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The impact of impoundment on the physical and chemical hydrology of Ibiekuma stream in southern Nigeria

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Abstract: A dam was constructed in 1994 at the headwaters of the Ibiekuma stream to provide treated drinking water for the Ambrose Alli University community and its environs. Changes in the physical and chemical characteristics of the stream after impoundment were investigated between February and August 1995. Three stations (two within the dam site and one downstream of the dam) were identified for this study along a 3 km stretch of the upper reaches of the First order stream. Only water level, flow velocity, transparency and dissolved oxygen were significantly different ($P<0.05$) among the study stations. The interstation comparison of parameters using Kruskal-Wallis test indicated that water level, flow velocity, transparency and dissolved oxygen were significantly different ($P<0.05$). Dissolved oxygen content of the pool stations at the dam site were similar but significantly lower than that of the lotic station. Variability Coefficients revealed two patterns: (1) low variability in all the stations for temperature, water level, total suspended solid and pH; (2) high variability in all the stations for the other parameters. The fluctuations in the physical and chemical hydrology of the stream appear to be influenced by the changes in the fluvial dynamics of the stream due to impoundment.

Resumen: En 1994 se construyó una presa en la cabecera del río Ibiekuma con el fin de proporcionar agua potable tratada a la comunidad de la Universidad Ambrose Alli y sus alrededores. Los cambios en las características físicas y químicas de la corriente después del represamiento fueron investigados entre febrero y agosto de 1995. Para este estudio se identificaron tres estaciones (dos dentro del sitio de la presa y uno corriente abajo de ella) a lo largo de un tramo de 3 km de la parte superior de la corriente de primer orden. Solamente el nivel de agua, la velocidad del flujo, la transparencia y el oxígeno disuelto difirieron significativamente ($P<0.05$) entre las estaciones de estudio. La comparación de los parámetros entre las estaciones por medio de la prueba de Kruskal-Wallis indicó que el nivel de agua, la velocidad del flujo, la transparencia y el oxígeno disuelto fueron significativamente diferentes ($P<0.05$). Los contenidos de oxígeno disuelto de las estaciones en el embalse en los sitios de la cortina fueron similares, pero significativamente más bajos que los de la estación lótica. Los coeficientes de variabilidad revelaron dos patrones: (1) poca variabilidad en todas las estaciones para la temperatura, el nivel de agua, el total de sólidos suspendidos y el pH; (2) alta variabilidad en todas las estaciones para los otros parámetros. Las fluctuaciones en la hidrología física y química de la corriente parecen estar influenciadas por los cambios en la dinámica fluvial de la corriente debida al represamiento.

Resumo: Em 1994 foi construída uma barragem na nascente do Ibiekuma para fornecimento de água potável para a comunidade de Universidade de Ambrose Alli e a sua vizinhança. As mudanças nas característica físicas e químicas do curso de água depois do represamento foram investigadas entre Fevereiro e Agosto de 1995. Para este estudo foram identificadas três

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estações (duas dentro da barragem e uma a jusante da represa) ao longo do percurso de 3 km do troço primário do curso de água. Só o nível de água, velocidade, transparência e oxigénio dissolvido foram significativamente diferentes (P<0,05) entre as estações estudadas. A comparação entre as estações amostra utilizando o teste de Kruskal-Wallis indicou que a velocidade do fluxo, a transparência e o oxigénio dissolvido eram significativamente diferentes (P<0,05). O teor de oxigénio dissolvido das águas das duas estações na represa eram semelhantes se bem que significativamente diferentes na outra estação. Os coeficientes de variabilidade revelaram dois padrões: (1) pequena variabilidade em todas as estações quanto à temperatura, nível da água, sólidos suspensos totais e pH; (2) elevada variabilidade em todas as estações para os restantes parâmetros. As flutuações físicas e químicas na hidrologia do curso de água pareceram ser influenciadas pelas mudanças na dinâmica fluvial devidas ao represamento.

Key words: Ibiekuma stream, impoundment, lotic and lentic systems, Nigeria, physical and chemical hydrology, seasonality.

Introduction

Ibiekuma stream is a first order (Morisawa 1968) rain forest stream with its source at the Ambrose Alli University, Ekpoma, southern Nigeria. The damming of the stream was sponsored by European Economic Community (EEC) to provide treated drinking water for the University community and its environs. Pre-impoundment (Edokpayi & Gbubemi 1998) and dam construction period (Osoata 1994), ecological investigations on the stream are available. The importance of pre- and post-impoundment investigations in the assessment of the ecological changes involved in the conversion of a fluviatile ecosystem to a lacustrine one (Baxter & Glaude 1980; Imevbore & Adegoke 1975) have been highlighted. The completion and commissioning of the dam in 1994 provided an opportunity to carry out a post-impoundment ecological investigation. Our findings are presented in this paper, which is the first of a series describing the immediate post-inundation hydrobiological characteristics of the Ibiekuma stream, with emphasis on the physical and chemical hydrological changes.

