EFFECTS OF POND FERTILIZATION ON THE PHYSICO-CHEMICAL WATER QUALITY OF SELECTED EARTHEN FISHPONDS IN IFE NORTH LOCAL GOVERNMENT AREA, OSUN STATE, NIGERIA

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Abstract

The effect of fertilization on the physico-chemical water quality of six selected earthen fishponds in Ife North Local Government Area of Osun State was investigated for a period of two years sampling the ponds every other month. The fishponds were grouped with regard to fertilization practice and water flowage regime into three sets comprising two non-flow-through ponds that received organic and inorganic fertilizers (FNF); two flow-through ponds that received the same organic and inorganic fertilizers (FF) and two unfertilized flow-through ponds. The investigated water quality parameters include water temperature, pH, transparency, dissolved oxygen, major ions, some plant nutrients and heavy metals using standard titrimetric and instrumental methods of analysis.The mean values of these parameters were not statistically different ($p > 0.05$) for the three sets of fishponds with the exception of sodium, Alkalinity, HCO_3^-, Conductivity and TDS which were each characterized with significant mean differences ($p = 0.05$). In general, the fertilized ponds were characterized by higher mean values in 24 of the 29 investigated water quality parameters than the non-fertilized ponds. Also the mean values of 22 out of the 29 investigated parameters were generally higher in the flow-through ponds than in the non-flow-through ponds. Increase in the parameters due to water flowage was statistically significant ($p > 0.05$) for sodium, alkalinity, bicarbonate, conductivity and TDS while the effect of fertilization was higher for the dissolved oxygen parameters, nutrients (NO_3, PO_4,), major ions and apparent colour. Thus, the fertilized ponds were more saline (based on conductivity and TDS), better buffered and richer in nutrient than the unfertilized ponds. These effects were enhanced by flowage hence the fertilized flow-through ponds were characterised by the most suitable water quality for fish culture in the study-area while the fertilized non flow-through ponds was least suitable. The study revealed that to achieve the desired effect, pond fertilization must be accompanied by adequate water flowage especially in shallow fishponds.

Keywords: water quality, fertilization, flow regime, fishpond, Nigeria.

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Introduction

Pond fertilization provides essential nutrient components such as nitrogen, phosphorus, and potassium compounds required for rapid phytoplankton development and hence increased primary and post-primary production in fishponds without the risk of dietary diseases to fish (Ita, 1980). The main purpose of pond fertilization is to increase the available natural food (phytoplankton and zooplankton) for fry or larval fish, or for fish species that are efficient filter feeders (Brunson *et al* 1999). However, pond fertilization may play a major role in determining water quality and could be detrimental to fish survival. For instance excessive fertilization rates result in deterioration of water quality manifested as low dissolved oxygen content, high un-ionized ammonia, high pH levels, and high biological oxygen demand, all

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which reduce fish survival and yield (Ngbede, 1996 and Ludwig, 2002).

To prevent the deterioration of the pond environment by the accumulation of large amounts of metabolites being continuously excreted into the pond, and unconsumed feeds which often add to the bottom load, pond water should ideally be continuously freshened by a flow-through system (Baluyut, 1989). In view of this, a flow-through system of water management that allows the simultaneous entry and exit of water into and out of the pond is essential in any high-density culture system.

The proper management of fertilizer application and water flowage is a sustainable way of minimizing the detrimental effect of pond fertilization and ensuring good water quality for increased fish production (Ajao, 1999; Ludwig, 2002). This was the motivation for this study, which aimed at determining the effect of pond fertilization and water flowage on the physico-chemical water quality of selected fishponds (of a commercial farm) in a sub-urban community in Osun State, Nigeria. The study also assessed whether the water quality parameters involved were within desirable limits for fish culture or not.

Area of study

The fish ponds investigated belong to a commercial fishing company, Niger Feeds and Agricultural Operations Limited (NIFAGOL), located in Yakoyo-Origbo, in Ife North Local Government Area (LGA) of Osun State. The LGA comprise mainly rural and semi-urban communities which lies roughly between Latitudes 07° 25′-07° 40′ N and Longitudes 004° 25′-004° 30′ E, on a general elevation range of 250-265 m above mean sea level. River Shasha (one of the major waterbodies in the south-west) drains the LGA nd other waterbodies including swamps, springs, streams and minor rivers.

