Physico-Chemical Characteristics of a Tropical Stream in Nigeria

Ibemenuga, K. N. and Inyang, N. M.
Fisheries and Hydrobiology Unit, Department of Zoology, University of Nigeria, Nsukka.

Corresponding author: Ibemenuga, K. N. Fisheries and Hydrobiology Unit, Department of Zoology, University of Nigeria, Nsukka, Nigeria. Email: jesusvesselofhonour@yahoo.com

Abstract

The physico-chemical characteristics of Ogbei stream in Anambra State, Nigeria were studied monthly for 12 months (May, 2002 – April, 2003). Samples and data were taken from six sites/stations along the stream. Water samples were analyzed using appropriate analytical methods. The annual mean values of some parameters studied were temperature 27.47 ± 0.79°C, transparency 26.73 ± 3.59 cm, pH 5.53 ± 0.35, free carbon dioxide 11.60 ± 6.49 mg/l $CaCO_3$, dissolved oxygen 5.14 ± 0.69 mg/l, phosphate 0.25 ± 0.06 mg/l. Temperature, transparency, free carbon dioxide and hardness were significantly higher in the dry season than in the rainy season. Temperature, pH, dissolved oxygen and total alkalinity varied significantly in all the sites/stations. Apart from the carbon dioxide and alkalinity the values of other parameters were within the recommended limits for aquatic life including fish. The proposed impoundment with proper management strategies has lots of fishery potentials.

Keywords: Physico-chemical parameters, Ogbei stream

Introduction

The quality of a stream or any water body, is influenced by both its physico-chemical and biotic characteristics. A number of factors, on the other hand, influence the physico-chemical characteristics of water body, which in turn influence the distribution, structure and functioning of the biotic communities. The survival, growth, abundance and diversity of the biotic communities within the system are mediated by the level of presence or absence of particular substances in the water system.

That is why it is necessary to study the physico-chemical characteristics of any system, if the resources of such a system are to be meaningfully managed and utilized. Streams and rivers have been intensively studied in the recent years because of the large and diverse number of sites/stations that can be examined at a relatively low cost with simple equipment (Resh and Jackson, 1993; Growns *et al.*, 1995).

Ogbei stream is an important source of water supply in Nkpologwu community. It is the main source of drinking water for the people and a number of activities (bathing, soaking/sieving of cassava, breadfruit, tapioca, fishing, lumbering, farming/gardening, etc) take place in and around the stream basin. Because of the stream's importance in the area, it has been proposed for impoundment to supply water for domestic and agricultural purposes. As part of the pre-impoundment studies of the stream, the macroinvertebrate fauna of the stream, has been reported (Ibemenuga and Inyang, 2006). The present paper which reports on the physico-chemical characteristics of the same stream is a further contribution to the scientific knowledge of the stream, first of its kind in the area. It is hoped that the information on the macroinvertebrate fauna of the stream will be useful for future studies and for the management of the stream resources.

Materials and Methods

Study area and sampling sites: A detailed description of the study area and the six sampling sites has been given in Ibemenuga and Inyang (2006). The study area is in Nkpologwu town in Aguata Local Government Area of Anambra State, Nigeria. It lies between latitude 5°58' N and 6° 01' N and longitude 7° 06' E. and 7° 08' E. The area is within the tropical rain forest region fringed with riparian vegetation. Six sampling sites were selected along the stream based on accessibility, type of substrate and human activities.

Sample collection and analysis: Samples and data were obtained monthly for 12 months (May, 2002 – April, 2003). At least three samples or data were obtained from each station on each sampling day. Temperature was obtained in the mornings (10.00 – 11.00 am) at each sampling site with a centigrade thermometer (0° C – 50° C). Water velocity (m/sec) at each site was determined between a known distance by floatation method using weighted cork and a stop watch. The depth (m) of water at each site was taken at different points using a graduated pole. The average of the depths at different points was taken as the mean depth of the station. The width (m) of the stream was measured at the widest portion of each site.

