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pH, ALKALINITY, HARDNESS AND CONDUCTIVITY RELATIONSHIPS IN THE FISH PONDS OF THE UNIVERSITY OF CALABAR, NIGERIA

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ABSTRACT:

The significance of the inter-relationships between pH, alkalinity, hardness and conductivity in fresh water ponds are highlighted using Water Quality Ratios (WQR) and pair-wise correlation analysis. While the relationship between alkalinity/hardness (r=0.96, p<0.025, n=84) and alkalinity/conductivity (r=0.50, p<0.05, n=84), gave good correlations, the relationship of pH with alkalinity, hardness and conductivity were poor and significant (p< 0.001). Moderately high WQR (2.9) was obtained only for alkalinity/ hardness relationship.

The elevated alkalinity/hardness ratios are indicative of sufficient quantities of carbon dioxide which are required for plankton development. High ratio also suggests alkalinity and hardness as the principal factors contributing to the ionic stability of the pond system. The low WQRs and the consistent highly significant linear relationships (0.05 > P < 0.001) between pH and the other variables predict a well buffered system. The implication of this favourable water quality in pond fish production is presented.

Key words: WQRs, Carbon dioxide, Fish production.

RÉSUMÉ

On met en vedette la signification des relations entre pH, alkalinité, dureté et conductivité dans des étangs d' eau fraîche par l'emploi des proportions de qualité d'eau et l'analyse de correlation des paires. Pendant que les relations alcalinité/dureté (r=0,96, P<0,025) et alkalinité/conductivité (r=0,50; P<0,05) donnet de bonnes correlations, les relations pH/alcalinité, dureté/conductivité s'averent manvaises et significatives (P< 0, 001). Des proportions de qualité d'eau modérement elevées sont obtenues seulement dans la relation alkalinité/dureté.

Des proportions éleveés alkalinité/dureté indiquent des quantités suffisantes de gaz carbonique dont on a besoin pour le développment du plancton. Des proportions élevées suggesent aussi que l'alcalinité et la dureté sont les facteurs principaux qui contribuent à la stabilité ionique du systeme d'etangs.

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Les basses proportions des qualites d'eau et les relations liniavies significatives hautement uniformes entre la pH et d'autres variables predisent un système bien tamponne. On presente l'implication de cette qualite d'eau favorable a la production des poissons de l'etang.

Mots-cles: Proportions de qualité d'eau, gaz Carbonique, production aquatique.

INTRODUCTION

The suitability of water for the survival and growth of fish is governed by a myriad of water quality variables (Boyd, 1982a). These factors include DO, temperature, pH, alkalinity, hardness and conductivity among others. Most aquaculturist are familiar with these factors, their limits and effects on fish production (Tucker & Boyd, 1979; Boyd, 1982a).

Tropical fresh waters are generally acidic and oligotrophic (low in nutrients). Fresh waters with pH values less than 5.0 are unsuitable for fish culture. Water quality management in pond fish culture in most cases are directed towards reducing acidity of natural waters through liming, thereby ensuring effective fertilizer application and plankton build-up (Davidson & Boyd, 1981., Boyd, 1982b., Green, Phelps & Alverenga, 1989., Akpan & Okafor, 1997). Liming increases the bicarbonate concentration of pond waters when properly done (Boyd, 1982c). Monitoring of water quality changes are necessary because unlimed ponds, or low alkalinity waters cannot supply the fish food (phytoplanktons) required for efficient fish production. This report assesses the relationships between pH, alkalinity, hardness and conductivity from 12 fish ponds and the significance of the relationships in fish pond management and fishery production.

MATERIALS AND METHODS:

Water samples were collected between 6 and 7 am weekly and analysed for pH, DO, water temperature and conductivity insitu. Sub-samples were collected and preserved at 4°C until further analysis in the laboratory. All chemical analysis were carried out at the water quality laboratory (WQL) of the Institute of Oceanography, University of Calabar, Calabar, Nigeria.

