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Microbiological and Physico-Chemical Characteristics of Fish Ponds in Port Harcourt

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Abstract

Commercial rearing of the African catfish (*Dutch clarias*) has gained prominence in Port Harcourt and its environs as it is considered a healthier source of protein and as a lucrative source of income. Bacterial infection of catfish poses a serious concern as it could lead to economic losses and an avenue for the spread of infection to consumers. The bacteriological and physicochemical properties of different water samples from three fish ponds (borehole water that is fed into the fish pond, borehole water plus fish feed and bore hole water plus fish feed and fish excreta was investigated. Results of pH in the water samples ranged from 3.79 to 6.27, temperature ranged from 31.3^{0}C to 32.1^{0}C, DO ranged from 1.62 mg/L to 7.30 mg/L while the BOD_5 ranged from 0.81 mg/L to 18.27 mg/L. The turbidity values ranged from 0-62NTU, electrical conductivity ranged from 124.5-896, TDS 6.6-55.7mg/l, chloride < 6.42-88.92mg/l, phosphate<0.05mg/l in all the samples, Nitrate<0.17-0.86mg/l, Total alkalinity 11.52-53.76mg/l, calcium<2.30-18.43mg/l, magnesium<0.93-2.34mg/l and potassium<0.05. The heterotrophic bacterial count of the borehole water ranged from 1.8×10^5 to 3.6×10^5cfu/ml, borehole water and fish feed ranged from 1.3×10^5 to 14.6×10^5cfu/ml while borehole water plus fish feed and fish droppings ranged from 2.0×10^5 to 28.8×10^5cfu/ml. Isolated bacteria genera from the fish ponds included *Bacillus*, *Salmonella*, *Shigella*, *Vibrio*, *Serratia*, *Escherichia coli*, *Pseudomonas* and *Staphylococcus.* The bacteria isolated were potential pathogens of humans and poses a health risk to the unsuspecting fish consumer.

Keywords: Fish ponds, Dissolved Oxygen, BOD_5, bacteria, pathogens,

Introduction

Fish is an important part of the human diet, it serves as a source of cheap protein and is a rich source of minerals and nutrients for the sustenance of man (FAO, 2002), according to the world fish center, 2013, fish is a most reliable source of protein to various populations of individuals worldwide.

Fish is preferred as a protein source as it can be consumed by all cadres of individuals regardless of their religious beliefs and nutritional preferences, a classic example being the Muslims who do not eat pork meat; this has resulted in the preference of fish over other sources of protein such as pork or red meat (Njoku *et al.*, 2015). According to the world fish center, (2003) fish is a most reliable source of protein to various populations of individuals worldwide. The increased daily demand for fish and its products in Nigeria has led to increased fish production by both public and private sectors (Obire and Ariyo, 2015).

In the Southern part of Nigeria, fish dishes such as catfish pepper soup and roasted fish are a culinary delight and this has further pushed up the demand for fish resulting in an increase in the number of fish farms in the region as consumer demands are being satisfied and to also make up for the reduced population of fish obtained from our natural water sources (Njoku *et al*., 2015).The cheapest source of protein is regarded as fish as it is cheap, easy to digest and has a high nutritional content; it makes up a vital part of the diet of large populations of individuals (Eze *et al*., 2011). In Europe, fish consumption per capita grew up to 24.5kg in 2011, as there has been a general increase in the utilization of fish and its products (Alkesanir *et al*., 2015).

