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# Preliminary Physico-Chemical Limnology of two Small Agricultural Ponds in Kaduna, Northern Nigeria.

✉**Akinbuwa, O.[1] and [2]Akeredolu O. Excellence**
[1]*Department of Biological Sciences, Joseph Ayo Babalola University (JABU) Ikeji Arakeji, Osun State, Nigeria.* e-mail: oakinbuwa@yahoo.com ;[2]*Department of Zoology, University of Lagos, Akoka, Lagos, Nigeria* email: excellencedolu@yahoo.com. ✉ Corresponding Author.

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**Abstract**

*A preliminary survey was carried out during the dry (November - March) season and the wet (April - October) season of the year 2000 and 2002 to determine the physico-chemical limnology of two small ponds in Kaduna, northern Nigeria. The investigated physico-chemical water quality parameters responded to general hydro-climatic, local micro-environmental and anthropogenic influences. The ponds were distinctly different in cationic hierarchy with the pond receiving fish meal dropping having a significantly higher conductivity, carbon dioxide, biochemical oxygen demand ($BOD_5$), nitrate, phosphate, sodium, and potassium than the other pond. However, the levels of the physico-chemical variation among the water quality parameters in both ponds still occurred within the allowable guidelines for most public, domestic and general agricultural uses such as fish culture and livestock productions.*

**Key words:** *Physico-chemical, variability, ionic hierarchy, water quality, small ponds, Northern Nigeria.*

## Introduction

Previous studies by Welcomme (1985), Timms (1986), Akinbuwa and Adeniyi (2001) and Ayodele and Adeniyi (2006) showed that the physico-chemistry of Nigerian and some Afro-tropical fresh waters respond to both regional and local environmental influences. In other words, even though the waters exhibit to some extent, general tropical characteristics, they invariably differ from one another largely due to differences in local micro-climate, geology, catchment basin characteristics, geographical location and anthropogenic influences. In certain respects these water bodies are comparable to temperate waters, in spite of the pronounced longitudinal or climatic differences between the two regions.

In Nigeria, there has been increasing awareness and concern about environmental quality especially on physico-chemical water quality due to obvious degradation and deterioration attributed to increased urbanization, agricultural development and industrialization notably, mining and oil exploration activities, (Edward *et al.*, 1983; NEST, 1991; Biney *et al.*, 1994; Calamari, 1994; Saad *et al*., 1994; Adeniyi, 2004; Ibe and Onu, 1998). Such concern and worry are no longer limited to urban centers; now in rural areas, the potable quality of water cannot be taken for granted (Edward *et al*, 1983; Ibe and Onu, 1998).

The present contribution is a preliminary investigation on selected physico-chemical water quality parameters of two small ponds in Kaduna Northern Nigeria –the College of

Agriculture pond, and the Federal Fish Farm pond. The two ponds were created specifically for agricultural purposes; mainly fish farming, production of fodder and supply of water for livestock. Recently, the Food and Agricultural Organization (FAO) of the United Nations took over the management of the fish farm pond as assistance to Nigeria in her fisheries development programme. In spite of their importance and international attention, there is so far no published information on the water quality of these ponds. Therefore, the present study aims to provide preliminary base line data to facilitate a detailed work relevant to the planning and management of these ponds and other water bodies in the area.

**Materials and Methods**

*The Study Area*

The study area is located within 1km radius of latitude $10^0$ $35^1$ N and longitude $7^035^1$E Kaduna, Kaduna State, Northern Nigeria. The catchment area of the water bodies involved (R. Mashi) is about 50km$^2$ lying within the Guinea Savannah vegetation zone of Nigeria. The climate of the area based on the meteorological data for the period of study October 2000 and October 2002 is depicted in Fig.1. The annual cycle is characterized by distinct dry and wet seasons. The dry season extends from November to March, while the wet season or raining season last from April to October. Minimum temperatures usually recorded either in December or January during the dry season. Relative humidity is high mostly during the raining season; it is inversely related to evaporation.

The two ponds under investigation are small and shallow water bodies located behind the building complex of the Ahmadu Bello University (ABU) College of Agriculture, and the Federal Ministry of Agriculture, along Mando Road, Kaduna (Fig.2).