The fish farm studied (NIFAGOL) comprised 18 ponds of varying sizes (ranging from 432m^2 to 6,383m^2), each rectangular in outline and are generally shallow. Water supply into the ponds is from a reservoir (surface area of 2 hectares) located within the farm. The aquaculture practice in the farm was semi-intensive with some of the ponds receiving organic fertilizers in the form of chicken droppings and cow dung while others had inorganic fertilizers (NPK) application as deemed fit by the pond management. The stocked fish in all the ponds were fed twice daily at the rate of 3% of the fish body weight using the supplemental feed (pelleted feed). The locally pelleted feed made from mixture of maize, soybeans, fishmeal, millet, palm kernel cake, groundnut cake and palm kernel oil, and brewer's waste. The water retention period for the fertilized ponds was six months while the unfertilized ponds were flowing-through and left undrained. In all the culture ponds, fish stock density was 3 fish/m^2. In the majority of the ponds, *Clarias gariepinus* are being in monoculture and in combination with *Oreochromis niloticus* in polyculture in the flow-through ponds.

Materials and method

Of the eighteen ponds in NIFAGOL fish farm, only ten ponds were operational during the present study. Water samples for water quality determinations were collected from six of these ten ponds every other month over a period of two years from February 2006 to February 2008. For the purpose of this study, the ponds were grouped into three sets with regard to fertilization (fertilizer treatment) and water flowage based on the existing culture practices. The first sets of two ponds, fertilized non-flow-through ponds (FNF) received organic and inorganic fertilizers and were non-flow-through ponds. The second sets of two ponds, fertilized flow-through ponds (FF) received organic and inorganic fertilizers as FNF but were flow-through ponds. The third sets of two ponds, not fertilized flow-through (NFF) received no fertilizer but were flow-through ponds.

Water temperature measured *in situ* with a mercury-in-glass bulb thermometer while pH was determined colorimetrically on the field using a Lovibond pH comparator. Water transparency was also measured *in situ* using a graduated secchi disc. The samples for the determination of dissolved oxygen (DO) collected in a 250/125 ml capacity glass reagent bottles, fixed in the field using Winkler's reagents and brought to the laboratory for further processing.Water samples (61 samples) for the determination of other chemical parameters collected in 2Litre polyethylene jerry cans. The samples were analysed for apparent colour and turbidity by colorimetric method (Mackereth *et al* 1978). The analysis of the water samples were in accordance with standard methods of Golterman *et al.* (1978), Mackereth *et al* (1978) and APHA *et al* (1992) as applicable. The chemical parameters analysed include major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}), salinity parameters (Conductivity, Total Dissolved Solid), plant nutrient and oxygen parameters (Organic matter, nitrate, PO_4^{3-}), and heavy metals (Cu, Pb, Mn, Ni). Data obtained subjected to analysis of variance (ANOVA) using SPSS software (SPSS, 2008).

Results

Most of the investigated water quality parameters occurred within wide range of values. However their mean and median values were very close with the former slightly higher than the latter suggesting slight positive skewness of the data set (Table 1). Based on their mean values, the investigated water quality parameters of the fishponds occurred over the following range of mass concentrations:

i. $< 0.1 mgL^{-1}$= Mn > Pb > Cu > Ni (heavy metals).
ii. $0.1\text{-}1.0\ mgL^{-1} = PO_4 > NO_3$ (nutrients).
iii. $1.1\text{-}10.0\ mgL^{-1}$ = Mg > K > Organic Matter> Organic Carbon>DO.
iv. $10.1\text{-}100.0\ mgL^{-1}$ = Alkalinity> Turbidity (NTU)> Cl > Ca >Na >SO_4> Acidity.
v. $> 100 mgL^{-1}$= Apparent color (Pt.Co), HCO_3^-, Conductivity (μScm^{-1}), Total dissolved solids, DO saturation (%).

The annual mean values for most of the parameters were not statistically different ($p > 0.05$) among the three sets of fishponds (Table 2) except Na^+, Alkalinity, HCO_3^-, Conductivity and TDS which were each characterized with significant mean differences ($p \leq 0.05$) among the three pond types. These five parameters and most of the other parameters all occurred in the mass ranking order of FF > NFF > FNF for the three pond types. In general the fertilized ponds (FF and FNF) were characterized by higher mean values in 24 of the 29 investigated water quality parameters than the non-fertilized ponds (NFF). For these 24 parameters, the fertilized ponds (FF and FNF) were on the average about 1.17 times or 17% (range = 1.01-1.44 times) higher than the unfertilized ponds (NFF). On the other hand, only four parameters (transparency, pH, manganese and lead) were higher in the non-fertilized ponds than in the fertilized ponds, on the average about 1.25 times (range = 1.004-1.754) higher.