Materials and methods

The Ibiekuma stream takes its source from a spring within the University Campus, Ekpoma (Lat. 6° 04′ N, 6° 06′ S; Long. 6° 00′ E, 6° 05′ W), and flows through a farm settlement before joining Orhionmwon river that finally empties into the Atlantic Ocean through the Benin river (Fig. 1).

The stream was impounded at the source resulting in a lake of about 1.5 m deep and 10.2 m wide. Three stations within a 3 km stretch of the river were chosen for this study (Fig. 1). Station 1 is about 700 m upstream of the Gravity dam with no visible unidirectional flow. The depth at this site is about 0.45 m with an average width of 3 m. It is shaded with fringing vegetation of mainly shrubs like *Sagitaria sagittifolia* and *Phoenix* palm. The substratum is mainly coarse sand and granite mixed with clay and large quantities of allochthonous matter, mainly logs and leaves of riparian vegetation. Human activity at this site is limited to occasional fishing and idol worshipping. Station 2 is located by the upstream face of the dam with a depth of 1.5 m and width of 10.2 m. This station is unshaded with visible unidirectional flow. Bankroot vegetation was mainly grass such as *Andropogon techtorum, Digitaria* sp., *Penisetum* sp., and *Talinum triangulare*. The substratum is coarse sand and granite. Human activities include bathing and washing of implements by rubber tapers. Station 3 is located about 2.3 km downstream of station 2. The stream channel at this site is narrow of about 0.36 m deep and 1.0 m wide. It is shaded with trees (*Alstonia boonei, Nauclea diderrchi, Havea braziliensis*) and shrubs (*Dryopteris* sp., *Sagittaria sagittifolia, Smilax krussiana* and *Phoenix* palm).

The stream is fast flowing at this station. The substratum is sand mixed with decaying leaves and fallen logs.

Routine sampling was carried out between 0800 hr and 1200 hr fortnightly from February to August 1995. Temporal changes in water level