The ABU college of agriculture pond covers a surface area of 5.5 hectares with a maximum depth of 2.4m. The pond was impounded in 1964 by constructing an earthen dam of about 200m long across River Mashi. It was impounded solely for watering livestock and growing of fodder for animal husbandry. The Federal Fish Farm pond was constructed by the Federal Department of Fisheries as a demonstration fish farm. It is Located at about 500m distance away from the College of Agriculture Pond. The reservoir is 8.15m long, 5.5m wide and 1.2m deep. It's water supply is the adjoining College Pond through an underground pipe connected to it. The pond water is regularly drained and replaced at least fortnightly through the process known as "demudding". This process eliminates bottom wastes and provide fresh aquatic environment for the fish. Also on regular basis, some processed plant and animal materials were dropped into fish farm as fish meals. These are composed of wheat grains, ox-blood, groundnut cake beans and starch. There are eleven of such water reservoirs in the fish farm, they are located close to each other but separated by high embankments. The two sampling stations established for the study were marked as stations A and B as shown in Fig. 2.

*Sample collection and physico-chemical analysis*

Surface water samples for physico-chemical analyses were collected fortnightly for 24 months covering three overlapping years. On some occasions however, the sampling interval was monthly. Ambient air and water temperatures were measured in the field with a mercury-in-glass bulb thermometer to the nearest $0.1^0$C. Water pH was determined colorimetrically in the field using Loving bond pH comparator and later re-checked in the laboratory with a pH

meter (Yokogawa Electric Corporation, Model pH 81). Dissolved oxygen concentration was fixed in the field with Winkler's reagents and later determined titrimetrically in the laboratory soon on returning from the field work. Conductivity was determined with a conductivity bridge (YSi model 33) at $25^0$C while total alkalinity was determined titrimetrically with 0.02N $H_2SO_4$ (APHA, 1980). Calcium and Magnesium were estimated titrimetrically using 0.01 EDTA (Mackereth *et al.*, 1978) while Sodium and Potassium were estimated by flame emission photometry (Golterman *et al.*, 1980). Chloride was determined titrimetrically by turbidometric $BaSO_4$ method, using 0.014N $AgNO_3$ solution (APHA, 1980). Free carbon dioxide was determined titrimetrically using 0.045N $Na_2CO_3$ (Lind, 1979)

*Biochemical Oxygen Demand ($BOD_5$)* was determined as for dissolved Oxygen after five days of incubation (Hynes, 1971). The Sodium Absorption Ratio (SAR) of water sample was estimated to evaluate the suitability of the water for irrigation according to Chapman (1992) using the formula:

$$SAR = \frac{Na^+}{\frac{1}{2}\sqrt{(Ca^{2+}+Mg^{2+})}}$$

Where the concentrations of $Na^+$, $Mg^{2+}$ and $Ca^{2+}$ were expressed in milli equivalent per litre.

**Results**

*Seasonal variations*

The data showing the 24 months seasonal variations of physico-chemical parameters are presented in Figs 3and 4. Generally, the physico-chemical parameters followed similar seasonal trends in both ponds. Ambient air and water temperatures were higher in the raining season than in the dry season. Minimum air and water temperatures (18-$22^0$C) occurred during the dry season in January or February, while high temperature in the range of (28-$31^0$C) were recorded mostly in rainy season. Water pH was generally higher during the dry season, than in the raining season. Low values of conductivity, Alkalinity, major ions (particularly, Sodium, potassium, Calcium, and Magnesium) were recorded in raining season, but a sharp rise at the onset of the rains. Dissolved Oxygen values were generally lower in the raining season than in the dry season while percentage oxygen saturation followed similar seasonal trends as dissolved oxygen .The values of Oxygen saturation were always above the 50% critical value while the supersaturated values (>100%) were recorded in the dry season. Biochemical Oxygen Demand ($BOD_5$),Carbon Dioxide, chloride, phosphate, and Nitrate did not show any definite seasonal trends- both high and low values occurred across the seasons. Sulphate concentrations were generally low sometimes in trace amounts.