Transparency (cm) was determined using a 20-cm diameter secchi disc with a calibrated line. The mean depth at which the secchi disc disappeared and reappeared at raising it up was recorded as the secchi disc transparency (cm). pH was measured with battery operated pH meter (Model EIL, 3055).

Water samples for chemical analysis were obtained at the water surface with 250 ml stoppered bottles and analyzed using appropriate analytical methods (APHA, 1976; Stainton *et al.*, 1977; Golterman *et al.*, 1978).

Dissolved oxygen: Dissolved oxygen (DO) (mg/l) was determined by Winkler's titration method. The water sample was fixed in the field with manganous sulphate and potassium iodide solutions (1 ml each) and analyzed later by titrating it with N/40 sodium thiosulphate using starch solution as indicator after dissolving the precipitate with concentrated sulphuric acid. The DO concentration was obtained from the equation DO (mg/l) = (ml of titre) (N) (1000) / Sample used (ml), Where N = normality of titrant.

Free carbon dioxide: The concentration of free carbon dioxide (CO_2) was determined by titrating 100 ml of the water sample with 0.045 M sodium carbonate using phenolphthalein as indicator. The free carbon dioxide was calculated from the formula. Free carbon dioxide = A x N x 22, 000 mg/l $CaCO_3$ / 100 (volume of water sample), where A = volume of titre used and N = Molarity of Na_2CO_3 (APHA, 1976).

Alkalinity: Alkalinity was determined by titrating 100 ml of the water sample with 0.02 M sulphuric acid, using methyl orange as indicator. Since phenolphthalein indicator titration did not give any positive result, the methyl orange alkalinity was taken as the total alkalinity calculated as: Total alkalinity (mg/l) = B x N x 50 x 1000 mg/l H_2SO_4 / 100(volume of water sample), where B = volume of titre and N = molarity of the acid (APHA, 1976).

Hardness: Hardness was determined by titrating 100 ml of sample with 0.01 M EDTA solution using Eriochrome Black T as indicator. The total hardness was calculated as: Total hardness (mg/l $CaCO_3$) =(volume of EDTA) (M) (100) / (volume of water sample, where M = molarity of EDTA (APHA, 1976).

Nitrate: The nitrate-nitrogen was determined using ultraviolet spectrophotometric method (APHA, 1976). A standard nitrate solution containing 0 to 350 μg was prepared and used to plot the standard curve. The colour of the water sample was removed by adding 4 ml of aluminium hydroxide suspension to 100 ml of the water sample. Therefore 1 ml of 1.0 M hydrochloric acid was added to 50 ml of the clear water sample. The optical density read at 220 nm was converted to nitrate equivalent by reading the nitrate value from the standard curve.

Phosphate: Phosphate concentration was determined using stannous chloride method (APHA, 1976). One drop of phenolphthalein indicator was added to 10 ml of the water sample. After mixing thoroughly, 4.0 ml of molybdate reagent and 0.5 ml (10 drops) of stannous chloride solution were added to induce colour development. Concentrated sulphuric acid was added drop by drop until the colour disappeared. About 8.0 ml of the mixed reagent was added to the sample and mixed thoroughly. After 10 minutes the absorbence of each sample was measured at 690 nm in the spectrophotometer using the reagent blank as the reference solution. The phosphate concentration was read from the standard curve prepared using standard phosphate. To obtain inference 1 – 2 drops of concentrated sulphuric acid was added to the sample.