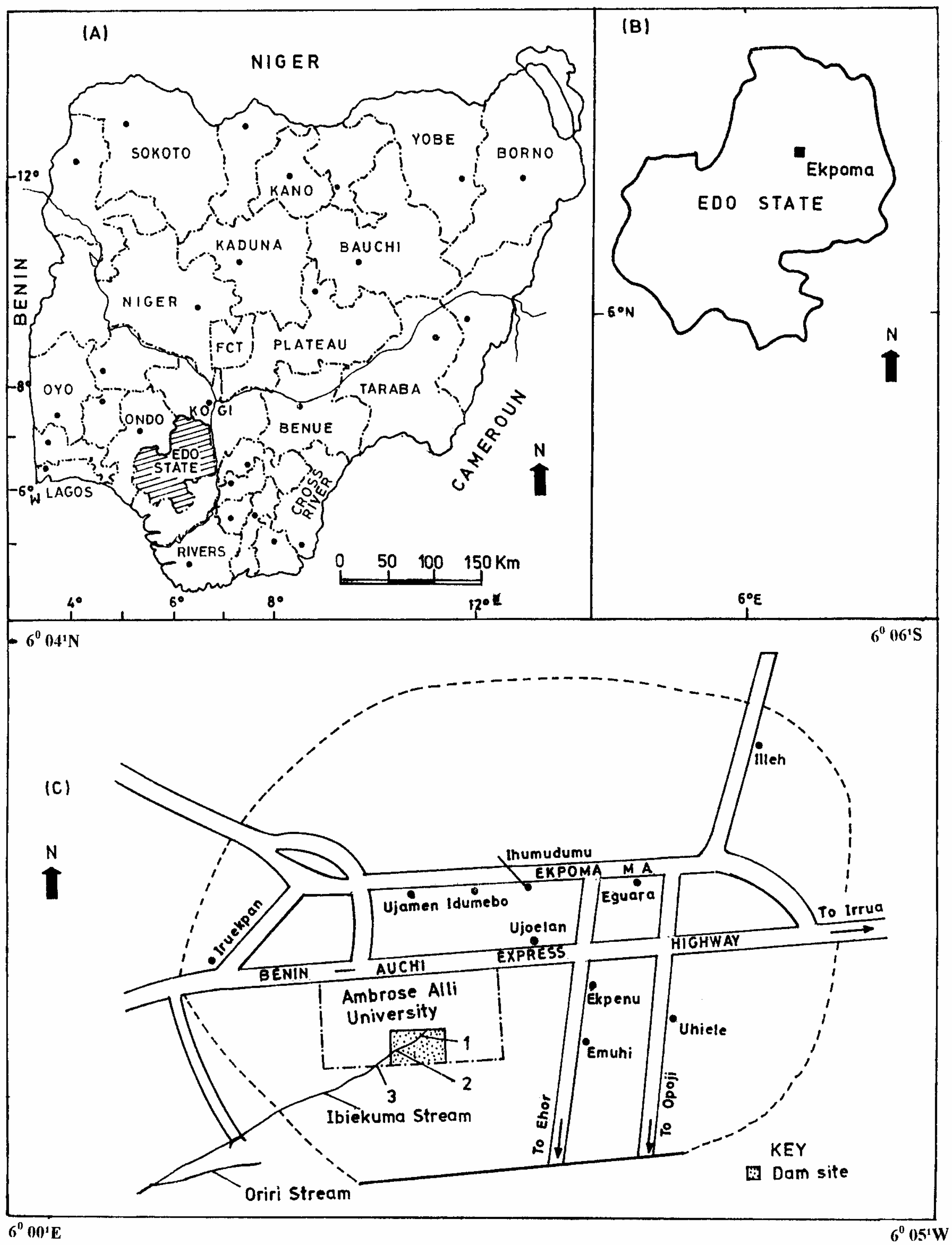

Fig. 1. Map of the study area; (a) Nigeria showing Edo State, (b) Edo State showing location of Ekpoma, (c) the Ibiekuma stream showing the study sites.

were measured using a graduated meter pegged at a fixed point in all the three stations. Air and surface water temperatures were measured in the field with a mercury-in-glass thermometer. Secchi disc transparency (APHA 1980) was used to estimate the water turbidity. The current velocity was determined by the float method (Carlsson *et al.* 1974). The total suspended solid was estimated using a portable Ciba Corning Meter (Model PP 3/1604). The pH was measured using the pH meter (Griffin, EIL 716) standardized with the pH 7 buffer. The conductivity was determined using a battery operated conductivity bridge (Model MC-1, Mark V). Dissolved oxygen content was determined by Winkler's method. Five day incubation method was used to measure the BOD and total alkalinity was analysed by hydrochloric acid titrimetric method using mixed indicator (methyl red and bromocresol green in distilled water) (APHA 1980).

Monthly rainfall data were obtained from the Agricultural Development Project (ADP) farm stations at Irrua, near Ekpoma. Aridity Index was used to delineate the dry and wet months. A dry month has an aridity index of less than 30 and wet month equal to or greater than 30. Aridity index was estimated using the following formula:

$$\text{Aridity index} = 12P/T + 10$$

where, P is the mean monthly rainfall (mm) and T mean monthly temperature (°C) (Ewer & Hall 1978).

In addition to the routine parametric statistical analysis, temporal and spatial variation in each parameter was evaluated by coefficient of variation and inter-station comparisons by the Kruskal-Wallis non-parametric test. Significant values were further subjected to non-parametric multiple comparison tests to determine the location of significant differences (Siegel 1956; Zar 1984). Excel 97 software was used to plot the graph.

Results and discussion

Meteorological conditions

The meteorological conditions in Ekpoma during the sampling period (February to August 1995) showed a typical wet and dry season governed by rainfall. The Aridity Index for the study months was February (4.47), March (25.65), April (27.55), May (34.28), June (61.20), July (54.60) and August (158.21). This indicates that the dry months were from February to April and the wet months were from June to August. However, rainfall was recorded throughout the study period with the lowest (16 mm) recorded in February and the highest (501 mm) in August 1995. Mean monthly atmospheric temperature was highest (34 °C) in February and April and lowest (23 °C) in March.

Spatial and temporal variations

The mean minimum and maximum values of the physical and chemical parameters of the Ibiekuma river study stations are summarized in Table 1, while the monthly fluctuations in the physi-

Table 1. Summary of the physical and chemical conditions at the Ibiekuma river study stations during February to August 1995. Mean (±S.E.) values (except that of pH) are given (minimum and maximum are in parenthesis).

Parameters	Station 1	Station 2	Station 3
Air Temperature (°C)	31.0 ± 0.67	30.8 ± 0.69	30.5 ± 0.72
Water Temperature (°C)	28.71 ± 0.35	28.8 ± 0.32	28.5 ± 0.37
Water Level (m)	0.54 ± 0.02	1.54 ± 0.01	0.36 ± 0.11
Flow Velocity ($cmsec^{-1}$)	0.0	0.059 ± 0.008	0.35 ± 0.01
Transparency (m)	0.51 ± 0.01	0.69 ± 0.037	0.36 ± 0.01
Total Suspended Solid ($mg\ l^{-1}$)	3406.78 ± 807.73	3954.07 ± 661.84	3431.29 ± 542.25
Conductivity (μScm^{-1})	40.03 ± 13.76	30.38 ± 11.38	27.49 ± 8.39
PH	(4.60 – 6.40)	(4.80 – 6.30)	(4.50 – 5.70)
Total Alkalinity (mgl^{-1} $CaCO_3$)	5.90 ± 0.56	5.36 ± 0.69	6.43 ± 0.77
Dissolved Oxygen ($mg\ l^{-1}$)	8.81 ± 0.48	9.28 ± 0.49	10.83 ± 0.53
Biochemical Oxygen Demand ($mg\ l^{-1}$)	2.00 ± 0.12	1.71 ± 0.21	1.75 ± 0.39

cal and chemical characteristics are presented in Figs. 2 & 3 respectively.