*Spatial variations*

Table 1 shows the mean concentration of the physico-chemical water quality parameters in section A and B. Conductivity, Biochemical Oxygen Demand, Carbon dioxide, Potassium, Sodium, Phosphate and Nitrate shows statistically significant higher values ($p<0.05$) in station B than station A. Alkalinity, Calcium, Magnesium, Sulphate and chloride also show some variation between the stations, but were not significantly different ($p>0.05$). The ambient air and water temperatures, pH and dissolved Oxygen showed apparently little or no variations. Cationic hierarchy was $Mg^{2+} > Ca^{2+} > Na^+ > K^+$ in Station A, and $Ca^{2+} > Na^+ > Mg^{2+} > K^+$ in Station B, while anionic hierarchy was $HCO_3^- > Cl^- > SO_4^{2-}$ in both stations. SAR values in both stations A and B were both less than 1 (0.33 and 0.51 respectively).

**Discussion**

The physico-chemical water quality data on the two investigated ponds in many ways are not different from what is obtainable in most Afro-tropical waters. They share many features with several relatively large and well known water bodies in other parts of Nigeria, including River Sokoto (Holden and Green, 1960), Eleiyele Reservoir (Imevbore,1967), River Oshun (Egborge, 1972), Asejire Lake (Egborge, 1981), Lower cross Rivers (Lovernberg and Kunzel, 1992), Opa Reservoir (Akinbuwa and Adeniyi, 1996, 2001). With conductivity values as low as 51-77*u*s $cm^{-1}$ average, the ponds can be classified among the most diluted African waters (Talling and Talling, 1965).

The lower values of conductivity, pH, Oxygen, and most of the major ions in the raining season than in the dry season is a tropical characteristics, usually attributed to dilution, deoxygenation and acidic effects of rain water. Similarly, the sharp rise in conductivity and some related chemical variables (such as alkalinity, the cations and anions, etc) at the onset of the rains, are linked to effects of run-off draining Electrolytes and other soluble substances that accumulated within the drainage basin during the dry season into the aquatic systems (Imevbore, 1967; Olaniyan, 1968; Egborge, 1972, 1981, 1994; Bowmaker, 1976; Lowenberg and Kunzel, 1992; Akinbuwa and Adeniyi, 1996, 2001).

The seasonal cycles of temperature in both ponds were very similar (both in magnitude and time), and this could be attributed to the close proximity of ponds to each other within the same geographical area. Similar result has also been reported for some man-made lakes in South-Western Nigeria (Akinbuwa and Adeniyi, 2001).On another note, the amplitude of temperature variation in the ponds was $13^0$ C. This figure is largely comparable to the range of temperature variation known to be worth considerable in tropical waters, which seemingly lends credence to the view of some scientists in recent times challenging the generalization that temperature variation is atypical of tropical waters (Olaniyan,1968; Akinbuwa and Adebuwa and Adeniyi, 2001). There was also a remarkable feature in the ponds in which water temperatures recorded during the dry season generally followed temperature minima, similar to the trends in River Sokoto (Green, 1960, Holden and Green, 1960) and in the tropical fish pond in Jos (Ufodike and Garba, 1992). However, these temperature conditions seem generally a converse to the conditions in the fresh water aquatic systems in the southern part of Nigeria where the higher temperatures coincide with the dry season, typical of most tropical waters (Egborge, 1981; Akinbuwa and Adeniyi, 1996, 2001). These contrasting features between Nigerian northern and southern waters could be attributed to the prominent effects of evaporation and cold harmattan winds in the northern region during the dry season described by Holden and Green (1960) and Adeyefa (1998). This in a way shows that local micro-climatological conditions could also play important role in temperature variation pattern in tropical waters. The relatively high concentrations of some chemicals nutrients particularly phosphates and Nitrate in the ponds during the raining season (in spite of general dilution condition) is a condition that has been recorded in some other tropical lakes (Welcomme, 1985; Timms, 1986; Akinbuwa and Adeniyi, 2001),which has been linked to possible infiltration of nutrient rich ground water. The spatial variations in the physico-chemical parameters between the two ponds shows that conductivity, $BOD_5$, Phosphate, Nitrate, Sodium and Potassium were of considerable or significantly higher concentrations in the fish farm than in the college pond. Since most of these chemical parameters are typical products of organic matter mineralization and hence often used as traditional

