Physico-chemical properties of concrete pond water used for *Clarias gariepinus* aquaculture

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Abstract: The world population is increasing every day and so is the need for food security. The increasing demand for fish can only be met by geometric expansion and sustainable development in aquaculture. The success of aquaculture to a large extent depends on water quality. Samples of rearing water collected from three concrete fish ponds located far from each other within Port Harcourt metropolis were analyzed using standard analytical methods. The data obtained were analyzed using ANOVA. Temperature, p H, salinity, alkalinity, conductivity, turbidity, total hardness and Chlorine were within the water quality criteria for aquaculture while total dissolved solids, phosphate, iron and ammonia did not conform to water quality criteria. Pond 2 contained high levels of most of the parameters measured while Pond 3 was low on most of the parameters analyzed. The values of total dissolved solids, phosphates, iron and ammonia were higher than permissible limits of FEPA. Better water quality and consequent increased fish productivity can be achieved if pond water is changed more frequently and contamination of water source by industrial effluents is effectively controlled.

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1. Introduction

Fish is an all-important resource in the economy of every nation. It provides an adequate protein source for the populace of the nation. Fish serves different purposes which include employment, food source, recreation/sports and economic growth. Aquaculture is the rearing of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants under controlled conditions. *Clarias gariepinus*is an important cultured species in Nigeria due to its popular demand. It has good rearing potentials in that it is hardy, omnivorous and can survive adverse environmental conditions. It can also grow into enormous sizes (maximum length:1.7 m (5 ft 7 in and maximum published weight: 60.0 kg) making good business for the fish farmer (Froese *et al*., 2014a). Intensive aquaculture has the potentials of meeting the growing fish demand, contribute to economic growth and support the sustainable livelihoods of many communities (FAO, 2006).

Aquaculture, however, is hindered by disease outbreaks, low water quality, pollution, high cost of feeds, low digestibility of feeds and adverse impacts of environmental changes (Okoliegbe *et al.,* 2017). Water quality describes the physical, chemical, biological and aesthetic properties of water which determine its fitness for use and its ability to maintain the health of farmed aquatic organisms. Many of the water quality characteristics are controlled by constituents who are either dissolved or suspended in water. Water quality criteria are scientific and technical information provided for a particular water quality parameter in the form of numerical data and/or narrative descriptions of its effects on the fitness of water for a particular use or on the health of aquatic ecosystems (SAWQG, 1996). Water quality largely depends on the physico-chemical and bacteriological quality of the water. The success of *Clariasgariepinus* aquaculture depends on providing the optimum environment for rapid growth while keeping the cost of production and capital at the barest minimum. One of the major advantages of intensive recirculation systems is the ability to manage the aquatic environment and critical physic-chemical parameters to maximize fish health and growth rates. Critical water quality parameters that play important roles in fish production are temperature, suspended solids, and pH and concentrations of dissolved oxygen, ammonia, nitrite, CO2, and alkalinity.

Each particular parameter is important, but it is the cumulative effect and interrelationship of all the parameters that influence the health and growth rate of the fish. The presence of both organic and inorganic substances in fish rearing water affects the survival, health, growth and general well-being of the fish. Wisdom *et al.* (2013) studied the physicochemical properties of fish ponds in Abuja, Nigeria and discovered that there is a strong correlation between physicochemical parameters and fish mortality. Routine monitoring of physicochemical parameters helps in early detection of deterioration of water quality so that timely correction measures can be undertaken to avoid stunted growth, disease outbreaks or fish death. Adverse alterations in critical parameters like dissolved oxygen, temperature and ammonia can lead to fish death and huge losses in aquaculture (Wisdom *et al.*, 2013). This study was aimed at investigating the physic-chemical properties of the pond water in concrete fish ponds used for *Clarias gariepinus* aquaculture in Port Harcourt metropolis.