pH and DO/temperature were measured using WTW pH 91 meter and WTW 90 dissolved oxygen meter respectively. Conductivity was measured using conductivity meter (Hach Model 4960, +0.1 uS/cm). Total alkalinty was determined titrimetricly using standard 0.1M HCl with methyl orange as indicator and total hardness was determined using EDTA according to APHA (1989). Statistical analysis were carried out to determine the relationships between the various variables using basic linear correlaion analysis and computed water quality ratios (WQRs) between the various variables. A total number of 6 parametric ratios were obtained namely: pH/alkalinity, pH/hardness, pH/conductivity, alkalinty/hardness, alkalinity/conductivity and hardness/conductivity. The justification for this is that the parameters are closely related. Since the parameters are inter-related, variations in one parameter can alter the quality of the pond water for fish growth and survival. Secondly, the same management approach was adopted for all the ponds. Such a ratio will change with any change in management scheme applied. Under similar schemes, the WQRs are expected to be comparable unlike the use of absolute values. WQR or Index have been used previously to assess the quality status of aquatic systems (Mathuthu, Zaranyika & Jannalagadda, 1993). Reproducibility of analytical results were ensured by carrying out duplicate analysis of each parameter. Coefficients of variation (%) were within the ranges of 3.03-11.2% for pH, 25.2-42.2% for alkalinity, 23.3-57.9% of hardness and 26.4-48.1 for conductivity.

RESULTS

The results of analyses show definite changes in pH, alkalinity, hardness and conductivity values for the twelve tilapia (*Oreochromis nilocticus*) ponds studied. pH ranged from 6.5 - 8.71, total alkalinity from 15 - 100 mg/l, total hardness from 8 - 40 mg/l and conductivity from 15.2 - 258.5 uS/cm for the fish ponds. Table 1 shows the water quality ratios (WQRs) for the relationships between the parameters. The highest ratio was obtained for alkalinity/hardness (2.9) while the lowest ratio was obtained for pH/conductivity (0.04) in the ponds.

Correlation coefficients and the corresponding levels of significance (P) are presented in Table 2. The four parameters were highly significant at 0.05>P<0.001 with the alkalinty/hardness pair having the highest value of r = 0.96 (P<0.025, n=84).

The spatial variation of the water quality factors during the period of study is as presented in Fig. 1. Similar fluctuation pattern was observed for all the parameters. There was an initial decrease in

Table 1:
Water Quality Ratios (WQRs) for the relationship between pH, Alkalinity, Hardness and Conductivity in UNICAL fish ponds (1992 - 1993).

No. of Ponds	pH / Alkali.	pH / Hardness	pH / Cond.	Alk. / Hardness	Alk. / Cond.	Hard. / Cond.
3	0.10	0.26	0.05	2.60	0.50	0.20
4	0.12	0.32	0.05	2.60	0.45	0.17
5	0.17	0.50	0.08	2.90	0.50	0.16
6	0.15	0.39	0.07	2.52	0.42	0.17
7	0.15	0.35	0.06	2.30	0.42	0.19
10	0.11	0.27	0.04	2.50	0.39	0.16
11	0.12	0.29	0.05	2.40	0.44	0.18
15	0.22	0.24	0.10	1.11	0.50	0.44
21	0.16	0.40	0.06	2.50	0.35	0.14
22	0.19	0.47	0.07	2.49	0.37	0.15

the concentration of the parameters (Peak A) followed by an increase (Peak B)

In other words, the liming (200 - 500 kg/ha of slaked lime applied) neutralised

Table 2: Correlation and their statistical significance (n = 84) between pH, alkalinity, hardness and conductivity in tropical fish ponds.

	pH	Alkalinity	Hardness	Conductivity
pH	—	0.32*	0.26***	0.7*
Alkalinity			0.96****	0.50*****
Hardness				0.55**
Conductivity				—

Levels of significance (P): *0.001; **0.005; ***0.02; ****0.025; and ******0.05

DISCUSSION

pH correlates positively with all the measured parameters (Table 2). This is due to the strong inter-dependence of pH on the other water quality parameters. For instance, pH can change remarkably to higher values where total alkalinity is high and total hardness is low during periods of excessive photosynthesis (Boyd, 1982a). During the study pH gave a highly significant correlation with alkalinity ($P < 0.001$), hardness ($P < 0.02$) and conductivity ($P < 0.001$). The main factor contributing to this relationship is the buffering capacity of the system which maintained the pH within the acceptable range 6.0 - 8.5 (Boyd & Lichtkoppler, 1979).

The chemistry of the buffering process involves the reaction of slaked lime with acidity to produce hydroxyl ions which in turn combine with free CO_2 to form bicarbonate ions:

$$Ca(OH)_2 + H^{+} \rightarrow Ca + H_2O + OH^{-}$$

$$OH^{-} + CO_2 \rightarrow HCO_3^{-}$$

the acidity (H+) by the formation of hydroxyl which buffer the water in the presence of available carbon dioxide. For the pond water the increase in alkalinity was caused primarily by HCO_3 ions (Boyd, 1982a).