parameters(particularly $BOD_5$, Phosphate and Nitrate) for measuring organic pollution, it is obvious that their higher concentrations in the fish farm could be linked only to the fish meals (rich in organic compounds) which were regularly dropped into the fish farm. The dissimilarity in the cationic order of the ponds could also be due to the presence of fish meals coupled with unstable nature of water in the fish farm brought about by demudding process. Based on some international water quality guide levels (Table 2), the chemical water quality parameters (including SAR values) of the two ponds fall within the allowable/ permissible guide levels for a wide range of water applications particularly fish production, irrigated agriculture and livestock productions. The ponds are therefore considered suitable for the specific purposes for which they are created i.e. fish farming (Federal Fish Farm), production of fodder and supply of water for Animal Husbandry (College of Agric pond). In conclusion the two ponds responded to some general tropical, local environmental as well as anthropogenic influences. In spite of this, the water qualities are considered suitable for the particular agricultural purposes they serve. Application of fish meal and unstable hydrology seem to be major factors responsible for certain differences in physico-chemical character between the two ponds. More importantly, the study reveals that the fish meal load does not have deteriorating effect on the water quality. Further research work should include more parameters e.g. heavy metal and cover other reservoirs of the fish farm as well as other sites on the college pond.

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**Table 1: The mean concentration of physico-chemical water quality parameters in College of Agric. Pond (Station A) and Federal Fish farm Pond (Station B) Kaduna, Nigeria.**

| PARAMETER | [ n ] | ABU Pond(Station A) | Fish Farm pond (Station B) |
|---|---|---|---|
| | | Mean | Mean |
| Ambient air Temperature (°C) | 34 | 26.0 | 26.7 |
| Water Temperature (°C) | 34 | 25.2 | 25.0 |
| Hydrogen ion con.(pH) | 34 | 7.1 | 7.3 |
| Electrical Conductivity (umhos.cm-) | 34 | 51.3 | 77.2* |
| Alkalinity (mgl- $CaC0_3$) | 34 | 29.6 | 37.8 |
| Dissolved Oxygen (DO) (Mgl-) | 34 | 7.2 | 7.1 |
| Oxygen Saturation (%) | 34 | 93.4 | 94. |
| Biochemical Oxygen Demand (BOD)(mgl-) | 34 | 2.2 | 7.4* |
| Carbon dioxide (mgl-) | 34 | 4.0 | 5.6* |
| Phosphate (mgl-) | 17 | 4.82 | 27.80* |
| Nitrate (mgl-) | 17 | 0.14 | 2.03* |
| Sulphate (mgl-) | 17 | 0.23 | 0.11 |
| Sodium (mgl-) | 17 | 3.33 | 5.80* |
| Potassium (mgl-) | 17 | 2.93 | 4.35* |
| Calcium(mgl-) | 17 | 3.51 | 5.37 |
| Magnesium | 17 | 2.88 | 2.47 |
| Chloride (mgl-) | 17 | 1.69 | 1.50 |

** Significant difference values (P<0.05) between stations*
*n = number of samples*

**Table 2: Recommended Guide levels for Physico-chemical parameters of water quality for multipurpose uses.**

| Parameters | Unit | Recommended/Allowable Standards (For Multipurpose Uses) |
|---|---|---|
| Hydrogen ion concentration | pH | 6.5-8.5<br>6-9 (Fisheries) |
| Dissolve Oxygen | $mgl^{-1}$ | 5-9 |
| Oxygen Saturation | % | 50 (Critical minimum value) |
| Conductivity | $\mu Scm^{-1}$ | 800-1600 |
| Alkalinity | $mgl^{-1}$ $CaCO_3$ | >25 (Minimum level) |
| Biochemical Oxygen Demand ($BOD_5$) | $mgl^{-1}$ $O_2$ | 3.0-6.0 |
| Calcium ($Ca^{2+}$) | $mgl^{-1}$ | 75-200 |
| Magnesium ($Mg^{2+}$) | $mgl^{-1}$ | 60-120(maximum) |
| Sodium ($Na^{+}$) | $mgl^{-1}$ | <200(maximum) |
| Potassium ( $k^{+}$) | $Mgl^{-1}$ | 75-200 |
| Sulphate ($SO_4^{2-}$) | $mgl^{-1}$ | <250(maximum)<br><1000(for livestock) |
| Chloride ($Cl^{-1}$) | $mgl^{-1}$ | <250(maximum) |
| Phosphate ($PO_4^{3-}$) | $\mu gl^{-1}$ | 350-6,100 |
| Nitrate ($NO_3^{-1}$) | $mgl^{-1}$ | < (50maximum)<br>90-200(for livestock) |
| Sodium Absorption Ratio (SAR) | _ | 8(maximum) |