2. Materials and Methods

2.1 Study Area

The study area is three concrete ponds within Port Harcourt metropolis which is situated approximately on latitudes $4^{o}40^{1}$N -50^{1} N and between longitude 70.00^{1}E – $7^{o}10^{1}$E. The source of water to these ponds is borehole. The ponds are densely stocked with healthy *Clarias gariepinus* juveniles. *Clarias gariepinus* is widely consumed by the populace in this area. Thus, the improvement of *Clarias gariepinus* aquaculture necessitated this study. The rearing water was changed every morning and evening to ensure good sanitary condition. There is no vegetation in the ponds. The fish were fed *ad libidum* three times daily on commercial artificial feed.

2.2 Sample collection

Water samples were collected in sterile plastic bottles (1000 ml) with a screw cap, 15–20 cm below the water surface and 1.5 meters away from the edge of the pond. The bottle was thoroughly rinsed with the water to be analyzed before collecting the sample. Water was collected from five different locations in each pond and the bottles tightly sealed. Samples were kept in ice box to avoid deterioration. They were immediately transferred to the laboratory for analyses. Samples were properly labeled on reaching the laboratory.

2.3 Physicochemical parameters of the water

Physico-chemical parameters of the pond were measured according to APHA, 1999. Unstable parameters such as temperature, conductivity, and pH were measured in-situ in the field. Temperature was measured with a mercury filled Celsius thermometer. pH was estimated using the Hanna pH meter; salinity was analyzed with Atago hand-held refractometer Model S/mill-E Cat. No. 2442, alkalinity was measured by titrating 50 ml of water sample to which two drops of methyl orange indicator has been added, against 0.02N HCl, total dissolved solids (TDS) content and electrical conductivity were estimated with the Oakton TDS/conductivity-meter. Turbidity was analysed using a spectrophotometer (HACH model DR/2010), using distilled water as a blank and read at a wavelength 860 nm. Water Hardness was determined by titrating water sample to which 1ml Ammonium Chloride buffer solution was added, with 0.01N Ethlene-diamine-tetraethonic acid (EDTA) solution using 0.2ml Eriochrome black T as an indicator, a blue solution results at the end-point. Total dissolved solids were measured using Analytic TDS meter, dissolved oxygen was determined using the Winkler's iodometric titration method. Total suspended solids was also determined using the spectrophotometer but on a wavelength of 810nm. BOD (mgl^{-1}) was determined by first measuring the Dissolved Oxygen of the water samples on the first day and then aerating the sample in a BOD bottle. The aeration was carried out for 5 days at 20°C in an incubator. Distilled water (used as water for dilution and as a blank) was aerated for five days too using a clean supply of compressed air, then the Dissolved oxygen, D.O. was measured after five days of incubation and So, BOD (mg/l) = DO on day 1 – D.O on day 5.

Acidity was determined titrimetrically by adding two drops of Phenol naphthalene to 50 ml of sample which is then titrated against 0.02 M sodium hydroxide (NaOH), pink colour appears because of the indicator in the sample. Sulphate, SO_4^{2-} (mgl^{-1}) was analyzed using the colorimetric method where equal volumes (25 ml) of sample and Barium chloride were measured into a Nessler tube. The turbidity of the resulting solution, was measured at a wavelength of 420 nm in a spectrophotometer after allowing it to stand for 15 min. Nitrate, NO_3^- (mgl^{-1}) Nitrate was determined by measuring the turbidity of the colour produced by each tube using a spectrophotometer at a wavelength of 470 nm, after adding, 0.5 ml of brucine and 20 ml of concentrated sulphuric acid to equal volumes (10 ml) of the sample and distilled water contained in two Nessler tubes.

Phosphate, PO_4^{3-} (mgl^{-1}) was determined by initial digestion using Sulphuric acid /nitric acid method and then determining the phosphate using ascorbic acid method (APHA, 1980). In the initial digestion stage, 200ml of water samples were measured into 250 ml conical flask, then1ml of concentrated Sulphuric acid (BDH, England) and 5ml concentrated Nitric acid (BDH, England) were added. The solution was digested to a volume of 1ml on a hot plate and continued until the solution became colourless signifying a total removal of nitric acid. In the ascorbic acid stage of determination of Phosphate, the digest was allowed to cool after which 10ml distilled water was added.