Fluctuations in the air and water temperatures at the three study stations were similar. Generally, water temperatures were lower than air temperatures throughout. The fluctuations in water temperature closely follow that of the ambient air temperature. The spatial and temporal varia-

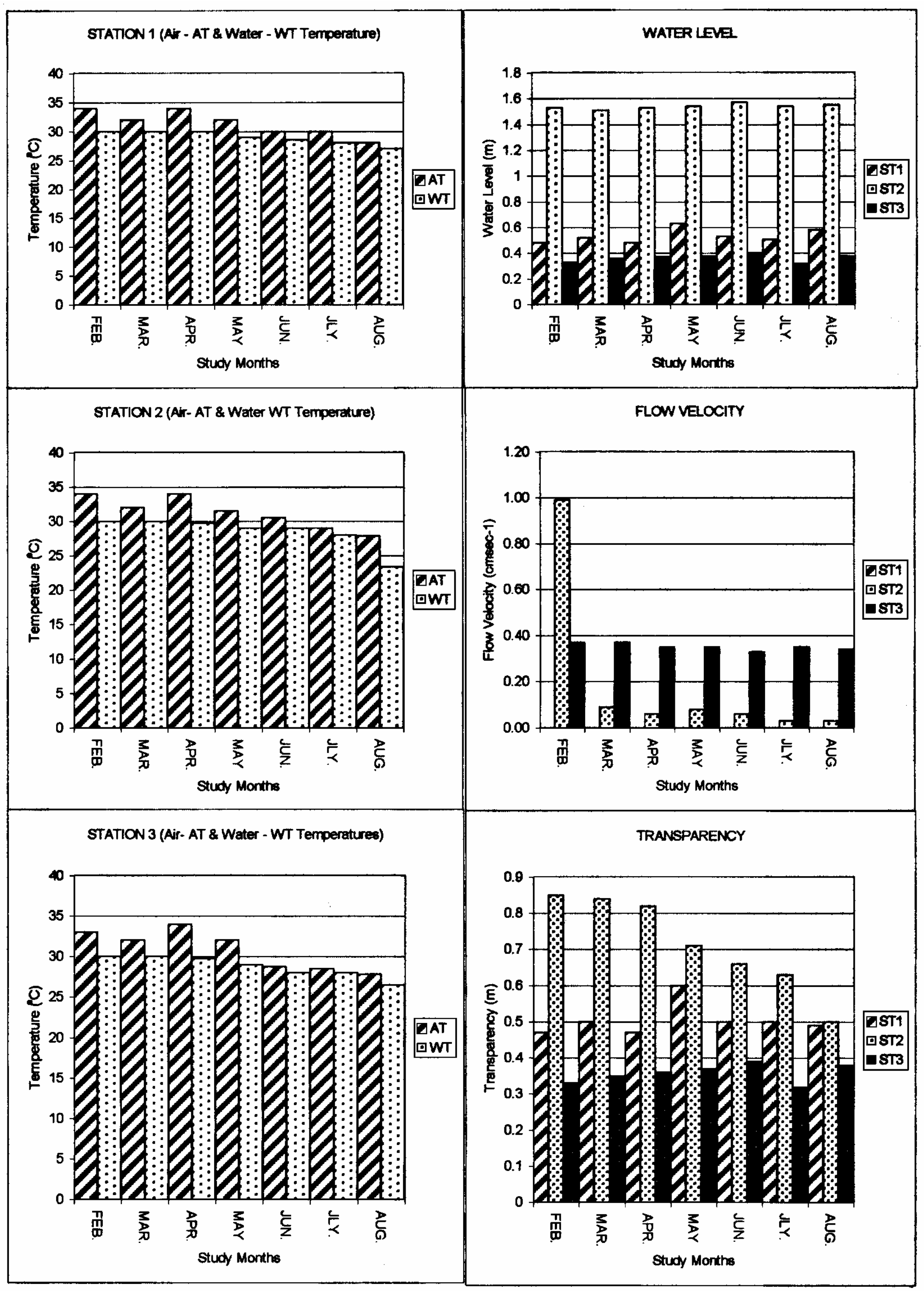

Fig. 2. Fluctuations in the physical characteristics of Ibiekuma stream study stations; February – August 1995.

tions in air and water temperatures appear to be governed primarily by the local climatic conditions, the volume of the water and the degree of exposure of the stations to sunlight (Ogbeibu & Victor 1995). The values of water temperature observed in this study were similar to those of the pre-impoundment values of the study river (Edokpayi & Gbugbemi 1998).

