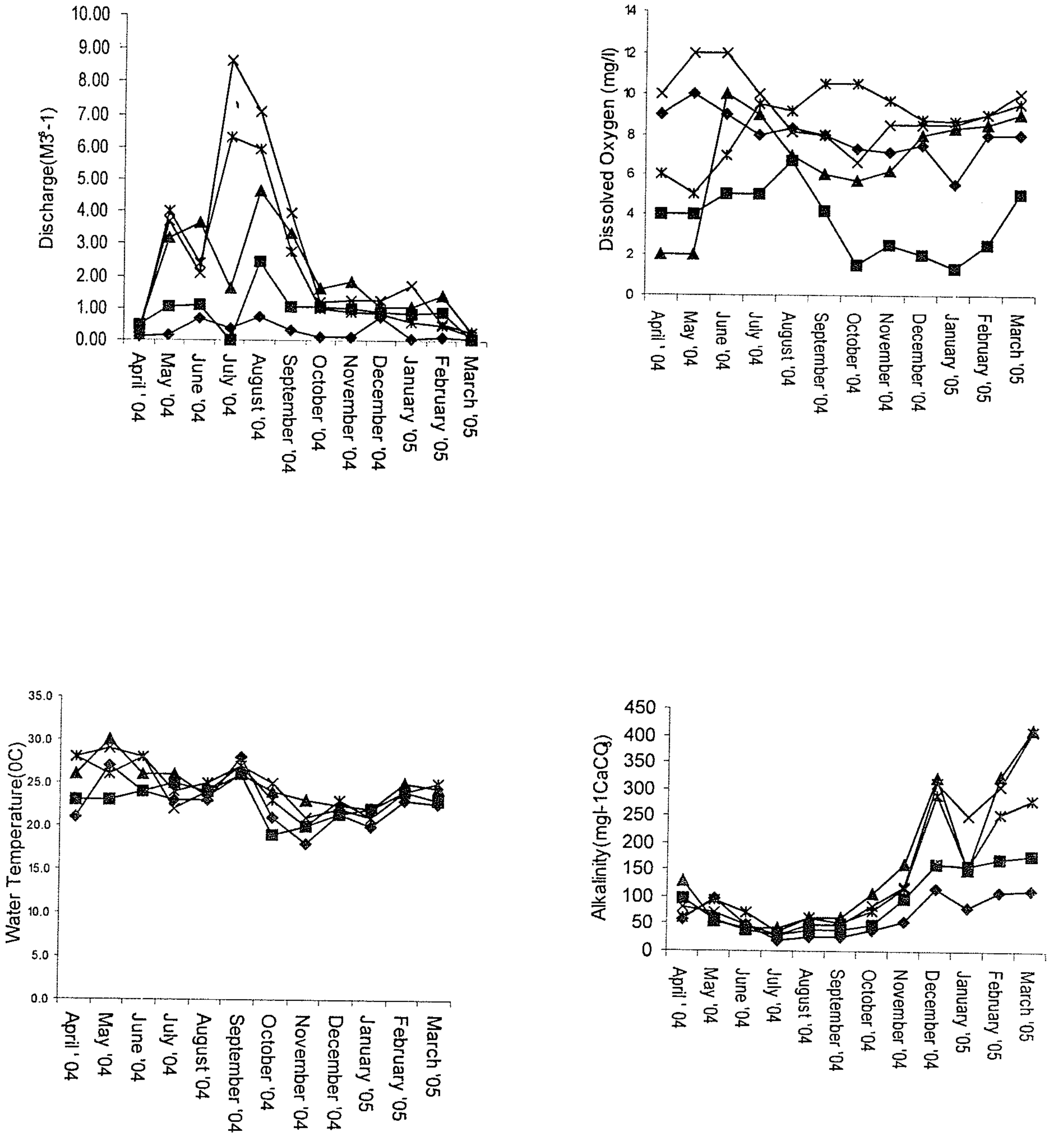


Fig 1: Monthly variation for different parameters studied for five stations on Dilimi River from April, 2004 to March, 2005.

Table 2: Summary of Physio-chemical properties of study sites, Dilimi River from April, 2004 to March, 2005.