One (1ml) Phenolphthalein indicator was added to the solution and the acid was neutralized by adding the amount of Sodium Hydroxide required producing a faint pink colour. About 6mm of combined reagent (made up of 5ml NH2S04, 5ml Potassium Antimonyl solution, 15ml Ammonium Molybdate and 30ml ascorbic acid) was added to the solution and made up to the 50ml mark with distilled water and the absorbance of each sample was measured at 880NM using a reagent balance as reference solution.

Table 1: Physicochemical parameters of rearing water

Parameters	Concrete Pond (1)	Concrete Pond (2)	Concrete Pond (3)	Water Quality criteria
Temperature (^oC)	27.00	28.00	27.60	20 – 30 (FEPA)
pH	7.24	7.50	7.00	5 – 9 (FEPA)
Salinity (ppt)	0.20	0.22	0.18	0 – 100 (FEPA)
Alkalinity (mgl^{-1})	21.00	28.00	24.00	100 – 400 (FEPA); 20-100(SA)
Conductivity (μScm^{-1})	165	170	158	20 – 1500 (FEPA)
Turbidity (FNU)	2.16	3.16	4.10	1 – 150 (FEPA)
Total hardness (mg/L)	40.00	48.10	45.00	(20 -100) (FEPA) (SA)
Total Dissolved Solids (mgl^{-1})	125.70	165.70	110.40	(11.6-Adults; 10-larvae)SA
Dissolved Oxygen (mgl^{-1})	6.80	6.10	6.40	> 1.00 (5-8)SA
BOD (mgl^{-1})	3.20	2.52	2.85	10 – 20 (FEPA)
SO_4^{2-} (mgl^{-1})	3.78	4.00	3.50	1000 (FEPA)
NO_3^- (mgl^{-1})	4.18	4.48	4.02	<300(mg NO_3-N/l) SA
PO_4^{3-} (mgl^{-1})	3.68	3.82	3.60	0.1 – 3.0 (FEPA); (0.1-0.6)SA
Mg (mgl^{-1})	4.50	5.68	5.41	
Na (mgl^{-1})	4.52	6.86	3.96	
K (mgl^{-1})	5.02	6.42	4.85	
Cl^- (mgl^{-1})	80.00	101.00	68.00	>60 (Stone and Thomforde, 2004) (< 600)SA
Ca (mgl^{-1})	8.48	9.88	9.00	25-100(Wurts & Durborow, 1992)
Iron II (mgl^{-1})	0.25	0.28	0.16	(<0.01)SA
NH_3 ($\mu mol/L$)	0.15	0.08	0.35	< 0.1(FEPA)

FEPA: Federal Environmental Protection Agency; SA: SAWQG (South African Water Quality Guidelines)