*Source: Edwards et al., 1983; Chapman, 1992; Adeniyi, 2004*

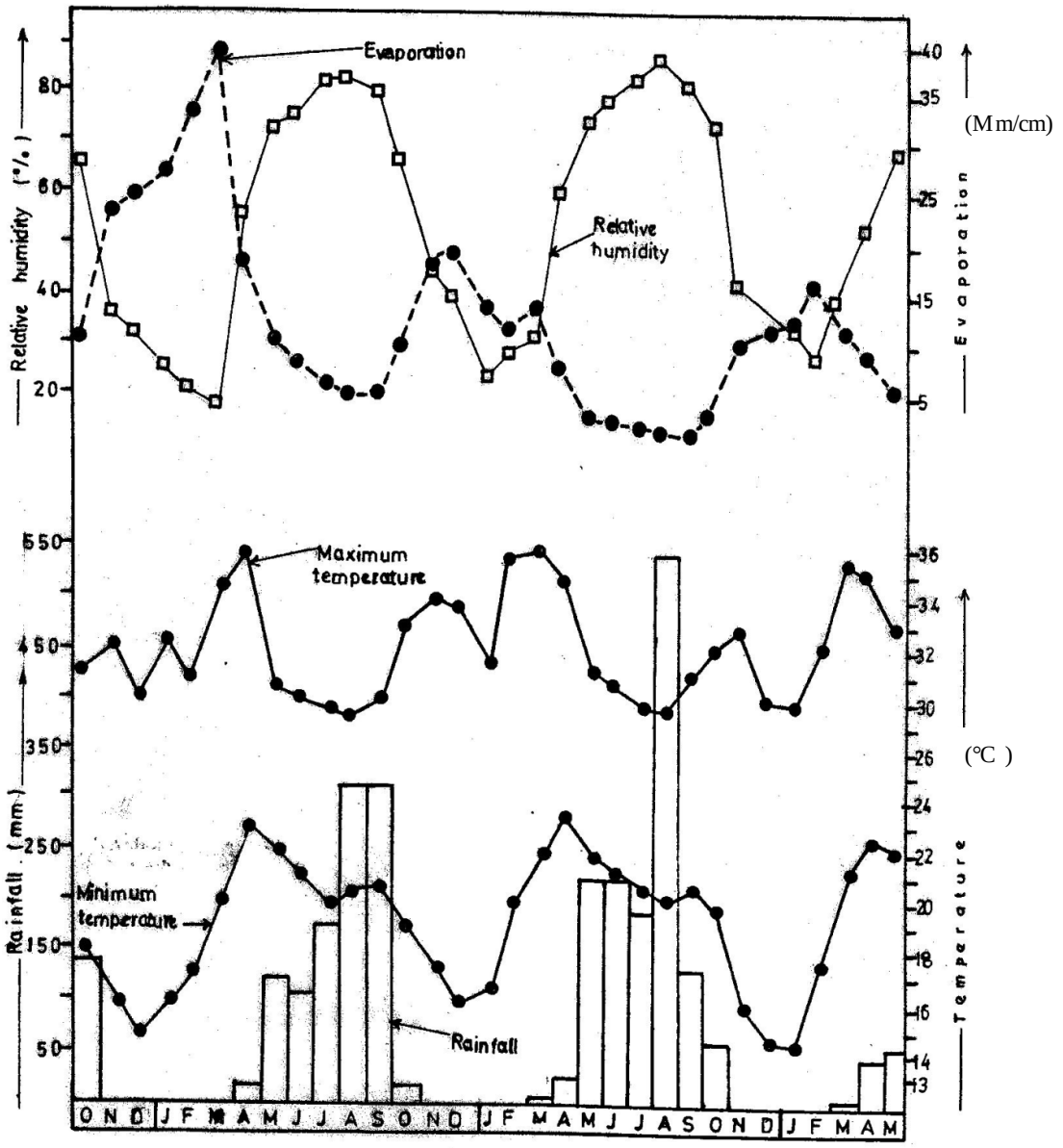


Fig1: The Climatic conditions in Kaduna during the study period (Oct 2000- Oct 2002)