PROPERTIES	N	SITE 1			SITE 2			SITE 3			SITE 4			SITS5			ANOVA
		Min.	Max.	Mean (S.E)	Min.	Max.	Mean (S.E)	Min.	Max.	Mean (S.E)	Min.	Max.	Mean	Min.	Max.	Mean (S.E)	
Physical																	
Air temperature (^{0}C)		26.0	33.0	28.667 (0.72)	27.0	33.0	29.667 (0.49)	27.0	34.0	30.875 (0.69)	26.0	37.5	30.583 (0.94)	26.0	38.0	30.633 (0.92)	P < 0.01
Water temperature (^{0}C)		18.0	28.0	22.683 (0.80)	19.0	26.0	22.875 (0.58)	22.0	30.0	24.875 (0.63)	21.0	29.0	24.667 (0.82)	20.0	28.0	24.500 (0.73)	P < 0.01
Mean depth (m)		0.09	0.63	0.248 (0.04)	0.20	0.47	0.294 (0.02)	0.18	0.61	0.365 (0.04)	0.24	0.87	0.434 (0.05)	0.18	0.65	0.384 (0.05)	P < 0.01
Mean Width (m)	12	1.19	4.45	2.557 (0.27)	4.11	15.50	10.479 (0.96)	5.33	15.30	10.933 (0.85)	3.77	20.47	8.64 (1.33)	3.51	15.80	7.39 (1.13	P < 0.01
Current ((M S^{-1})		0.12	0.64	0.422 (0.04)	0.12	0.76	0.428 (0.06)	0.22	0.91	0..542 (0.06)	0.24	1.12	0.603 (0.08)	0.26	1.25	0.603 (0.30)	P < 0.01
Discharge/Flow (M^3s^{-1})		0.063	0.728	0.293 (0.27)	0.015	2.466	0.901 (0.62)	0.245	4.617	1.992 (0.40)	0.278	8.670	2.663 (0.79)	0.154	6.305	2.119 (0.64)	P < 0.01
Turbidity (FTU)		6	55	27.540 (5.70)	18	85	53.670 (6.83)	16	82	52.33 (7.09)	10	92	49.17 (9.34)	7	50	27.42 (4.84)	P < 0.01
Chemical																	
Conductivity µmhoscm^{-1})		142	285	198.67 (13.88)	155	655	326.67 (43.50)	210	1125	525.9 (75.22)	180	950	441.42 (70.80)	176	960	434.08 (72.77)	P < 0.01
pH		6.2	7.2	6.700 (0.09)	6.5	6.9	6.687 (0.04)	6.4	7.5	7.118 (0.11)	6.5	7.7	7.175 (0.13)	6.6	7.8	7.267 (0.13)	P < 0.01
Alkalinity (mgl^{-1}$CaCO_3$)		20	116	65 (10.47)	28	176	92 (16.95)	41	410	155.08 (36.69)	28	409	15.38 (37..98)	36	289	127.92 (27.07)	P < 0.01
Dissolved Oxygen (mgl^{-1})		5.5	10	7.975 (0.32)	1.3	6.7	3.642 (0.48)	2.0	10.0	6.808 (0.75)	6.6	12	9.267 (0.46)	5.0	10.5	8.583 (0.50)	P < 0.01
Nitrate-Nitrogen (mgl^{-1})		1.0	4.0	1.990 (0.28)	1.8	5.0	4.070 (0.30)	2.0	6.6	4.240 (0.47)	3.0	5.5	3.950 (0.25)	2.2	4.5	3.330	P < 0.05
Phosphate- Phosphorus (mgl^{-1})		0.85	2.0	1.635 (0.12)	0.90	2.90	2.200 (0.17)	0.78	2.50	1.968 (0.15)	0.60	2.80	1.935 (0.21)	0.84	2.60	1.824 (0.14)	P < 0.01
Sulphate (mgl^{-1})		5.0	18.0	13.938 (1.47)	16.0	24.0	20.750 (1.02)	12.0	26.0	18.563 (1.87)	13.0	19.0	15.688 (0.73)	15.0	38.0	20.250 (2.89)	P < 0.05

NB: Standard error of mean in parenthesis. N= 12

Table 3: Correlation coefficient (r) values between some environmental variables at the various sampling sites in the river