The effect of water flowage on the ponds was also observed in 22 out of the 29 investigated parameters. These parameters were generally higher in the fertilized flow-through ponds (FF) than in the fertilized non-flow-through ponds (FNF), (Table 2). They include oxygen parameters (DO, BOD_5, DO % sat), all major ions, two of the heavy metals (Pb and Cu) and transparency.

On the average, the major ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, SO_4^{2-}, HCO_3^-) were about 1.32 times or 32% (range = 1.010-1.497 times) higher in the flow-through ponds (FF) than in the non-flow-through ponds (FNF). While the mean values of apparent colour, turbidity, Organic matter, organic carbon, phosphate, manganese and nickel were slightly higher ($p > 0.05$) in the non-flow- through ponds (FNF) than in the flow-through ponds (FF), (Table 2). On the average, these parameters were 1.20 times higher in the non-flow- through ponds (FNF) than in the flow-through ponds (FF).

The seasonal pattern of variations in the three pond types were similar for water temperature, sodium, chloride, pH, conductivity, total dissolved solids, manganese and lead which were all higher during the dry season than in the rainy season (Table 3). On the contrary, depth, calcium, alkalinity, bicarbonate, acidity, BOD_5 and copper were higher in the rainy season than in the dry season. Significant seasonal differences ($p \leq 0.05$) occurred among the three pond types for water temperature, sodium and manganese during the dry season and for alkalinity, bicarbonate, acidity, BOD_5 depth and copper during the rainy season. The other parameters (apparent colour, turbidity, magnesium, nitrate, dissolved oxygen, organic matter, organic carbon, nickel) were not governed by any definite seasonal pattern (Table 3), as they varied differently among the different pond types over the two seasons involved.

The Jaccard index of association (based on seasonal mean value of the parameters) between the two fertilized ponds (FF and FNF) showed perfect association (JI = 1.000) while the relationship between the two flow-through ponds (FF and NFF) which although very high was less than 1.000 (JI = 0.966).

Similarly, the correlation coefficient value of 0.991 between the two fertilized-ponds (FNF and FF) was slightly higher than the value of 0.983 between the two flow-through ponds (FF and NFF). The effect of fertilization was also reflected on the seasonal mean values of turbidity, phosphate, organic matter and manganese which were significantly different ($p \leq 0.05$) between the fertilized-ponds and non-fertilized ponds. The effect of water flowage was also reflected in the seasonal mean values some of the parameters (apparent colour, transparency, magnesium, sulphate, nitrate and copper), but the differences between the flow-through ponds and non- flow-through ponds were not statistically significant ($p > 0.05$).

Discussion

Most of the investigated water quality parameters remained within the desirable range for optimal aquacultural productivity except turbidity (1.5-174.2 NTU) and phosphate (0.07-1.82 mg/l) in all the ponds throughout the period of study (Table 4; Boyd, 1998). The result has revealed that fertilization could cause slight increase in all the essential nutrients (nitrate,

Table 1: Descriptive statistics of the water quality parameters of earthen fish ponds in NIFAGOL Farm, Osun State, Nigeria, 2006-2008.