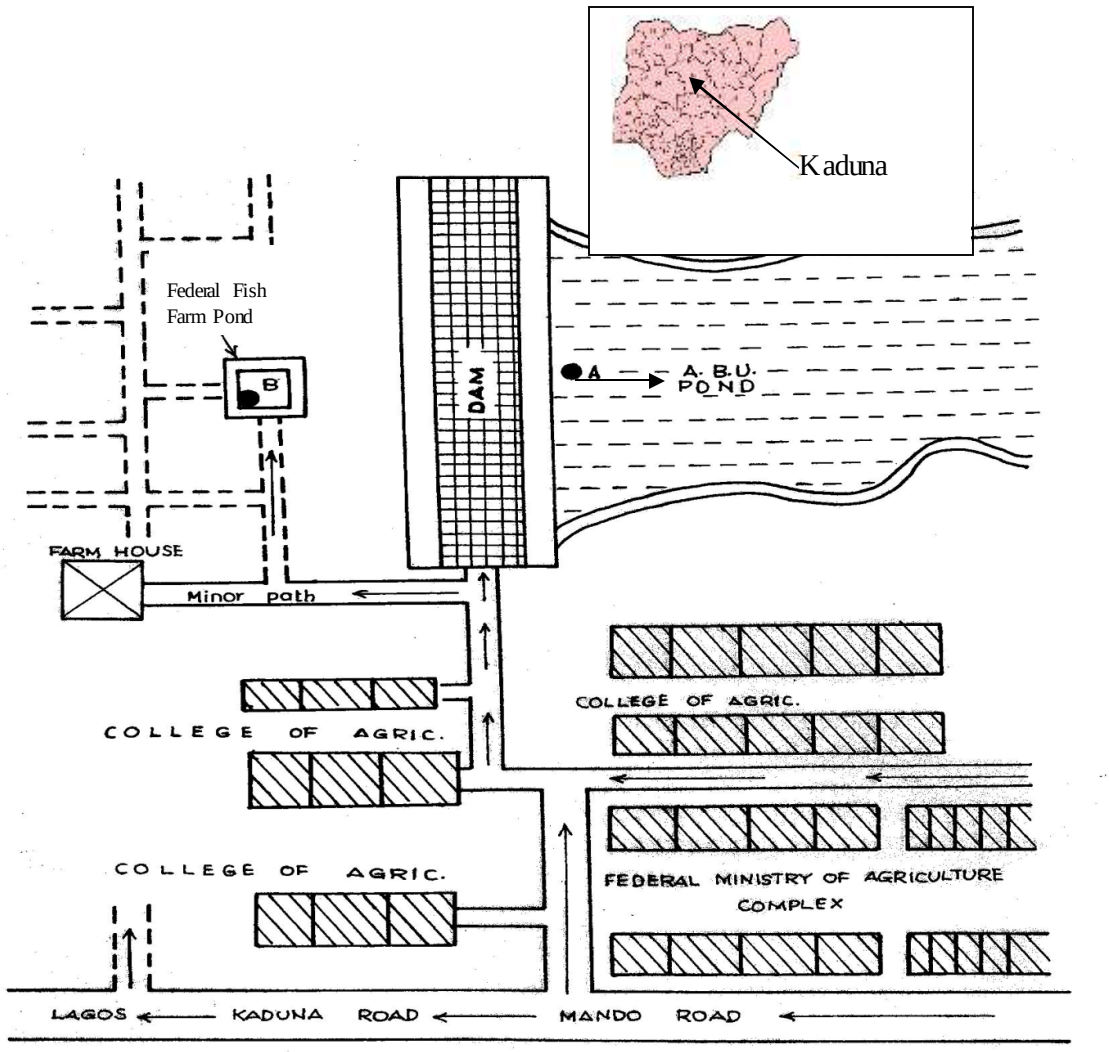


Fig 2: Sketch of the Study Area showing the two ponds under investigation.