Results

Monthly variations in the physico-chemical parameters: Table 1 shows the mean monthly variations of the parameters studied. Temperature varied between 25.9 $\pm$ 0.82° C in August and 28.5 $\pm$ 0.13° C in March with an annual mean value of 27.47 $\pm$ 0.79° C. Depth varied slightly between February/March (0.46 $\pm$ 0.05 m) and August/September (0.62 $\pm$ 0.05 m) corresponding with variations in width (2.22 $\pm$ 0.39 m to 2.44 $\pm$ 0.40 m) in March and August respectively. The annual mean width was 2.33 $\pm$ 0.37 m. The mean monthly velocity in all the sites ranged from 0.05 $\pm$ 0.02 m/sec in March to 0.17 $\pm$ 0.03 m/sec. in August. Secchi disc transparency (cm) varied from 23.02 $\pm$ 2.50 cm in August to 30.93 $\pm$ 1.98 cm in March with an annual mean of 26.73 $\pm$ 3.59 cm. Dissolved oxygen (DO) concentration ranged from 4.35 $\pm$ 0.28 mg/l in March to 6.00 $\pm$ 0.33 mg/l in September with an annual mean of 5.14 $\pm$ 0.69 mg/l. The monthly pH varied slightly between 5.3 $\pm$ 0.38 and 5.8 $\pm$ 0.18 in March and December respectively with an annual mean of 5.53 $\pm$ 0.35. Free carbon dioxide (CO_2) varied widely from 5.65 $\pm$ 0.27 mg/l $CaCo_3$ in September to 24.98 $\pm$ 7.13 mg/l $CaCO_3$ in February with an annual value of 11.60 $\pm$ 6.49 mg/l $CaCO_3$. Total alkalinity fluctuated between 26.33 $\pm$ 2.14 mg/l $CaCO_3$ in December and 39.27 $\pm$ 7.64 mg/l $CaCO_3$ in May with an annual value of 33.25 $\pm$ 6.53 mg/l $CaCO_3$. Hardness ranged from 9.83 mg/l $CaCO_3$ in June to 19.98 $\pm$ 3.27 mg/l $CaCO_3$ in January. The highest value of phosphate concentration was recorded in September (0.34 $\pm$ 0.02 mg/l) and the lowest (0.19 $\pm$ 0.02 mg/l) in December and March respectively. The nitrate-N level in the stream was not detectable by the method used.

Seasonal variations of some parameters in Ogbei Stream: Table 2 shows the mean values of some parameters in the dry and rainy season months. The mean values of temperatures, transparency, free carbon dioxide and hardness were significantly higher ($P < 0.05$) in the dry season months than in the rainy season. The reverse was the case for the other parameters. Though the values for width and pH were higher in the rainy season, the difference was not significant ($P > 0.5$).

Variations of some physico-chemical parameters according to stations: Table 3 shows the variations of some parameters in relation to stations. The parameters varied slightly in all the stations. Temperature was highest at station 3 (27.8 $\pm$ 0.60° C) and lowest at stations 1 and 6 respectively (27.3° C). There was no significant difference in the values recorded in all the stations.

Table 1: Monthly variation in the physico-chemical characteristics of Ogbei stream, Nigeria