Highly positive and significant correlation were obtained for alkalinity/hardness relationship ($r=0.96$, $P < 0.025$). This is attributed to the values of total alkalinity being consistently higher than the total hardness in the pond waters. Despite this the total hardness values (15-29.7 mg/l) were within the desirable level for fishery waters (Boyd, 1982a). A good correlation occured for alkalinity/conductivity relationship ($r=0.5$, $n=84$). This relationship was significant ($P<0.05$) suggesting that the bicarbonate ions also contribute significantly to the electrical conductivity of the pond waters. Thus, low alkalinity could result in a decrease in the conductivity of pond waters.

The relationship between hardness and conductivity was also good ($r=0.55$, $n=84$) and highly significant ($P<0.005$).

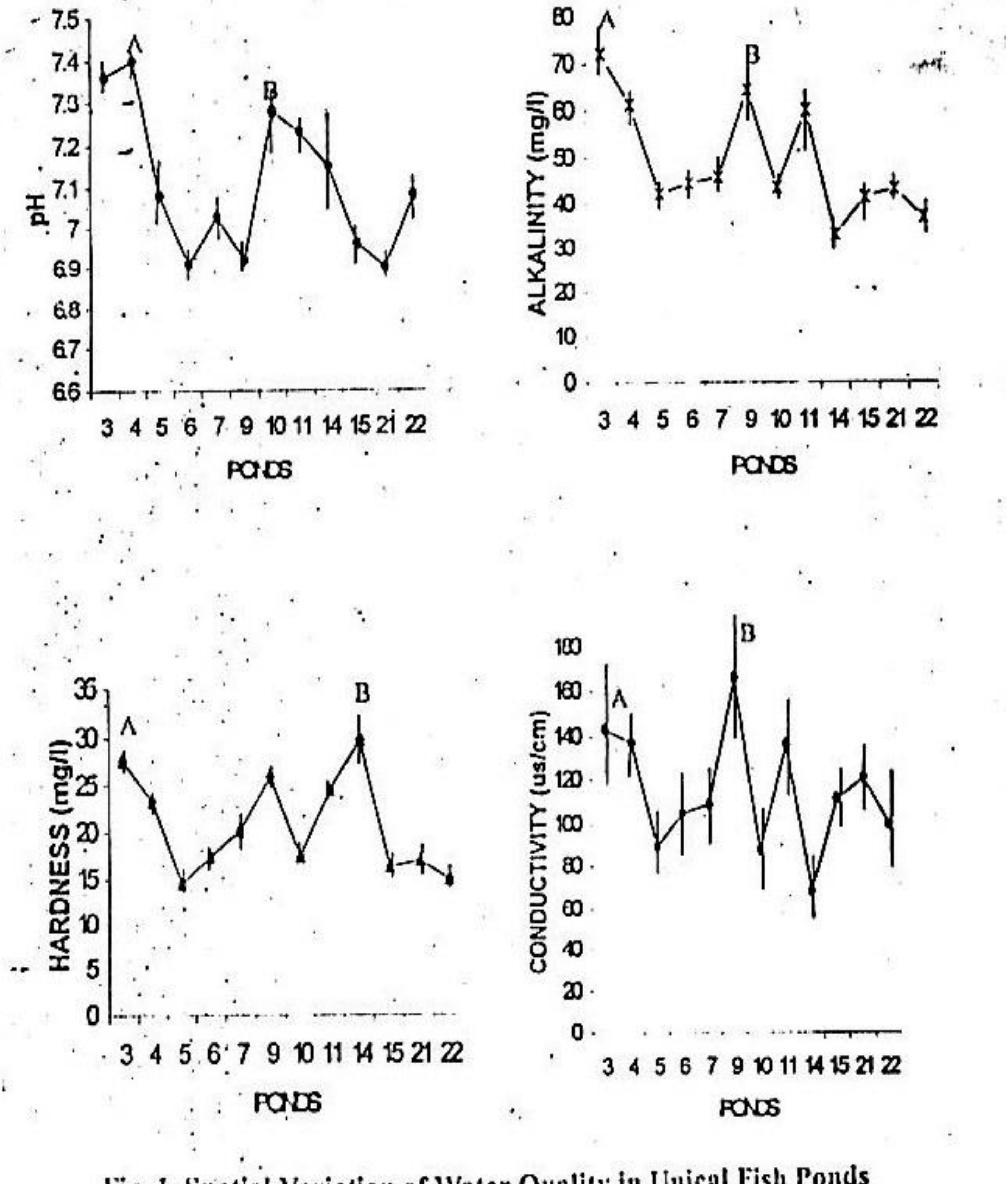

Fig. 1 Spatial Variation of Water Quality in Unical Fish Ponds between 1992 and 1993.