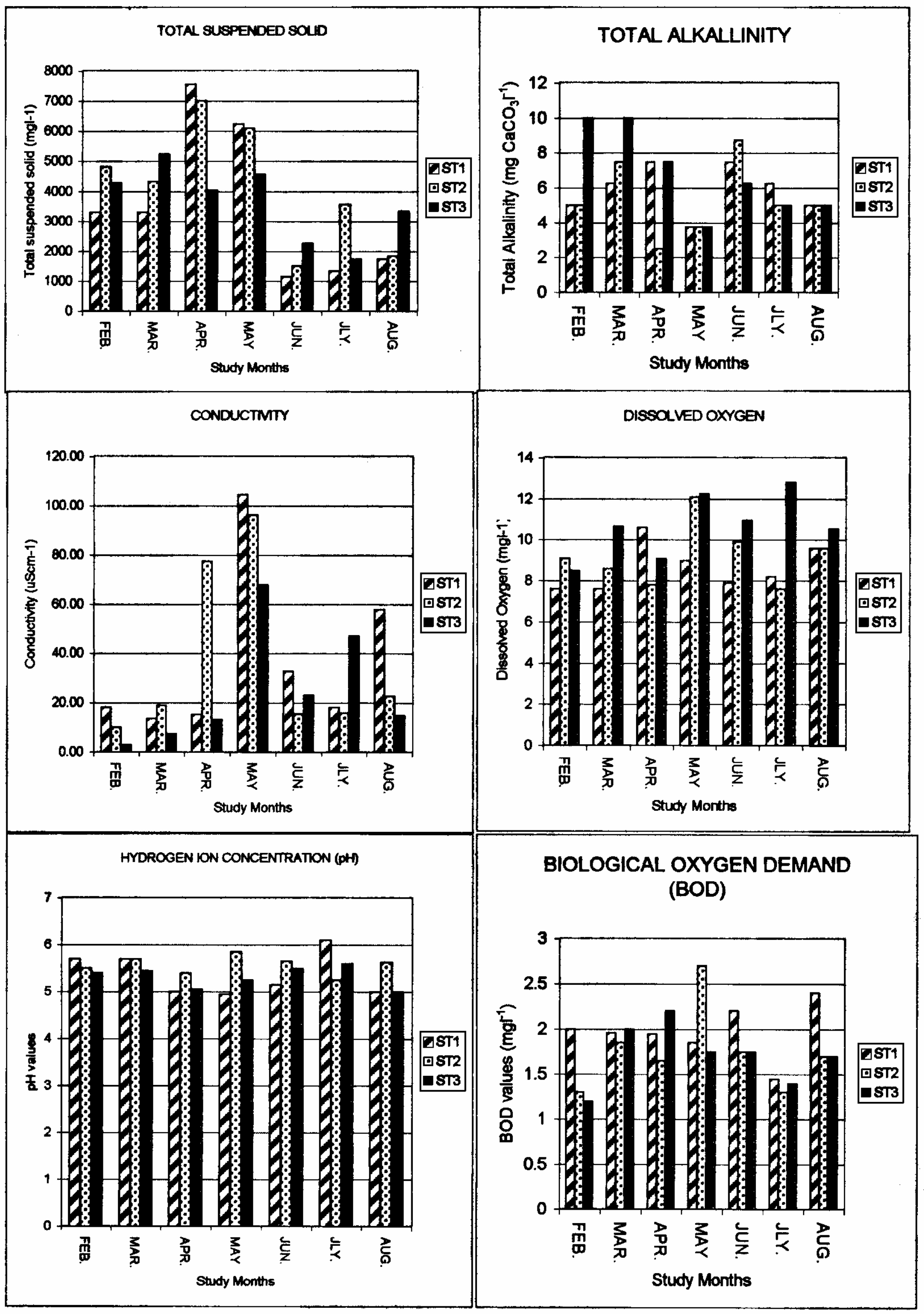

Fig. 3. Fluctuations in the chemical characteristics of Ibiekuma stream study stations; February – August 1995.