Parameter	Descriptive Statistics								
	Mean	Standard Deviation	Standard Error of Mean	Median	Minimum	Maximum	Range	Skewness	Kurtosis
Air Temperature (°C)	31.20	3.0	0.399	31.00	27.00	37.00	10.00	0.235	-1.348
Water Temperature(°C)	31.00	1.4	0.188	31.00	28.00	33.00	5.00	-0.413	-0.864
Apparent Colour (Pt.Co)	598.20	423.4	55.600	470.40	66.50	1739.80	1673.30	1.104	0.608
Turbidity (NTU)	58.00	43.6	5.727	44.00	1.50	174.20	172.70	1.150	0.543
Transparency (m)	0.26	0.1	0.018	0.27	0.02	0.61	0.59	0.248	-0.554
Depth (m)	0.54	0.2	0.024	0.53	0.20	1.05	0.85	0.342	-0.155
Calcium (mg/L)	16.90	4.7	0.620	16.40	8.30	29.00	20.70	0.171	-0.378
Magnesium mg/L)	2.00	1.9	0.252	1.80	0.10	7.70	7.60	1.217	0.990
Sodium (mg/L)	13.20	3.8	0.500	12.70	7.00	24.90	17.90	0.713	0.652
Potassium (mg/L)	8.94	2.4	0.310	8.80	4.80	15.20	10.40	0.576	0.211
Chloride (mg/L)	29.90	20.6	2.711	25.50	6.80	118.10	111.30	1.903	5.401
Sulphate (mg/L)	14.98	6.6	0.873	13.20	8.40	49.80	41.40	3.021	12.923
Phosphate (mg/L)	0.88	0.5	0.059	0.90	0.07	1.82	1.75	-0.174	-0.903
Nitrate (mg/L)	0.83	0.1	0.017	0.82	0.68	1.49	0.81	2.467	9.859
Alkalinity (mg/L $CaCO_3$)	108.40	36.3	4.773	102.00	42.00	214.00	172.00	1.419	2.307
HCO^-_3 (mg/L)	132.10	44.4	5.825	124.00	51.00	261.00	210.00	1.419	2.304
Acidity (mg/L $CaCO_3$)	12.80	12.4	1.626	10.00	0.00	70.00	70.00	2.533	7.806
pH	7.55	0.5	0.067	7.39	6.07	8.41	2.34	-0.013	-0.195
Conductivity (μscm^{-1})	226.10	51.7	6.789	227.50	120.00	338.00	218.00	0.070	-0.803
TDS (mg/L)	120.10	17.4	2.290	121.50	84.00	157.00	73.00	0.006	-0.859
Dissolved Oxygen (mg/L)	6.23	2.4	0.312	6.40	2.00	15.20	13.20	1.079	2.935
DO Saturation (%)	83.80	32.2	4.229	83.20	26.20	204.90	178.70	1.054	2.841
BOD_5 (mg/L)	4.44	2.6	0.347	4.00	0.40	11.50	11.10	0.655	0.041
Organic Matter (mg/L)	8.58	4.9	0.645	8.30	1.70	25.20	23.50	1.495	2.919
Organic Carbon (mg/L)	5.05	2.8	0.372	4.90	1.00	14.60	13.60	1.450	2.844
Nickel (µg/L)	0.28	1.00	0.000	0.00	0.00	3.00	3.00	2.852	7.165
Manganese (µg/L)	37.00	36.00	0.005	22.00	8.00	134.00	134.00	1.850	2.032
Lead (µg/L)	32.00	47.00	0.006	0.00	0.00	170.00	170.00	1.469	1.257
Copper (µg/L)	4.00	4.00	0.001	3.00	0.00	15.00	15.00	1.171	0.445

Table 2: Mean values of physico-chemical parameters of the investigated fish ponds in NIFAGOL Farm, Osun State, Nigeria, 2006-2008.