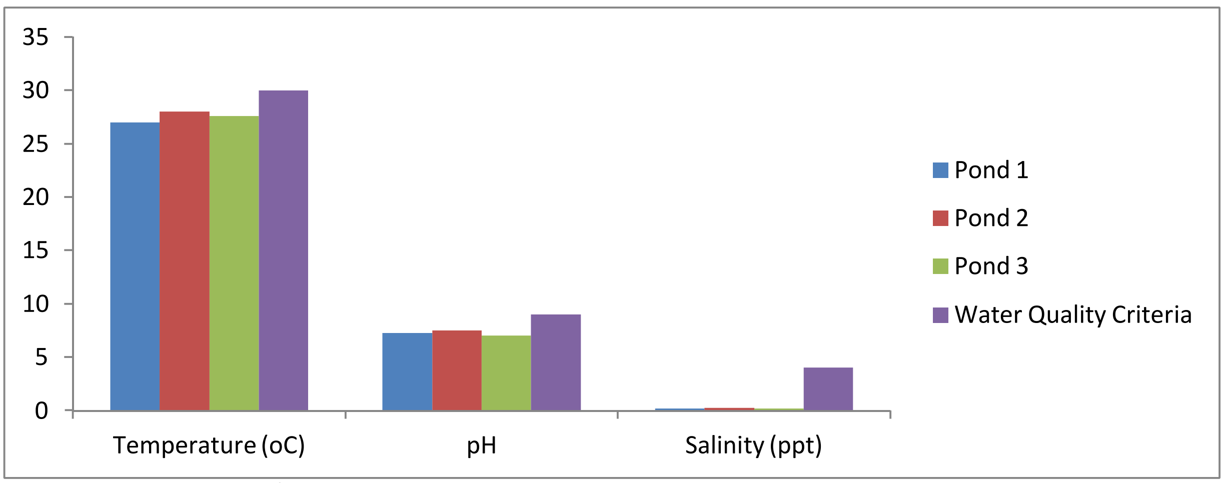

Fig.1: Temperature ((^oC), pH and Salinity (ppt) of the three ponds compared with Water quality criteria

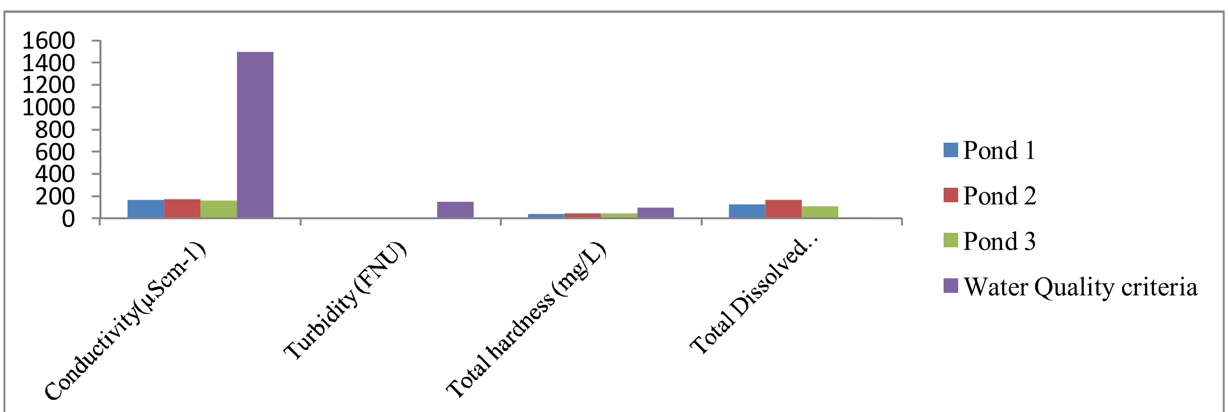

Fig.2: Conductivity (μScm^{-1}), Turbidity (FNU), Total hardness (mg/l) and Total Dissolved Solids (mg/l) of the three ponds compared with Water quality criteria