Month	Temperature (°C)	Depth (m)	Width (m)	Velocity (ms^{-1})	Transparency (cm)	pH	Free carbon dioxide ($mgl^{-1}CaCO_3$)	Dissolved oxygen (mgl^{-1})	Alkalinity ($mgl^{-1}CaCO_3$)	Hardness ($mgl^{-1}CaCO_3$)	Phosphate (mgl^{-1})
May	27.8±0.23	0.53±0.05	2.31±0.40	0.11±0.03	27.32±3.28	5.5±0.34	7.87±1.03	5.20±0.41	39.27±7.64	11.33±1.75	028±0.03
Jun.	27.6±0.31	0.55±0.06	2.35±0.40	0.12±0.03	26.28±3.06	5.5±0.50	6.42±0.15	5.47±0.68	33.50±6.77	9.83±1.08	0.28±0.05
July.	26.9±0.46	0.59±0.06	2.39±0.40	0.13±0.03	25.22±2.87	5.5±0.35	6.33±0.21	5.77±0.89	34.52±3.34	10.13±1.55	0.30±0.03
Aug.	25.9±0.82	0.62±0.06	2.44v0.40	0.17±0.03	23.02±2.50	5.7±0.27	6.17±3,24	5.95±0.40	37.73±6.95	12.58±1.24	0.34±0.03
Sept.	26.6±0.58	0.62±0.05	2.42±0.40	0.14±0.03	23.20±4.06	5.5±0.34	5.65±0.27	6.00±0.33	34.87±3.52	14.42±0.85	0.34±0.03
Oct.	27.2±0.47	0.56±0.06	2.35±0.40	0.13±0.02	25.97±3.18	5.4±0.18	11.75±4.01	5.13±0.31	36.17±11.21	13.62±2.45	0.24±0.01
Nov.	27.4±0.10	0.54±0.06	2.32±0.41	0.11±0.03	26.30±3.37	5.6±0.23	11.78±0.62	4.8±0.21	35.42±9.44	11.53±0.68	0.23±0.03
Dec.	27.7±0.39	0.51±0.05	2.31±0.40	0.10±0.03	27.18±3.11	5.8±0.18	13.97±1.57	4.87±0.45	26.33±2.14	12.05±0.43	0.19±0.02
Jan.	27.8±0.08	0.51±0.05	2.28±0.39	0.09±0.03	28.23±3.21	5.5±0.55	13.95±1.54	4.6±0.33	30.33±4.22	19.98±3.27	0.21±0.01
Feb.	28.1±0.20	0.46±0.05	2.25±0.40	0.07±0.02	29.30±2.23	5.5±0.50	24.98±7.13	4.58±0.58	30.58±0.97	16.5±3.16	0.20±0.03
Mar.	28.5±0.13	0.46±0.05	2.22±0.39	0.05±0.02	30.93±1.98	5.3±0.38	21.02±2.19	4.35±0.28	30.42±1.46	12.43±1.02	0.19±0.02
April	28.0±0.31	0.51±0.05	2.26±0.40	0.10±0.03	27.87±3.61	5.7±0.27	10.27±4.15	5.02±0.53	29.83±0.43	13.06±3.18	0.24±0.02
Annual mean	27.47±0.79	0.54±0.07	2.33±0.37	0.11±0.04	26.73±3.59	5.53±0.35	11.60±6.49	5.14±0.69	33.25±6.53	13.06±3.18	0.25±0.06

Table 2: Seasonal variations in physico-chemical parameters of Ogbei stream (May, 2002 – April, 2003)

Parameters	Dry season (Oct. – Mar.)	Rainy season (Apr. – Sept.)	Significance
Temperature (°C)	27.8±0.47	27.1±0.81	*
Depth (m)	0.51±0.06	0.57±0.07	
Width (m)	2.29±0.37	2.36±0.37	
Velocity (ms^{-1})	0.09±0.03	0.13±0.03	*
Transparency (cm)	27.99±3.17	25.48±3.56	*
pH	5.5±0.37	6.92±8.08	
Free CO_2 (mg/l $CaCO_3$)	16.09±6	7.12±2.58	*
Dissolved oxygen (mg/l)	4.72±0.42	5.56±0.66	*
Alkalinity (mg/l $CaCO_3$)	31.54±6.77	34.95±5.88	*
Hardness (mg/l $CaCO_3$)	14.36±3.64	11.76±1.88	*
Phosphate (mg/l)	0.21±0.03	0.29±0.04	*
Nitrate-nitrogen (μg/l^{-1}))	Not detectable	–	

* *Significant $P < 0.05$*

Table 3: Physico-chemical characteristics of different sites (stations)

Site (Station)	Temperature (°C)	Depth (m)	Width (m)	Velocity (ms^{-1})	Transparency (cm)	pH	Free carbon dioxide ($mgl^{-1}CaCO_3$)	Dissolved oxygen (mgl^{-1})	Alkalinity ($mgl^{-1}CaCO_3$)	Hardness ($mgl^{-1}CaCO_3$)	Phosphate (mgl^{-1})
1	27.3±0.99	0.50±0.04	2.11±0.06	0.09±0.03	30.44±2.62	5.37±0.27	11.22±5.99	5.02±0.80	30.19±6.19	12.85±3.67	0.25±0.05
2	27.6±0.53	0.06±0.07	2.31±0.06	0.15±0.04	27.21±2.21	5.55±035	12.88±9.99	5.14±0.80	31.26±3.86	12.83±3.44	0.25±0.06
3	27.8±0.60	0.58±0.05	2.44±0.08	1.12±0.03	26.73±3.14	5.47±0.27	11.28±5.45	5.10±0.56	33.09±5.76	13.04±2.47	0.26±0.06
4	47.4±1.10	0.47±0.05	2.67±0.07	0.11±0.04	28.12±2.15	5.6±0.24	10.64±4.58	5.09±0.58	34.29±7.30	13.03±2.91	0.27±0.06
5	27.5±0.77	0.57±0.04	2.84±0.06	0.10±0.03	26.06±1.68	5.50±0.38	11.34±6.32	5.22±0.60	36.07±9.11	13.77±4.54	0.23±0.04
6	27.3±0.65	0.54±0.05	1.70±0.07	0.10±0.03	21.8±3.24	5.71±0.51	12.26±6.50	5.28±0.72	34.58±5.08	12.83±2.06	0.24±0.06