Parameter	Pond						ANOVA	
	FNF		FF		NFF		F value	P
	Range	Mean ± S.D.	Range	Mean ± S.D.	Range	Mean ± S.D.		
Air Temperature (ºC)	27.0-35.5	30.4 ± 3.1a	27.0-37.0	31.5 ± 3.1a	27.0-36.0	31.4 ± 2.9a	0.848	0.434
Water Temperature(ºC)	29.0-33.0	30.9 ± 1.4a	28.0 -33.0	31.1 ± 1.6a	28.0-33.0	31.1 ± 1.4a	0.461	0.634
Apparent Color (Pt.Co)	66.5-1595.6	664.5 ± 541.3a	181.9-1710.9	645.7 ± 372.6a	153.0-1739.8	528.1 ± 424.1a	0.080	0.923
Turbidity (NTU)	1.50-165.2	61.0 ± 52.1a	13.7-159.1	58.4 ± 35.7a	16.68-174.2	57.6 ± 49.2a	0.078	0.925
Transparency (m)	0.05-0.36	0.21 ± 0.12a	0.02-0.51	0.25 ± 0.13a	0.08-0.61	0.29 ± 0.14a	0.025	0.976
Depth (m)	0.21-0.59	0.50 ± 0.14a	0.20-0.85	0.65 ± 0.19b	0.23-1.05	0.39 ± 0.11c	0.825	0.444
Calcium (mg/L)	8.3-22.9	14.2 ± 4.8a	9.0-24.7	17.4 ± 4.5a	9.8-29.0	17.2 ± 4.5a	0.753	0.476
Magnesium (mg/L)	0.10-7.10	1.43 ± 2.07a	0.10-5.60	2.14 ± 1.62a	0.10-7.70	1.91 ± 1.98a	0.451	0.640
Sodium (mg/L)	7.0-15.2	9.8 ± 2.8a	8.6-24.9	14.4 ± 4.2b	8.5-20.7	13.5 ± 2.9b	4.173*	0.021
Potassium (mg/L)	6.10-12.90	8.93 ± 2.16a	4.80-14.8	9.02 ± 2.28a	4.80-15.20	8.82 ± 2.68a	0.380	0.686
Chloride (mg/L)	6.8-44.2	24.7 ± 12.2a	6.8-118.1	35.0 ± 26.6a	6.8-73.1	27.7 ± 15.8a	1.266	0.291
Sulphate (mg/L)	11.90-17.70	14.16 ± 1.86a	9.10-49.80	16.72 ± 8.68a	8.40-31.70	13.34 ± 5.34a	1.540	0.224
Phosphate (mg/L)	0.16-1.45	0.93 ± 0.42 a	0.11-1.42	0.92 ± 0.37a	0.07-1.82	0.77 ± 0.53a	0.388	0.680
Nitrate (mg/L)	0.75-0.89	0.82 ± 0.05a	0.68-1.49	0.87 ± 0.17a	0.68-1.15	0.80 ± 0.11a	1.562	0.220
Alkalinity (mg/L $CaCO_3$)	42.0-142.0	87.8 ± 30.7a	82.0-214.0	120.5 ± 40.7b	68.0-190.0	105.9 ± 30.4ab	3.455*	0.039
HCO_3 (mg/L)	51 .0-173.0	103.8 ± 41.8a	100.0-261.0	146.9 ± 49.6b	83.0-232.0	129.1 ± 37.1ab	3.760*	0.030
Acidity (mg/L $CaCO_3$)	6.0-70.0	18.9 ± 19.7a	2.0-40.0	12.2 ± 10.1b	0.0-32.0	9.1 ± 6.6ab	0.348	0.708
pH	6.07-8.10	7.14 ±0.53a	6.90-8.41	7.61 ± 0.47b	7.10-8.39	7.64 ± 0.43b	1.396	0.257
Conductivity (μscm^{-1})	120.0-310.0	195.0 ± 55.2a	159.0-338.0	246.2 ± 51.8b	134.0-292.2	222.4 ± 41.2ab	3.783*	0.030
TDS (mg/L)	84.0-148.0	109.4 ± 18.6a	97.0-157.0	126.8 ± 17.4b	89.0-142.0	119.1 ± 14.0ab	3.793*	0.029
Dissolved Oxygen (mg/L)	2.00-15.20	6.24 ± 3.96a	2.80-11.20	6.80 ± 1.62a	2.40-10.40	5.65 ± 2.06a	1.163	0.321
DO Saturation (%)	26.2-204.9	84.1 ± 53.6a	36.10-148.70	91.3 ± 22.3a	32.1-139.2	76.3 ± 27.7a	1.200	0.310
BOD_5 (mg/L)	1.90-11.50	4.59 ± 3.43a	0.40-9.60	5.15 ± 2.26a	0.40-10.20	3.57 ± 2.53a	1.421	0.251
Organic Matter (mg/L)	3.30-25.20	8.94 ± 6.41a	1.70-22.50	8.63 ± 4.35a	2.40-23.60	8.54 ± 4.91a	0.091	0.981
Organic Carbon (mg/L)	1.90-14.60	5.18 ± 3.71a	1.00-13.00	5.19 ± 2.47a	1.40-13.70	4.96 ± 2.86a	0.082	0.921
Nickel (µg/L)	0.00-3.00	0.60 ± 1.00a	0.00-3.00	0.30 ± 0.70a	0.00-3.00	0.20 ± 0.70a	1.239	0.298
Manganese (µg/L)	13.4-16.0	53.0 ± 47.0a	12.0-119.0	32.0 ± 29.0a	8.0-122.0	34.0 ± 35.0a	0.856	0.431
Lead (µg/L)	0.0-60.0	10.0 ± 20.0a	0.0-140.0	34.0 ± 46.0a	0.0-170.0	42.0 ± 55.0a	0.535	0.589
Copper (µg/L)	0.0-12.0	4.0 ± 4.0a	0.0-14.0	5.0 ± 4.0a	0.0-15.0	4.0 ± 4.0a	0.419	0.660

NB: Values in a row followed by different letters are significantly different ($p = 0.05$).
* = Significant. FNF – Fertilized non-flow-through pond. FF – Fertilized flow-through pond.
NFF – Not fertilized flow-through pond.

Table 3: Seasonal mean values of the physico-chemical water parameters of investigated fish ponds in NIFAGOL Farm, Osun State, Nigeria, 2006-2008.