A wide longitudinal variation with slight temporal changes in water levels was observed at the study stretch. Station 2 was relatively deeper than station 1 and 3. The maximum water levels recorded were 0.66 m, 1.59 m and 0.46 m at stations 1, 2 and 3 respectively. Fluctuations in the water levels at the study stations were significantly different ($H_{0.001,\ 2} = 47.43$). Non-parametric multiple of the fluctuations in the water level at the three stations indicated that the stations were distinct and dissimilar (Table 3, Fig. 2). Water level of an aquatic ecosystem is usually influenced by the rainfall pattern of the drainage basin (Ikusima *et al.* 1982). The highest water level was recorded at station 2 (dam site) during the rainy months. An increase in water level could result in erosion of shoreline, which may change capacity of a reservoir (Baxter & Glaude 1980). The high water was due to the dam construction, which resulted in accumulation of water.

There was no measurable unidirectional flow velocity at station 1 throughout the study period. Higher flow velocities were recorded at station 3 than station 2. Flow velocity values at the study stations were significantly different ($H_{0.001,\ 2} = 56.76$; Tables 2 & 3). The relatively high flow velocity observed at station 3 (downstream of the dam) could be associated with the direct effect of impoundment in addition to the nature of the slope of the river valley at this station. The adverse effects of increased stream flow downstream of an impoundment on aquatic organisms in addition to the possible changes could impact on the morphology of the streambed (Baxter & Glaude 1980).

Irregular fluctuations in transparency were observed at all stations throughout. Variations in transparency at stations 1 and 3 follow closely the fluctuations in water level. There was a significant difference ($H_{0.001,\ 2} = 35.74$) in the transparency values recorded at the study stations (Tables 2 & 3). Transparency values at the study stations were statistically distinct. The dam site stations (1 and 2) were relatively less transparent than station 3. The trapping of sediments due to impoundment and the subsequent discharging of clearer water downstream in addition to the shallow depth are

Table 2. Coefficients of Variability of the physical and chemical parameters of the study stations at Ibiekuma river, Ekpoma, Nigeria.

Parameters	Station 1	Station 2	Station 3	Kruskal-Wallis Test (H)
Air Temperature (°C)	8	8	9	$P > 0.05$
Water Temperature (°C)	5	4	5	$P > 0.05$
Water Level (m)	11	2	11	$P < 0.001$
Flow Velocity (cm sec^{-1})	–	46	8	$P < 0.001$
Transparency (m)	14	20	12	$P < 0.001$
Total Suspended Solid (mg l^{-1})	6	9	11	$P > 0.05$
Conductivity (µScm^{-1})	128	170	205	$P > 0.05$
PH	9	8	6	$P > 0.05$
Total Alkalinity (mg l^{-1} $CaCO_3$)	36	48	45	$P > 0.05$
Dissolved Oxygen (mg l^{-1})	21	19	18	$P < 0.05$
Biochemical Oxygen Demand (mg l^{-1})	22	39	23	$P > 0.05$

Table 3. Summary of non-parametric multiple comparisons of parameters in the study stations, Ibiekuma river, Ekpoma. Italicised indicates not significantly different stations (P > 0.05).

Parameters	Stations ranked by mean ranks		
	Station 1	Station 2	Station 3
Water Level (m)	21.43	35.50	7.57
Flow Velocity (cm sec^{-1})	7.50	21.86	34.86
Transparency (m)	23.25	34.25	7.79
Dissolved Oxygen (mg l^{-1})	*16.07*	*19.46*	28.96

perhaps responsible for the clarity to the bottom at station 3. The low transparency at the dam sites may be due to the absorption and scattering of sunlight by dissolved substances, inorganic particles, detritus and plankton (Chacon-Torress 1993; Francisco & Martinez 1993).

Erratic temporal and spatial variations in total suspended solids were observed at the study stretch. Peak values (> 6000 mg l^{-1}) were recorded in April 1995 at the pooled station 1 and 2. The changes observed in the physical hydrology of the study stations were associated with the change from loctic to lentic environment after impoundment. One of the most serious effects is the resultant destabilization of substratum and increased siltation. The high levels of total suspended solids (TSS) recorded in this study could be attributed to silt suspension caused by erosion of the shoreline. The high level of TSS recorded in the period of dry month is probably due to concentration of solids by evaporation of water. Silt suspension have been associated with reduced light penetration, primary productivity and dissolved oxygen (Baxter & Glaude 1980).

Fluctuations in the conductivity of water at the study stations were similar with slight spatial differences. Elevated values (> 100 μScm^{-1}) were recorded at all three stations in May 1995. Conductivity is the measure of the total ionic composition of water and in fact a good indicator of its overall chemical richness. Although the conductivity values observed appears high (10.56 – 193.8 μScm^{-1}), the overall ionic content of the stream was low with the exception of few sporadic peaks. The usual pattern in which conductivity rises during the dry season and falls during the wet season (Ogbeibu & Victor 1995) was not pronounced in this study. However, the higher conductivity of the pooled stations (1 and 2) compared to the downstream lotic site observed in this study is similar to report of Egborge (1976) for Lake Asejire after the impoundment of Oshun River in Nigeria.