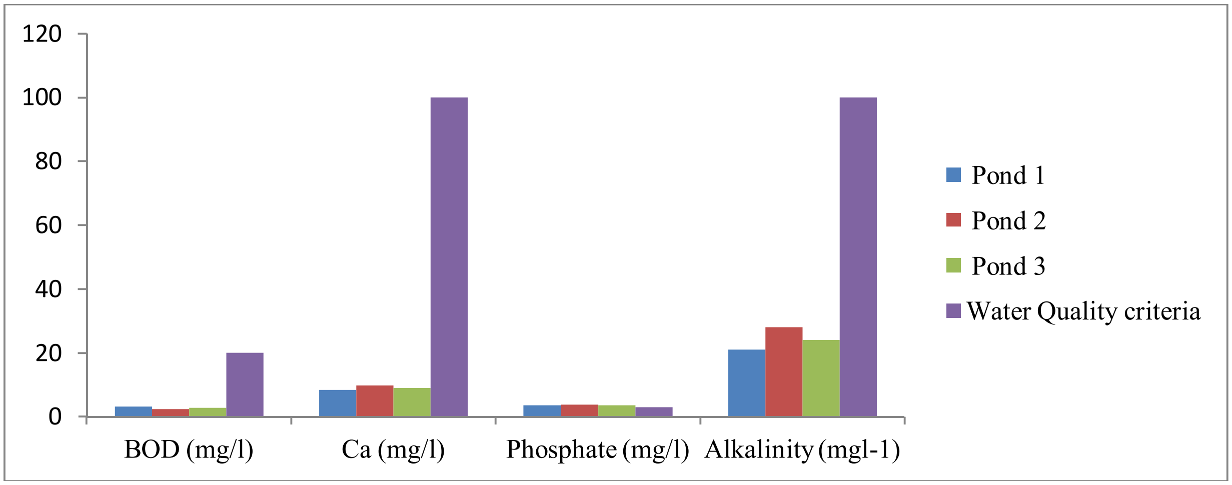

Fig.3: BOD (mg/l), Ca (mg/l), Phosphate (mg/l) and Alkalinity (mg/l) of the three ponds compared with Water quality criteria

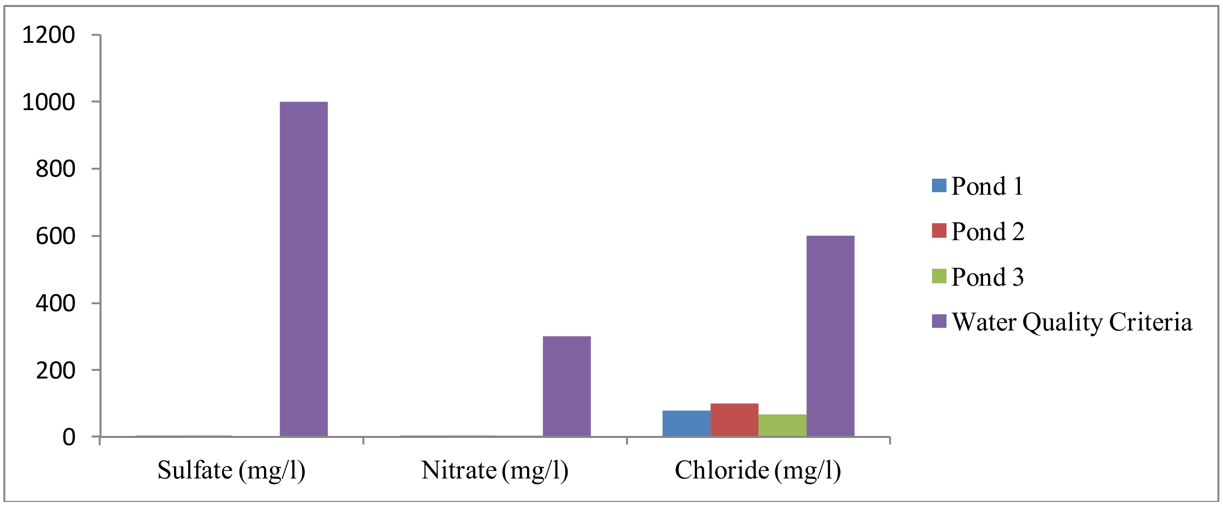

Fig.4: Sulfate (mg/l), Nitrate (mg/l) and Chloride (mg/l) of the three ponds compared with Water quality criteria