Parameter	Pond									ANOVA	
	FNF			FF			NFF				
	DS	RS	DS / RS	DS	RS	DS/ RS	DS	RS	DS / RS	F-value	P
Air Temperature (°C)	32.9 ± 2.3	28.3 ± 1.9	1.163	33.9 ± 2.8	29.7 ± 1.9	1.141	33.8 ± 2.6	29.5 ± 1.3	1.146	50.104***	0.000
Water Temperature (°C)	31.6 ± 0.6	30.3 ± 1.6	1.043	31.7 ± 1.5	30.7 ± 1.5	1.033	31.8 ± 1.1	30.4 ± 1.3	1.046	9.011**	0.004
Apparent Colour (Pt.Co)	851.2±539.5	508.9±537.8	1.673	631.9±282.7	655.7±435.9	0.964	499.2±300.1	552.1±517.9	0.904	0.521	0.474
Turbidity (NTU)	86.9 ± 53.3	39.4 ± 43.8	2.206	60.3 ± 28.8	56.9 ± 40.9	1.060	51.8 ± 39.5	62.4 ± 57.4	0.830	1.096	0.300
Transparency (m)	0.13 ± 0.07	0.27 ± 0.11	0.481	0.21 ± 0.08	0.29 ± 0.16	0.724	0.29 ± 0.13	0.29 ± 0.15	1.000	3.532	0.066
Depth (m)	0.38 ± 0.14	0.41 ± 0.09	0.927	0.43 ± 0.12	0.56 ± 0.15	0.768	0.60 ± 0.19	0.68 ± 0.18	0.882	4.421**	0.041
Calcium (mg/L)	13.8 ± 5.3	14.6 ± 4.8	0.945	15.6 ± 4.4	18.8 ± 4.3	0.830	15.6 ± 3.11	18.7 ± 5.1	0.834	3.644	0.062
Magnesium (mg/L)	0.78 ± 1.19	1.98 ± 2.59	0.394	1.77 ± 1.56	2.41 ± 1.67	0.734	2.22 ± 1.86	1.67 ± 2.12	1.329	0.626	0.433
Sodium (mg/L)	11.3 ± 3.6	8.5 ± 1.2	1.329	15.6 ± 3.5	13.5 ± 4.6	1.156	14.2 ± 3.7	12.9 ± 2.0	1.101	4.390**	0.041
Potassium (mg/L)	9.40 ± 2.03	8.53 ± 2.37	1.102	9.38 ± 2.05	8.78 ± 2.48	1.068	9.23 ± 3.46	8.48 ±1.90	1.088	1.209	0.277
Chloride (mg/L)	28.5 ± 15.1	21.6 ± 9.5	1.319	40.6 ± 32.9	30.9 ± 21.6	1.314	32.3 ± 21.0	23.8 ± 8.9	1.357	1.972	0.166
Sulphate (mg/L)	15.28 ±1.78	13.21 ± 1.41	1.157	15.12 ± 4.70	17.85 ± 10.71	0.847	11.47 ± 2.82	14.90 ±6.48	0.770	0.455	0.503
Phosphate (mg/L)	1.14 ± 0.24	0.76 ± 0.48	1.500	0.98 ±0.42	0.87 ± 0.35	1.126	0.73 ± 0.57	0.80 ± 0.51	0.913	1.237	0.271
Nitrate (mg/L)	0.85 ± 0.04	0.80 ± 0.11	1.063	0.83 ±0.09	0.90 ± 0.20	0.922	0.78 ± 0.09	0.81 ± 0.13	0.963	0.221	0.640