This indicates that the contribution of Mg^{2+} and Ca^{2+} ions play a vital role in determining the conductivity of the pond waters.

Assessment of the degree of variability of the parameters was done by calculating the coefficient of variation (CV) for each of the parameters. The most variable parameters were alkalinity (2.25 - 42.7%) conductivity (26.4 - 48.1%) and total hardness (23.3 - 57.9%) while the least variable was pH (3.0 - 11.2%). The stability of pH is as a result of the high buffering caused by liming with slaked lime (139%).

The pH, alkalinity, hardness and conductivity values are indicative of the electrolyte concentration and buffering capacity of the aquatic system (Myllymaa, 1985). Fig. 1 shows that all the parameters exhibited similar pattern of distribution with points A and B showing the highest variation. The occurence of the two maxima is attributed to hydrological condition of the ponds characterised by muddy bottom and or clay turbidity.

The significant relationship between the four parameters as calculated from their WQRs indicate the close inter-relationship between the parameters and their contribution to changes in water quality. For all the ponds investigated, WQRs were generally low (< 3.0). Higher WQRs (>10) would indicate the unsuitability of such waters for fish production and would denote a higher degree of variability among the parameters. This is consistent with the observation that alkalinity values above 200 mg/l cannot adequately support fish production (Boyd, 1982a). The pond waters were generally soft (0-60 mg/l). (Roberts, 1989) and of low ionic content (salinity < 1.0 ppt). The lowest WQR occured for pH/conductivity relationship (<0.1) and depicts a stable ionic state of the waters. The low linear correlation coefficient (r=0.07) between the two parameters also suggest that pH showed little contribution to the changes in the water quality of the ponds.

CONCLUSION

The values for pH, alkalinity, hardness and conductivity were within the desirable ranges for fish production (Boyd & Litch koppler, 1979, Boyd, 1982a). Spatial fluctuations in the individual ponds were similar and were caused by the hydrological characteristics of the ponds such as muddy bottom and clay turbidity. High WQRs and linear coefficient were obtained only for alkalinity/hardness relationship indicating that they are the primary determinants of the pond productivity. High WQRs for alkalinity and hardness are also responsible for major water quality changes for the pond system. The elevated ratios obtained for alkalinity and hardness indicates the availability of sufficient carbon dioxide which is essential for plankton development.

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REFERENCES

Akpan E. R. & Okafor E., 1997,. On organic fertilization and plankton development in two experimental fresh water ponds in Nigeria. *Journal of Aquaculture in the tropics* 12; 147 - 154.

APHA 1989, American Public Health Association (APHA, AWWA, WPCH). Standard Method for the Examination of water and waste water 12 (ed), 1134 pp.

Boyd, C. E. & Lichtkoppler, F. 1979,. *Water quality management in ponds fish culture*. Internation center for Aquaculture, Agricultural experimental station., Auburn University. Research and Development Series No. 22, Project AID/DSANG 0039, 30 pp.

Boyd, C. E. 1982a. *Water Quality Management for pond fish culture*. Elsevier Publications, Amsterdam, 318 pp.

Boyd, C. E. 1982b,. Managing water quality in channel cat fish ponds. *Journal of Soil and water conservation*. 37; 207 - 209.

Green, B. W; Phelps, R. P. & Alvarenga, H. R. 1989,. The effect of manures and chemical fertilizers on the production of *Oreochromis niloticus* in earthen ponds. *Aquaculture* 76, 37-42

Mathuthu, A. S.; Zaranyika, F. M. & Jannalagadda, S. B. 1993,. Monitoring of Water Quality in upper Mukuvisi River in Harare, Zimbabwe. *Environment International*. 19,51-63.

Myllymaa, U.; 1985, *Influence of drainage area factors on the water quality of small lakes in the Koutajoki river basin with special reference to metals*. Publication of the Water Research Institute, NBW, Finland, pp 54.

Roberts, R. J; 1989, *Fish Pathology*. Bailliere Tindall Publishers, London, pp. 11.

Tucker, L & Boyd, C. E; 1979, Effect of feeding rate on water quality, production of channel cat fish and economic returns. *Transaction of the American Fisheries Society*. 108; 389-396.