Depth varied between 0.47 ± 0.05 m at station 4 and 0.58 ± 0.05 m at station 3. The difference between stations was not significant ($P > 0.05$). The lowest and highest values of water velocity were recorded at station 1 (0.09 ± 0.03 m/sec.) and station 3 (1.12 ± 0.03 m/sec.) respectively. Transparency varied from 21.8 ± 3.24 cm at station 6 to 30.44 ± 2.62 cm at station 1. The transparency values were significantly different in the stations. DO varied slightly between 5.02 ± 0.80 mg/l at station 1 and 5.28 ± 0.72 mg/l at station 6. There was wide variation in the total alkalinity ranging from 30.19 ± 6.19 mg/l $CaCO_3$ at station 1 to 36.07 ± 9.11 mg/l $CaCO_3$ at station 5. Phosphate varied slightly between the stations (Table 3).

Discussion

Physico-chemical qualities of water play important roles in the life processes of aquatic organisms. Tait (1981) and Dawson (1992) reported that adequate temperature influences several major processes including feeding, respiration, osmoregulation, growth and especially reproduction. The mean temperature (27.47 $\pm$ 0.79^o C) recorded in Ogbei stream is within the recommended limits (25^{o}C – 35^{o}C) for aquatic life including fish growth and production (Boyd and Lichkroppler, 1979). The temperature in Ogbei stream is consistent with that in River Niger (Imevbore, 1970) and Adada River (Inyang and Anozie, 1987), but was lower than that in Anambra River (Odo, 2004) partly because of the vegetation canopy over some sections of the stream which reduced the solar radiation into the stream and partly because of the in and out radiation effect to which small streams are more subjected to daily temperature variations than large rivers. The temperature decreased during the rainy season due to the lowering of solar/heat radiation and the inundation of run off into the stream during the rainy months.

Depth is a prime factor in aquatic environment particularly in lakes and large rivers. It influences abundance and distribution of animals. Ibemenuga (2005) reported on a significant inverse relationship between depth and macroinvertebrate abundance in the small tropical stream. Although Ogbei stream is relatively small, its depth increased during the rainy season as a result of precipitation and run-off into it during the rainy months and was highest at Station 2 where there were no human activities.

The pattern of the flow rates of rivers and streams depends on many physical and climatic factors. Water current is known to impact heavily on the substratum of the system which in turn influences the type, abundance and distribution of the micro- and macro-benthos of the system. Welcomme (1979) reported that the water flow in African rivers decreases as the river moves downstream. This was not the case in Ogbei stream as the least flow rate was recorded in station 1. Also, the flow rate was far less than the 2 – 3 m/sec given by Welcomme (1985) for African rivers because Ogbei stream is relatively small bodies of water compared with the rivers on which Welcomme's observations were based. However, water current apart from helping to create different habitats in a system also through water turbulence helps to generate adequate oxygen concentration in the water, a situation which favours growth and survival of life.

Transparency is an expression of the optical property in the river. It is influenced by both the absorption characteristics of the water and the dissolved and particulate matter in the water. In practical sense transparency/turbidity determines the extent to which light penetrates into water. It has therefore something to do with productivity of the system particularly in terms of phytoplankton populations. The secchi disc transparency of the stream was generally high and was higher during the dry season than during the rainy season. The decreased secchi disc transparency during the rains was as a result of increased input of silt/fine particulate and organic debris washed from the catchment area into the stream through run-off. The same observation was reported by Odo (2004) in Anambra River.