Alkalinity (mg/L $CaCO_3$)	82.4 ± 27.8	92.3 ± 34.8	0.893	103.5 ± 10.4	132.7 ± 49.7	0.780	92.3 ± 14.2	117.3 ± 35.9	0.787	5.468**	0.023
HCO^-_3 (mg/L)	93.2 ± 43.0	112.6 ± 42.5	0.828	126.2 ± 12.7	161.8 ± 60.6	0.780	112.4 ± 17.3	143.1 ± 43.9	0.785	6.361**	0.015
Acidity (mg/L $CaCO_3$)	11.2 ± 3.3	25.3 ± 25.7	0.443	12.0 ± 7.1	12.4 ± 12.1	0.968	6.6 ±3.7	11.2 ± 7.9	0.589	3.910*	0.054
pH	7.33 ± 0.28	6.99 ± 0.67	1.049	7.67 ± 0.43	7.58 ± 0.52	1.012	7.33 ± 0.28	6.99 ± 0.67	1.049	2.168	0.147
Conductivity (μscm^{-1})	214.0 ± 79.9	179.2 ± 18.1	1.194	252.0 ± 46.5	242.1 ± 56.7	1.041	226.5 ± 44.9	218.9 ± 39.5	1.035	1.453	0.234
TDS (mg/L)	115.6 ± 26.9	104.2 ± 6.24	1.109	129.1 ± 15.6	125.1 ± 18.9	1.032	121.0 ± 15.29	117.4 ± 13.3	1.031	1.692	0.199
Dissolved Oxygen (mg/L)	6.60 ± 4.86	5.93 ± 3.50	1.113	6.56 ± 0.89	6.97 ± 2.01	0.941	5.68 ± 1.37	5.63 ± 2.56	1.009	0.012	0.912
DO Saturation (%)	89.4 ± 65.3	79.7 ± 47.7	1.122	88.1 ± 13.8	93.6 ± 27.1	0.941	77.5 ± 18.9	75.2 ± 34.2	1.031	0.037	0.848
BOD_5 (mg/L)	3.88 ± 3.65	5.18 ± 3.46	0.749	3.91 ± 1.99	6.05 ± 2.05	0.646	2.68 ± 1.97	4.32 ± 2.77	0.620	5.677**	0.021
Organic Matter (mg/L)	9.66 ± 3.82	8.33 ± 8.34	1.160	8.94 ± 2.45	8.41 ± 5.40	1.063	8.07 ± 3.63	8.33 ± 8.34	0.969	0.056	0.814
Organic Carbon (mg/L)	5.60 ± 2.22	4.83 ± 4.83	1.159	5.18 ± 1.42	5.20 ± 3.06	0.996	4.68 ± 2.11	5.18 ± 3.44	0.903	0.014	0.905
Nickel (µg/L)	0.4 ±1.0	0.6 ± 1.0	0.667	0.3 ± 1.0	0.2 ± 1.0	1.500	0.4 ± 1.0	–	–	0.073	0.788
Manganese (µg/L)	84.0 ± 55.0	26.0 ± 11.0	3.231	45.0 ± 41.0	23.0 ± 10.0	1.957	43.0 ± 42.0	27.0 ± 30.0	1.593	11.693***	0.001
Lead (µg/L)	12.0 ± 27.0	8.0 ± 13.0	1.500	43.0 ± 39.0	27.0 ± 50.0	1.593	51.0 ± 48.0	35.0 ± 65.0	1.457	0.800	0.375
Copper (µg/L)	0.6 ± 0.5	7.0 ± 4.0	0.086	2.0 ± 2.0	6.0 ± 5.0	0.333	1.0 ± 2.0	6.0 ± 5.0	0.167	28.520***	0.000