Parameters	Mean Width (m)	Mean Depth (m)	Air Temperature (^0C)	Water Temperature (^0C)	pH	Conductivity(µmhoscm^{-1})	Turbidity (FTU Units)	Alkalinity(mgl^{-1}CaCO$_3$)	Current (M S-1)	Discharge(M^{3}s^{-1})	Dissolved oxygen(mgl^{-1})	Nitrate-Nitrogen(mgl^{-1})	Phosphate-Phosphorus(mgl^{-1})
Mean Depth (m)	0.531**												
Air Temperature (^0C)	0.030	0.046											
Water Temperature (^0C)	0.213	0.173	0.635**										
pH	-0.013	0.054	-0.234	-0.241									
Conductivity(µmhoscm^{-1})	-0.034	-0.066	0.283*	0.135	0.484**								
Turbidity (NTU Units)	0.432**	0.392**	0.087	0.304*	-0.247	0.112							
Alkalinity(mgl^{-1})	-0.255*	-0.159	-0.006	-0.211	0.540**	0.781**	-0.128						
Current (M s^{-1})	0.490**	0.492**	0.091	0.350**	-0.121	-0.247	0.249	-0.441					
Discharge (M^{3}s^{-1})	0.738**	0.745**	0.083	0.261*	0.088	-0.060	0.324*	-0.213	0.724**				
Dissolved oxygen(mgl^{-1})	-0.149	0.228	0.013	0.186	0.283*	0.016	-0.009	0.024	0.108	0.111			
Nitrate-Nitrogen(mgl^{-1})	0.376**	0.179	0.373**	0.134	0.036	0.305*	0.201	0.147	0.056	0.226	-0.099		
Phosphate-Phosphorus(mgl^{-1})	0.616**	0.459**	0.122	0.242	-0.231	-0.276	0.398	-0.421	0.334	0.492**	-0.201	0.228	
Sulphate(mgl^{-1})	0.132	0.016	0.063	-0.267	0.148	0.302	0.288	0.389	-0.340	-0.081	-0.094	0.317*	0.013

**Correlation Coefficient (r) is significant at the 0.01 level (2-tailed).
* Correlation Coefficient (r) is significant at the 0.05 level (2-tailed)

Table 4: Mean monthly values of some physico-chemical parameters measured in the study sites from April, 2004 to March, 2005.

Sampling Period	*Mean Width (m)*	*Mean Depth (m)*	*Air Temperature(^0C)*	*Water Temperature(^0C)*	*pH*	*Conductivity($\mu mhoscm^{-1}$)*	*Turbidity(FTU)*	*Alkalinity($mgl^{-1}CaCO_3$)*	*Current $m\ s^{-1}$)*	*Discharge(m^3s^{-1})*	*Dissolved oxygen(mgl^{-1})*	*Nitrate-Nitrogen(mgl^{-1})*	*Phosphate-Phosphorus(mgl^{-1})*	*Sulphate(mgl^{-1})*
April, 2004	3.70	.24	35.1	25.2	6.76	504.40	32.00	84.4	0.39	0.29	6.2	N.D	N.D	N.D
May, 2004	8.54	.34	31.0	27.0	6.58	323.00	63.40	74.0	0.82	2.45	6.6	N.D	N.D	N.D
June, 2004	9.97	.40	32.6	26.0	6.66	269.60	60.00	49.4	0.66	1.97	8.6	4.2	2.0	N.D
July, 2004	13.02	.44	27.4	24.0	6.71	177.20	63.00	30.8	0.66	3.39	8.3	3.7	2.3	N.D
August, 2004	11.16	.61	27.6	23.9	7.16	244.40	59.00	46.6	0.72	4.17	7.8	2.2	2.4	14.9
September, 2004	9.50	.33	32.2	26.8	6.68	250.60	27.20	44.2	0.68	2.27	7.3	3.4	2.2	12.9
October, 2004	8.88	.30	30.2	22.4	7.12	265.40	13.40	69.8	0.43	0.98	6.3	4.1	2.0	19.8
November, 2004	6.90	.30	29.0	20.4	7.36	295.40	13.20	108.0	0.41	1.01	6.8	4.1	2.0	20.9
December, 2004	6.88	.29	26.8	22.1	7.32	374.00	27.40	239.6	0.42	0.95	6.9	3.4	1.8	17.2
January, 2004	6.66	.37	29.4	21.2	7.20	540.80	56.20	159.2	0.39	0.85	6.4	3.5	1.8	19.2
February, 2004	6.21	.27	29.9	24.0	7.32	634.40	58.20	232.8	0.43	0.67	7.4	3.7	1.9	20.3
March, 2004	4.55	.25	29.8	24.0	7.00	745.00	31.30	277.2	0.23	0.16	8.3	2.8	0.8	17.5

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