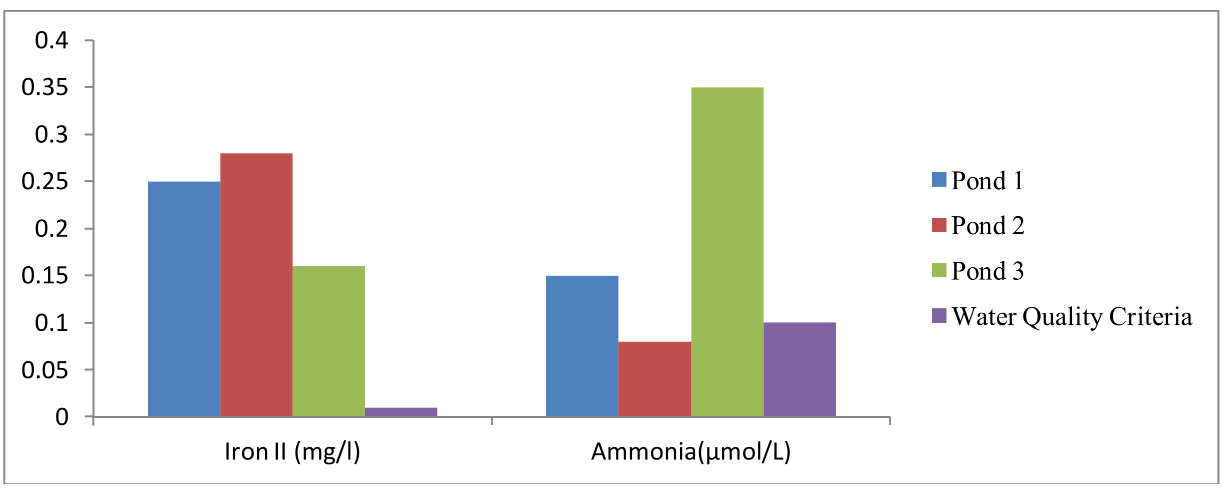

Fig.5IronII (mg/l) and Ammonia (μmol/L) of the three ponds compared with Water quality criteria

Phosphate-phosphorus of the sample was then read from the calibrated curve, The concentrations of Na^+(mgl^{-1}) and K^+(mgl^{-1}) were determined with a flame Emission Analyser. Chloride, Cl^- was also measured with appropriate titrimetric method. Iron II (mgl^{-1}) was analyzed by transferring 10 ml of sample into a graduated cylinder and one-quarter teaspoon of ascorbic acid crystals added and stirred until dissolution of the crystals. An iron testing strip coated with 2,2'- bipyridine, which forms dark, highly visible molecule with Fe (II), was then dipped for one second. The colour change after 10 seconds was then matched and corresponding concentration values read off using the colour chat provided. For ammonia, NH_3 (µmol/L), 1ml of 10- mol caustic soda was added to 100ml of standard solution and 100ml of the sample, respectively, until the pH value was 11 while stirring continuously with a magnetic stirrer and a mixer paddle. The ammonia sensor was mounted on a stand and immersed in the sample water inside the sample vessel, placed on the mixer. Any air bubbles on the membrane were removed and readings taken.

2.4. Statistical analysis

All data were statistically treated using one-way ANOVA. All statistical analyses were performed with SPSS for Windows, (versions 13.0 and 14.01).

3. Result

3.1. Physico-chemical properties of the pond

The temperature and pH of the three ponds recorded in this study are conducive for aquaculture. Although they vary, there is no significant difference between the temperature values but there is significant difference ($P < 0.05$) in the pH, salinity, alkalinity, conductivity, turbidity, total hardness values recorded in the three ponds. Table 1 shows the physico-chemical properties of the three ponds (Ponds 1, 2 and 3) studied. Mean water temperature ranged from 27°C in Pond 1 to 28°C in Pond 2. The temperature of the pond water of Pond 3 was 27.60°C. pH was 7.24, 7.50 and 7.00 in Ponds 1,2 and 3 respectively. Salinity (ppt) measurements were 0.20, 0.22 and 0.18 for Ponds 1, 2 and 3. Conductivity ranged from 158 μScm^{-1} (Pond 3) to170 μScm^{-1} (Pond 2). Turbidity ranged from 2.16 FNU (Pond 1) to 4.10 FNU (Pond 3). The highest turbidity was recorded in Pond 3. Among the three Ponds, Pond 2 had the highest concentration of calcium (9.88 mg/l) and total hardness (48.10 mg/l); Pond 2 also had the highest salinity (0.22 ppt), alkalinity (28 $mgCaCO_3l^{-1}$), Total dissolved solids (165.70 mgl^{-1}), phosphates (3.82 mgl^{-1}), Mg (5.68 mgl^{-1}), Na (6.86 mgl^{-1}), K (6.42 mgl^{-1}), Cl (101.00 mgl^{-1}) and Iron II (0.28 mgl^{-1})). The highest BOD was recorded in Pond 1 (3.2 mgl^{-1}) while the lowest was recorded in Pond 2 (2.52 mgl^{-1}), Pond 3 had the highest ammonia (0.35 µmol/L). The highest dissolved oxygen (6.80 mgl^{-1}) was recorded in Pond 1. The highest amounts of most of the salts were recorded in Pond 2. Fig 1 – 5 shows the various water quality parameters analyzed in comparison with the water quality criteria.