* = Significant. ** = highly significant. *** = Very highly significant. FNF – Fertilized non-flow-through pond. FF – Fertilized flow-through pond. NFF – Not fertilized flow-through pond. DS – Dry season. RS – Rainy season.

Table 4: Mean values of physico-chemical water parameters of the investigated fish ponds in NIFAGOL Farm, Osun State, Nigeria, 2006-2008, in comparison with desirable limits.

Parameter	Pond			Desirable limits (Boyd, 1998)
	FNF	FF	NFF	
	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	
Water Temperature(°C)	30.9 ± 1.4	31.1 ± 1.6	31.1 ± 1.4	25-32
Apparent Color (Pt.Co)	664.5 ± 541.3	645.7 ± 372.6	528.1 ± 424.1	<100
Turbidity (NTU)	61.0 ± 52.1*	58.4 ± 35.7	57.6 ± 49.2	30-60
Transparency (m)	0.21 ± 0.12	0.25 ± 0.13	0.29 ± 0.14	25-30
Calcium (mg/L)	14.2 ± 4.8a	17.4 ± 4.5	17.2 ± 4.5	5-50
Magnesium (mg/L)	1.43 ± 2.07	2.14 ± 1.62	1.91 ± 1.98	5-100
Sodium (mg/L)	9.8 ± 2.8	14.4 ± 4.2	13.5 ± 2.9	2-100
Potassium (mg/L)	8.93 ± 2.16	9.02 ± 2.28	8.82 ± 2.68	1-10
Chloride (mg/L)	24.7 ± 12.2	35.0 ± 26.6	27.7 ± 15.8	31-50
Sulphate (mg/L)	14.16 ± 1.86	16.72 ± 8.68	13.34 ± 5.34	5-100
Phosphate (mg/L)	0.93 ± 0.42*	0.92 ± 0.37*	0.77 ± 0.53*	0.005-0.2
Nitrate (mg/L)	0.82 ± 0.05	0.87 ± 0.17	0.80 ± 0.11	0.1-3
Alkalinity (mg/L $CaCO_3$)	87.8 ± 30.7	120.5 ± 40.7	105.9 ± 30.4	50-200
HCO^-_3 (mg/L)	103.8 ± 41.8	146.9 ± 49.6	129.1 ± 37.1	50-300
pH	7.14 ±0.53	7.61 ± 0.47	7.64 ± 0.43	6.5-9.5
Conductivity (μscm^{-1})	195.0 ± 55.2	246.2 ± 51.8	222.4 ± 41.2	100-250
TDS (mg/L)	109.4 ± 18.6	126.8 ± 17.4	119.1 ± 14.0	>100
Dissolved Oxygen (mg/L)	6.24 ± 3.96	6.80 ± 1.62	5.65 ± 2.06	5-15
BOD_5 (mg/L)	4.59 ± 3.43	5.15 ± 2.26	3.57 ± 2.53	< 10
Nickel (µg/L)	0.60 ± 1.00	0.30 ± 0.70	0.20 ± 0.70	20
Manganese (µg/L)	53.0 ± 47.0	32.0 ± 29.0	34.0 ± 35.0	50-200
Lead (µg/L)	10.0 ± 20.0	34.0 ± 46.0	42.0 ± 55.0	50
Copper (µg/L)	4.0 ± 4.0	5.0 ± 4.0	4.0 ± 4.0	5-10

*= Above desirable limit.
FNF – Fertilized non-flow-through pond.
FF – Fertilized flow-through pond.
NFF – Not fertilized flow-through pond.

phosphate and potassium) required for primary productivity while flowage could cause increase in the salinity parameters (conductivity, alkalinity and total dissolved solid). The fertilized ponds were more saline (based on conductivity and TDS), better buffered and richer in nutrients than the unfertilized ponds.

High mean turbidity as observed might be as a result of colloidal clay particles and the suspended organic particles due to fish movement in the ponds as well as the abundance of phytoplankton (Boyd, 1979). This was further reflected in the extent of light penetration which was generally below 1 m for all the ponds and over the two seasons of the annual cycle. While the high level of phosphate concentration in the fishponds could be as a result of pond management practices employed such as fertilization with inorganic fertilizers (Adedeji, 2011). These, however according to Ludwig (2002) could favour increased ammonia concentration which is hazardous to the organism inhabiting the ponds.

The high level of BOD_5 (0.40 mgL^{-1}-11.50 mgL^{-1}) as reported in the present study is in accordance to the resultant effect of organic fertilization of ponds (Ngbede, 1996; Ludwig, 2002). While the BOD_5 of the non-fertilized ponds which was equally high (0.40 mgL^{-1}-10.20 mgL^{-1}) as observed might probably be due to uneaten feeds which are being decomposed (Baluyut, 1989). The BOD_5 of the fertilized flow-through ponds (0.40 mgL^{-1} -9.60 mgL^{-1}) was however much more within the desirable limit than that of fertilized non flow-through pond (1.90 mgL^{-1}-11.50 mgL^{-1}). This could be as result of effect of water flowage leading to continuous refreshening of the water in the pond.Conductivity values were generally less than 400 μscm^{-1}, hence the ponds can be classified among African most dilute water (conductivity less than 600 mhos cm^{-1}); this class of water is known to be poor in ionic concentration (Talling and Talling, 1965 cited in Kemdirim, 2005). Moreover, these ponds can be classified mesotrophic according to Olsen's (1950) trophic classification of water (cited in Garg *et al* 2010), hence will support diverse species of organisms (Dumont, 1999).

The significant variation based on water flowage as

observed for sodium, alkalinity, bicarbonate, conductivity and TDS could be as a result environmental modifications (alterations in water chemical composition) due to inlet and outlet flows of water in the flow-through ponds (Pereira *et al* 2004). Effect of fertilization was however observed for the oxygen parameters, nutrients, major ions and apparent colour which are known to increase on account of fertilizer application (Abdel-Tawwab *et al* 2005). Based on these observations, it could be inferred that the fertilized flow-through ponds were characterised by water quality most suitable for fish culture in the study area.

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