Welcomme (1985) reported that savanna rivers are usually almost neutral or slightly alkaline. Ogbei stream is within the tropical rain forest and is acidic (pH 5.53 ± 0.35). Low pH values are found in natural waters rich in dissolved organic matter (Wetzel, 1975). Some tropical rivers tend to be acidic because the rain water entering the rivers is always high in carbon dioxide content. Also, the high rate of respiratory and organic decomposition processes during the dry season months increase the carbon dioxide concentration in the water thus accounting for a higher value of pH during the dry season than during the rainy season as observed in the present study. The low variability of pH values observed, according to Hynes (1972), may be attributed to the streams being resistant to pH changes as a result of chemical buffering effects. The pH value in Ogbei stream is consistent with the pH value for Adada River (5.18 ± 0.45), another small tropical rain forest river (Inyang and Anozie, 1987), but less than the ranges recorded in many African large rivers such as Sokoto River, Nigeria, (Holden and Green, 1960), Chari River, Chad and Black Volta, Ghana, (Welcomme, 1975) respectively; Idodo River, (Anibeze, 1995) and Anambra River, (Odo, 2004). This may be due to their large volume of water in relation to the amount of dissolved organic matter in them compared with Ogbei stream. Although Adeniji (1989) and Nwachukwu (2000) recommended a pH range of 6.5 to 9.0 as suitable for aquatic life, the pH of the stream (5.53 $\pm$ 0.35) was within the limits (5.5 - 10.0) recommended for tropical fish production (Bennet, 1973). Cust and Bird (1972) and Inyang and Anozie (1987) had earlier reported on some fish species that are well adapted to acidic waters.

Free carbon dioxide was higher than the value considered to be suitable for fish production (< 6.0 mg/l) (Boyd, 1979). Adeniji (1975) also asserted that a good fishery is correlated with low carbon dioxide content of the water. Bush clearing and burning around the stream for farming/gardening could lead to increased input of organic matter and free carbon dioxide content of the water which explains the higher value obtained during the dry season. On the other hand the reduction of free carbon dioxide during the rainy season may be due to its utilization by aquatic vegetation which bloom during these months.

Dissolved oxygen (DO) is essential for life and in most tropical rivers and streams it is often not a limiting factor. The mean value of oxygen concentration (5.14 $\pm$ 0.69 mg/l) is adequate for life in the stream (Akeredolu, 1972; Boyd, 1979). The value is also consistent with the values obtained in Adada River (Inyang and Anozie, 1987), Nnamdi Azikiwe stream (Aguigwo, 1998) and Anambra River (Odo, 2004). The seasonal changes in oxygen concentration were more or less inversely related to changes in water temperature. The same observation was made by Huet (1972) who reports that increase in water temperature decreases dissolved oxygen. The high dissolved oxygen during the rainy season apart from the temperature effect may also be attributed to vegetation bloom in the water as well as high volume and turbulence which enhances the solubility of oxygen in the water.

Alkalinity of the stream water was relatively low compared with the range 75 mg/l to 200 mg/l considered to be productive water (Hem, 1970). The alkalinity of a water body of course reflects the geochemistry of the watershed (Kemdirim, 1993). Winger (1981) in his review on the physical and chemical characteristics of warm water, reported that excessive land use in the catchment area influences the quality of nutrients that enter the receiving waters. Hynes (1975) also stated that the majority of nutrients entering a water system comes from allochthonous organic input. The importance of allochthonous material in the functioning of streams and rivers has been documented (Anderson and Sedell, 1979; Allan, 1995; Pope *et al.*, 1999). The alkalinity of the stream was generally higher during the rainy season than during the dry season probably as a result of reduction in evaporation, leaching of the bedrocks and rocks of the catchment area. It was also higher at station 5 than in all other stations where light penetration was much. Generally, Ogbei stream may be considered to be a good quality and unpolluted source of water. Apart from free carbon dioxide and alkalinity all other physico-chemical parameters studied are within the limits recommended for aquatic life including fish growth and production. The proposed impoundment with proper management strategies has lots of fishery potentials.

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