4. Discussion

The variations observed in the physico-chemical properties of the three fish ponds studied could be attributed to differences in the physical and chemical properties of the surrounding soil, water and underlying aquifers which transmits or contacts the borehole water used in the fish ponds. The temperature range of 27 to 28°C observed in the ponds was within the recommended temperature range for aquaculture. Solomon *et al.* (2013) observed a wider temperature range of 24 -29 °C in fishponds studied in Abuja. Temperature determines the rate of metabolism in aquatic organisms. Temperature affects the solubility of oxygen in water. If the temperature is high, lesser oxygen dissolve at the water-air interface, and dissolved oxygen in the deeper parts of the pond floor further decreases (Ezekiel *et al.*2011).

Boyd (1979) defined pH as the negative logarithm of hydrogen ion concentration. As pH increases, the salinity and alkalinity of the medium increases also. The pH range recorded in the pond was within WHO limit (6.8 -8.5) for optimum aquaculture Low pH values favour the existence of toxic heavy metals in mobile form making the water hazardous for aquaculture (Olatayo,2014). Salinity is the total concentration of electrically charged ions in the water. These ions are the four major cations-calcium, magnesium, potassium and sodium, and the four common anions carbonates (CO_3), sulphates (SO_4), chlorides (Cl^-) and bicarbonates (HCO). Other components of salinity are charged nitrates (NO_3), ammonium ions (NH_4) and phosphates (PO_4). Onyema and Nwankwo (2009) asserted that conductivity and salinity are directly proportional. This concurs with the values obtained in the three ponds that conductivity increased as salinity increased. Moreso, Pond 2 which had the highest concentration of both positive and negative ions had the highest conductivity. The alkalinity range observed in this study was 21 – 28 mgl^{-1}. It is within the alkalinity range posited by Wurts and Durborow (1992) for aquaculture production – at least more than 20 mgl^{-1}. The differences observed in both conductivity and alkalinity among the 3 ponds could be due to the influences of prevailing edaphic factors, particularly the substratum, as the ponds were far apart and as such ought not to have one common source of water supply. The ability of water to conduct electricity is referred to as conductivity. Conductivity is a function of the total ionic content of the water. The conductivity range of the ponds studied was 158 – 170 μScm^{-1}.

This range agrees with the values obtained by Khan *et al.* (2017) who reported values between 158 and 185 μScm^{-1}during summer. Higher values were obtained by Anyanwu and Solomon (2015) who studied two fish ponds in Abuja metropolis and observed electrical conductivity range of 250-280 μScm^{-1} on the average. The higher the concentration of salts in water, the higher the conductivity of the water (Olatayo, 2014). Sikoki and Veen (2004) opined that different fishes differ in the conductivity range in which they can grow optimally because they differ in their capacity to maintain osmotic balance. Turbidity values observed in this study range from 2.16 – 4.10 FNU. Solomon *et al.* (2013) observed a similar range of 2.15 - 4.45 FNU in the fish ponds studied. High turbidity reduces fish productivity because it reduces penetration of light thereby hindering photosynthetic activities of the pond microflora on which the fish feed. Total hardness ranged from 40 mg L^{-1} (in Pond 1) to 48 mg L^{-1} (in Pond 2). Hardness measures the total content of calcium and magnesium in the medium. It also includes other ions such as aluminum, iron, manganese, strontium, zinc and hydrogen ions.