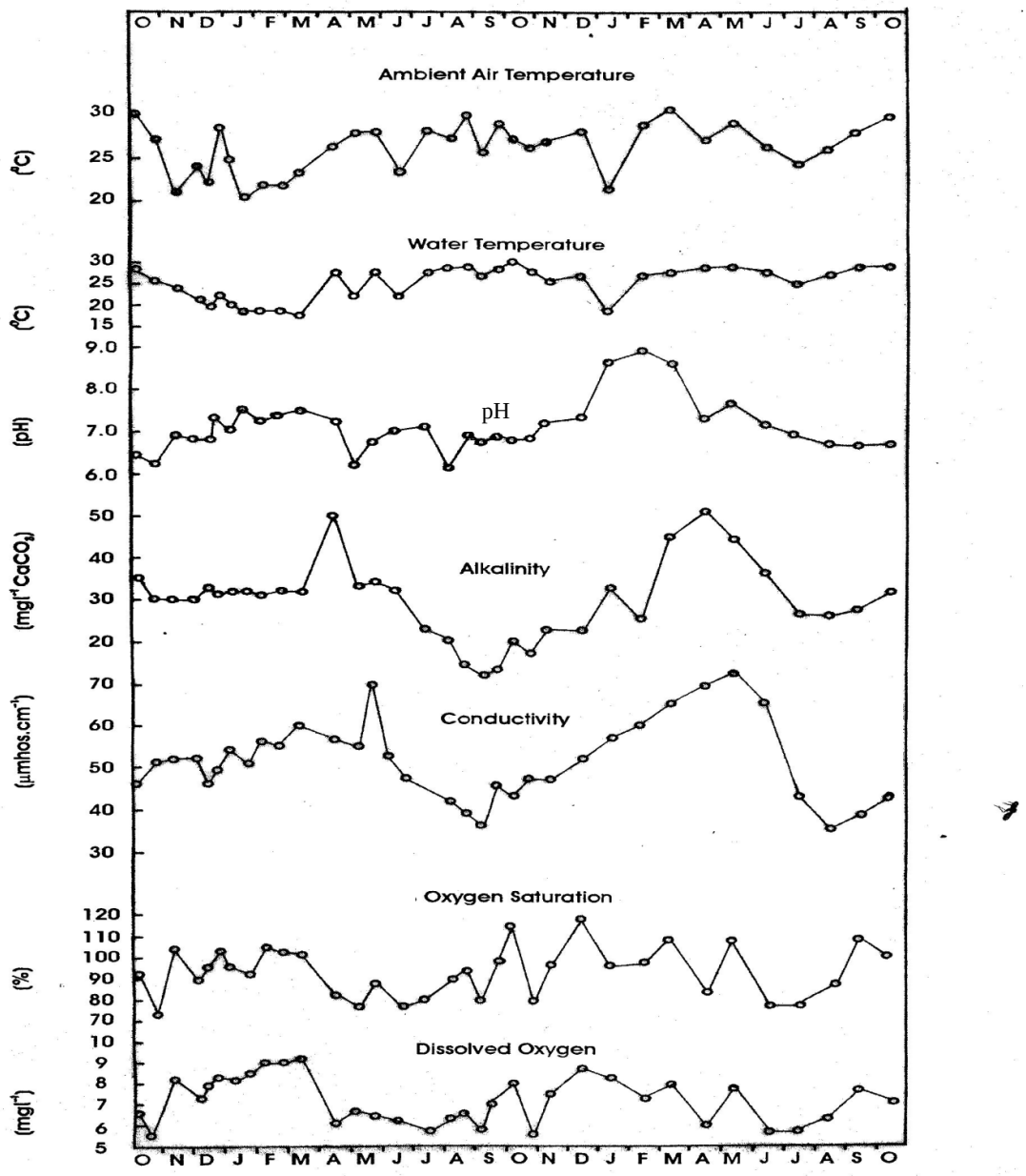


Fig 3: The mean seasonal variation in Dissolved Oxygen, Percentage Oxygen Saturation, Conductivity, Alkalinity, pH , Water and Ambient temperatures in the waters of College of Agric pond and Federal Fish Farm (Oct 2000- Oct 2002).