A pH of 4.5 – 6.4 was recorded during the study. Variations in pH values generally followed the fluctuations in water level, with the maximum pH values occurring in July during the period of high water level (rainy season). The acidic pH range (4.5 – 6.4) observed in this study is similar to the pre- impoundment values (Edokpayi & Gbugbemi 1998) earlier reported. Generally, the pH values of run – off waters from predominantly lateritic tropical forest soils like the study area are low (Bishop 1973). The low pH recorded here may be due to the reduced photosynthetic activity by phytoplankton and submerged macrophytes due to shading, in addition to increased free carbon dioxide and TSS levels associated with impoundment (Ogbeibu & Victor 1995). The lack of seasonality in the pH of the study stream could be related to the fact that most the hydrogen - ions are derived *in situ* and thus there is minimal influence of increases in precipitation and inputs from surface run – off during rains (Ogbeibu & Victor 1995).

Fluctuations in the total alkalinity were erratic during the dry months (February to May) and relatively stable during the rainy months (June to August) at the study stations. The total alkalinity values range from 0 to 10 mg (Table 1). The zero phenolphthalein alkalinity recorded throughout the study period implies that the total alkalinity was produced principally by HCO_3 ion. The low alkalinity level observed in this study is a reflection of the low lime content of the underlying rock type. The seasonality regime of the study stream contrast with that of the Oshun river and the lotic water bodies of the Okomu Forest Reserve (Egborge 1971; Ogbeibu & Victor 1995), but compares favourably with the pattern in most tropical rivers (Adebisi 1981; Hall *et al.*1977).

Wild temporal and spatial fluctuations in dissolved oxygen were observed at the three stations during the study. Peak value (15.3 mg) was recorded at station 3 and the lowest value (6.8 mg) at station 1 (Table 1). The fluctuations in dissolved oxygen at the three stations were significantly different ($H_{0.05,2}$= 8.31). Dissolved oxygen recorded at stations 1 and 2 were statistically similar and lower than that of station 3 (Table 1). The dissolved oxygen levels observed here were similar to those reported for other African rivers (Dance & Hynes 1980; Hare & Carter 1984) and some Nigerian rivers (Courant *et al.* 1987). Generally, the oxygen content of the pooled stations was lower than that of the lotic station downstream. The low levels of dissolved oxygen observed at the pooled stations may be due to the dense vegetation cover and high oxygen demand by the microorganisms during the oxidation of dead drowned macrophytes, tree trunks and other debris (Amund 2000) resulting from the elevated water level associated with impoundment. The high TSS levels may have also contributed indirectly to the low oxygen levels by interfering with the photosynthetic process (Tait & Dipper 1998). High TSS have been associated with reduced light penetration and primary productivity, consequently affecting negatively the autochthonous production of dissolved oxygen (Baxter & Glaude 1980; Nybakken 1997). The elevated oxygen values downstream could be attributed to the turbulent flow and the growth of green algae and submerged aquatic plants (Nybakken 1997).

Irregular fluctuations of biochemical oxygen demand values were observed at all stations with a range of 0.8 mg l^{-1} to 3.2 mg l^{-1}. Low values were recorded in the rainy season at all stations. The biochemical oxygen demand at the study stretch was generally low. The fact that the study stretch was mainly restricted to the headwaters in addition to the low human activities was probably responsible for the low BOD_5 (Dance & Hynes 1980).

Coefficient of variability of parameters

Inter- station comparison of variability (Table 2) revealed two groups of parameters. The temperature (air and water), water level, total suspended solids and hydrogen- ion concentration had low variability in all stations irrespective of inter-station differences. The other parameters fell in the second group, which had high variability in all stations. The low variability observed for temperature and pH at the study stream is similar to that reported for most tropical water bodies (Courant *et al*. 1987; Ogbeibu & Victor 1995). The narrow range of spatial and temporal fluctuations of these parameters is a characteristic feature of tropical waters (Tait & Dipper 1988). The high variability in the other water quality parameters may be due to the effects of extrinsic factors such as rainfall and surface run-off (King & Nkanta 1991). In addition, local variations in substrate characteristics, floral and faunal components, biological activities principally controlled by the fluvian characteristics of stream were responsible for the significant inter-station differences in water quality.

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References

Adebisi, A.A. 1981. The physiochemical hydrology of a tropical season river-upper Ogun river. *Hydrobiologia* **79**: 157-165.

APHA (American Public Health Association), American Water Works Association, Water Pollution Control Federation. 1980. *Standard Methods for the Examination of Water and Wastewater*.

Amund, D. 2000. *The Oil-eating Microbe: A Remedy to the Menace of Oil Pollution*. University of Lagos Inaugural Lecture Series, University of Lagos Press, Lagos, Nigeria.