The recommended ideal range for total hardness for aquaculture is 30-180 mg l^{-1} (Sadashivaiah, 2008). High level of total hardness increases the pH and reduces nutrient availability in the water. The dissolved oxygen (DO) ranged from 6.10 in Pond 2 to 6.80 mg/l in pond 1. Ehiagbonare and Ogunrinde (2010) observed a higher range of 9.3 – 16.2 mg/l in concrete and earthen fish ponds analyzed in Edo State, Nigeria. Towers (2014) posited that a minimum constant D.O of 4.0 mg/l is adequate for optimum yield in aquaculture. These results imply that fishes in the three ponds analyzed in this study had adequate dissolved oxygen supply. Low D.O. is caused by small size of pond and eutrophication due to over fertilization with manure. Consistently high DO levels can cause the gas bubble disease while consistently low levels of DO (1.5 mg/l) reduces the fish feed intake and growth rate. Fish breathe in oxygen for carrying out metabolic activities. DO is also needed for breaking down potentially harmful metabolic wastes into less harmful substances e.g. breaking down ammonia (NH_3) into nitrites (NO_2) and nitrates (NO_3) (Towers, 2014). Biochemical oxygen demand (BOD) is the measure of oxygen needed by microorganism for the aerobic degradation of organic matter in the pond. BOD reflects the organic load in a water body. According to Dinesh *et al.* (2017).

BOD is influenced by temperature, the extent of biological activity, the concentration of organic matter and microbial population such as bacteria and fungi. Inflow of sewage increases the BOD. High BOD depletes the dissolved oxygen in the pond. Bhatnagar and Singh (2010) asserted that BOD of less than 1.6 mgl^{-1} is best for optimum aquaculture. The BOD level between 3.0 to 6.0 mg/L has been reported as optimal for normal activities for fishes (Dinesh *et al.,* 2017). FEPA recommended standard (FEPA, 1991) for aquaculture is 30 mg/l and the APHA (1992) recommended standard is 4 mg/l. The BOD measured in this study ranged from 2.52 (Pond 2) - 3.20 mgl^{-1} (Pond 1) and is considered conducive for optimum aquaculture since these values do not imply any organic pollution.

Rana and Jain (2017) posited that in productive inland water bodies in Africa, nitrate range is from 9.8 – 49 mg/l while, phosphate range is between 3.2 and 6.30mg/l. This implies that the nitrates range obtained in this study i.e., 4.02 – 4.48mg/l, and the phosphate range (3.6 - 3.82 mgl^{-1} observed here are typical of productive inland waters and as such may be considered adequate for fish productivity, though the FEPA stipulated phosphate range for aquaculture is 0.1-3 mg/l. The range of ammonia recorded in this study is 0.08 – 0.35 mgl^{-1}. This range is higher than < 0.01 which is the range stipulated by FEPA. The relatively high level of ammonia observed in the three ponds could be attributed to accumulation of un-eaten protein-rich feed and fish wastes.

Ammonia is the most abundant form of dissolved inorganic nitrogen. It is used as indicator of organic pollution and becomes toxic to aquatic organisms in concentration of more than 2-5 mg/l (Khattaby, 2015). There was a significant variation in ammonia content of the three ponds. Point sources of sulfates include sewage treatment plants and industrial discharges such as tanneries, pulp mills, and textile mills and runoff from fertilized agricultural lands. According to Davies (2008), sulfate had positive correlations with EC and salinity. The higher sulfate in Pond 2 might be the possible reason for the significantly higher conductivity and salinity in the pond. However, the recorded sulfate could be linked to natural occurrence or the result of municipal or industrial discharges that leaked in to the underground water from which the pond water was obtained.

5. Conclusion

High water quality is the life-wire of any aquaculture operation. Of critical importance are temperature, pH and dissolved oxygen. Tolerance to different water quality parameters differ according to the fish spacies. The results of this study showed that Pond 2 had the highest values of most physico-chemical parameters studied followed by Pond 1 and then Pond 3. Thus it can be asserted that Pond 2 is more productive biologically than other ponds and can be recommended as most conducive for fish production. The values of all the physico-chemical parameters investigated in this study were within the range recommended for good fish production, except total dissolved solids, phosphates, iron and ammonia. Intensive fish rearing facilities are encouraged to frequently carry out routine monitoring of the water quality of the fish ponds so as to ascertain adverse changes in the physico-chemical parameters and adequate ameliorating measures taken before it gets to threshold limits which may lead to fish mortality.

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