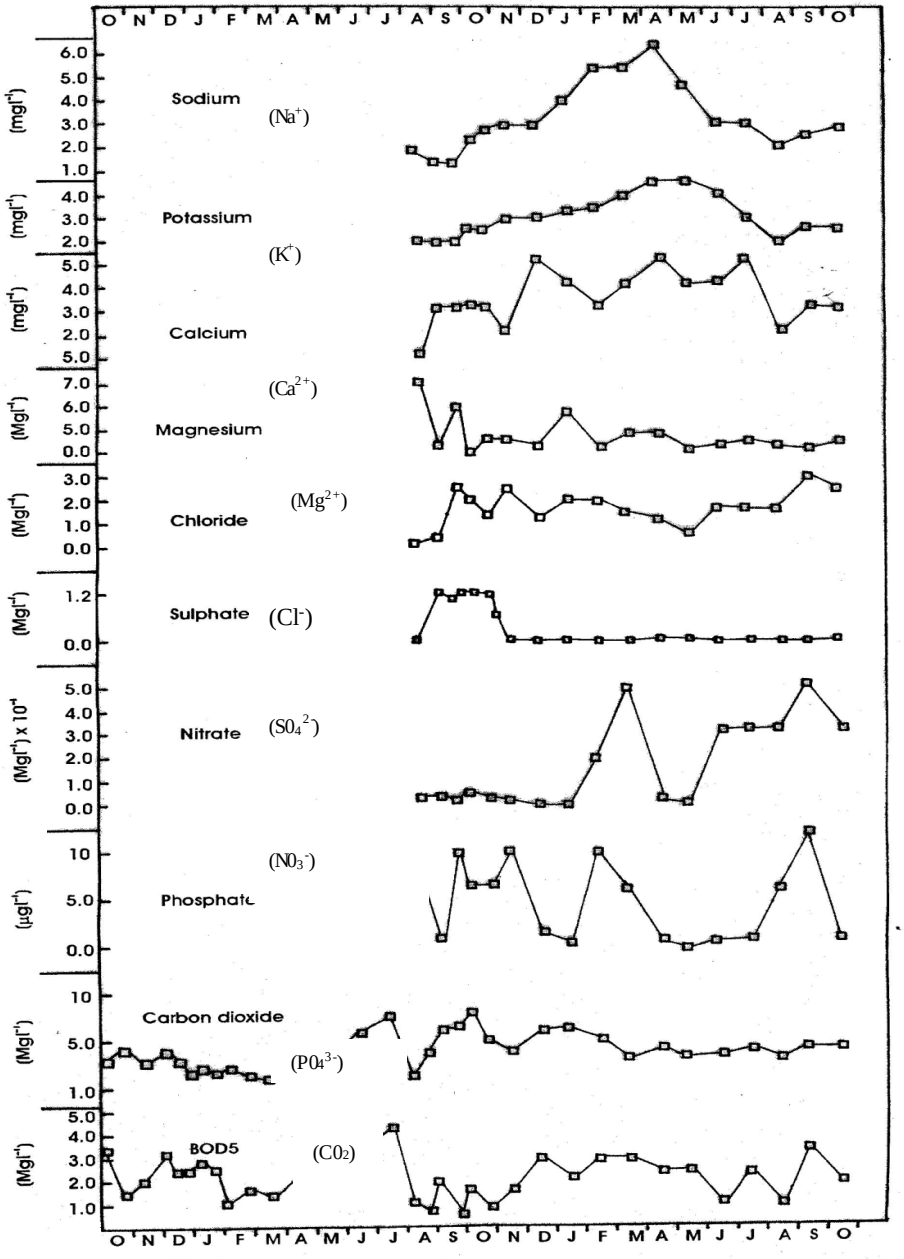


Fig. 4: Mean Seasonal variation in BOD, Carbon Dioxide, Phosphate, Nitrate, Sulphate, Chloride, Magnesium, Calcium, Potassium, and Sodium in waters of College Pond and Federal Fish Farm (Oct 2000- Oct 2002).