Awachie, J.B.E. 1981. Running water ecology in Africa. pp. 339-366. *In*: M.A. Lock & D.D. Williams (eds.) *Perspectives in Running Water Ecology*. Plenum Press, New York and London.

Baxter, R.M. & P. Glaude. 1980. Environmental effects of dams and impoundments in Canada. Experiences and Prospects. *Canadian Bulletin of Fisheries and Aquatic Sciences* **205**: 34.

Bishop, J.E. 1973. *Limnology of a Small Malayan River, Sungai, Gambak*. Dr. W. Junk, The Hague.

Carlsson, G., C.H. Bailey, B. Mondet, R.F. Nyers & D. Quillivere. 1974. *Procedures for Investigating Benthic Fauna in Running Waters with Special Reference to Blackfly Populations*. pp. 1-8. Report No. 102/Oncho/Tech./74. O.R.S.T.O.M. Bouake, Ivory Coast.

Chacon-Torres, A. 1993. Lake Patzcuaro, Mexico: Effects of turbidity in a tropical high altitude lake. *Tropical Fresh Water Biology* **4**: 253-271.

Courant, R., B. Powel & J. Michel. 1987. Water-type classification for Niger delta and creek waters. pp. 295-310. *In*: *Proceedings of 1985 Seminar on the Petroleum Industry and the Nigerian Environment*. The Petroleum Inspectorate, NNPC; and Protection Division, The Federal Ministry of Works and Housing Lagos.

Dance, K.W. & H.B.N. Hynes. 1980. Some effects of agricultural land use on stream insect communities. *Environmental Pollution Series A* **22**: 19-28.

Edokpayi, C.A. & O. Gbugbemi. 1998. A preliminary survey of the fish species composition in the Ibiekuma stream headwaters before the dam construction. *Nigerian Annals of Natural Sciences* **4**: 10-15.

Egborge, A.B.M. 1971. The chemical hydrology of the river Oshun, Western state, Nigeria. *Fresh Water Biology* **4**: 177-191.

Egborge, A.B.M. 1976. The effect of impoundment on the water chemistry of Lake Asejire, Nigeria. *Freshwater Biology* **9**: 403-412.

Ewer, D.W. & J.B. Hall. (eds.) 1978. *Ecological Biology 2: The Inter-relations of Organisms.* Longman Group Ltd.

Francisco. F.J. & J. Martinez. 1993. Comparative limnology of three reservoirs on the Mexican Altiplano (A transitional zone), Aguascalients, Mexico. *Tropical Freshwater Biology* **3**: 319-329.

Hall, A. I.M. Cvalente, & B.R. Davies. 1977. The Zambezi river in Mozambique. The physico-chemical status of the middle and lower Zambezi prior to the closure of the Cabora Bassa Dam. *Freshwater Biology* **7**: 187-206.

Hare, L. & J.C.H. Carter. 1984. Diel and seasonal physico-chemical fluctuations in a small natural west African lake. *Freshwater Biology* **14**: 597-610.

Ikusima, I., R.P. Lim & J.I. Furtado. 1982. Environmental conditions. pp. 55-148. *In*: J.I. Furtado & S. Mori (eds.) *Tasek Bera, the Ecology of a Tropical Freshwater Swamp.* Dr. W. Junk, the Hague.

Imevbore, A.M.A. & O.S. Adegoke (eds.) 1975. *The Ecology of Lake Kainji: The Transition from River to Lake.* University of Ife Press, Nigeria.

King, R.P. & N.A. Nkanta. 1991. The status and seasonality in the physico-chemical hydrology of a Nigerian rainforest pond. *Japanese Limnology* **52**: 1-12.

Morisawa, M. 1968. *Streams, their Dynamics and Morphology.* McGraw-Hall Book Company, New York.

Nybakken, J.W. 1997. *Marine Biology: An Ecological Approach.* Addison-Wesley Educational Publishers Inc., New York.

Ogbeibu, A.E. & R. Victor. 1995. Hydrobiological studies of water bodies in the Okomu Forest Reserve (Sanctuary) in Southern Nigeria. 2. Physical and chemical hydrology. *Tropical Freshwater Biology* **4**: 83-100.

Osoata, A.O. 1994. *Physico-chemical Conditions of Ibiekuma River Dam at Ekpoma, Edo State.* B.Sc. Thesis, Edo State University, Ekpoma, Nigeria.

Seigel, S. 1956. *Non-parametric statistics for the behavioural Sciences.* McGraw Hill, New York.

Tait, R.V. & F.A. Dipper. 1998. *Elements of Marine Ecology.* Butterworth-Heinemann, London.

Zar, J.H. 1974. *Biostatistical Analysis.* Prentice-Italy Inc., New Jersey.