The beginning of aquaculture in Nigeria according to (Akinrotimi *et al*., 2011) was in Jos in 1951 with the popular Panyan fish farm, the farm functioned as the pioneer training and extension centre for the aquaculture industry in Nigeria. Aquaculture possibly arose as an intervention measure to boost food production, specifically fish protein and it has become one of the fastest growing sectors worldwide (Erondu *et al*., 2005) ' From an activity that was principally small scale, non-commercial and family based, aquaculture now includes, large scale commercial and industrial production of high value species that are being traded at local, regional and international levels (Akinrotimi *et al*., 2010) .The worth of the Nigerian aquaculture industry in dollars as at 2010 was 800 dollars, this included the value of fingerlings, feed and farmed fish(Adewumi *et al*., 2010) . Available data showed that fish production from aquaculture, ranged from 15.840 metric tons in 1991 to 25,720 metric tons in the year 2000. The current production capacity according to Anetekhhai *et al*., 2004 is about 26,000 metric tons which is less than 0.5% of the national capacity.

In Nigeria, catfish is the common fish of choice in the aquaculture industry. The *Heterobranchus* specie and the *Clarias* species of catfish are the most commonly cultured fish in the south eastern part of Nigeria, this is because it is highly resilient, can survive substandard water quality and can be transported alive or smoked to its point of sales (Anetekhaie *et al*., 2004). Other characteristics of the African catfish that make it suitable for commercial cultivation are, ability to withstand the tropical environment, suitability for monoculture and polyculture with other fresh water species, tolerance to high stocking densities, high rate of laying eggs, nutritional value and high weight gain (Anyanwu and Chah, 2016). All possible forms of aquaculture are practiced in Nigeria due to the presence of marine, fresh and brackish water resources. Each of these water sources pose their special problems to the aquaculture industry including but not limited to discharge of effluents into the environment, effect of crude oil activities (Anetekhai *et al*., 2004)

Catfish basically are grown in ponds which could be earthen, concrete, wooden, plastic or manmade fiber glass materials (Osawe, 2004). The major types of systems are the earthen ponds that employ the use of turn down elbows as drainage system. Most of these ponds depend on natural water sourced from the ground in form of boreholes. Concrete tanks are gradually catching up to the earthen ponds in catfish culture as a result of the high cost of land and its unavailability (Onome and Ebinimi, 2010).

Success in aquaculture is dependent on fish health management as bacterial diseases constitute a major threat to aquaculture (Anyanwu and Chah, 2016) the source of these bacteria in aquaculture production could be from both commercial and homemade feed. High cost of fish feed is one of the constraints involved in the fish farming industry, some fish farmers therefore employ the use of animal manure to augment the conventional fish feed. The downside to this practice according to Njoku *et al*., (2015) is that the use of organic manure leads to the release of high concentrations of pathogens into the fish ponds which pose a public health risk. Such feed can be a source of pathogenic bacteria such as *Salmonella* species which can be transmitted to catfish and subsequently contracted by consumers (Titik *et al*., 2012). Animal manure is also used traditionally for pond fertilization, as pond water becomes fertile upon the application of manure, however it has been reported that average counts of heterotrophic bacteria were significantly higher in the pond water upon the application of livestock manure (Omojowo and Omajosola, 2013). Other possible sources of bacterial contamination have been identified as poor water quality and high stocking densities (Njoku *et al*., 2015). These bacterial pathogens are often detected in fish and have the potential to cause death of fish which lead to economic losses to the farmer. In order to counter this, the fish farmer uses antibacterial agents ranging from fish cure which comprises of oxytetracycline, chloromphenicol and neomycin phosphate and other materials used for treating sick fish such as salt and aqua Enro.

This investigation is therefore necessary in order to determine and identify the bacterial pathogens present in the borehole water used for fish farming, the borehole water after fish feed has been added to it and the borehole water after fish feed has been added to it and the fish have excreted into it in addition to the physico-chemical parameters of the different water samples.

Materials and Methods

Study Area

The study was conducted in the Port Harcourt metropolis of Rivers State located within longitude 7.0498 degrees E and latitude 4.8156 degrees N with a land mass of 360km squared. The vegetation of the area reflects a tropical wet climate with lengthy and heavy rainfall and a very short dry season. The harmattan which climatically influences many cities in West Africa is less pronounced in Port Harcourt.

Collection of Samples

Water samples were obtained from three plastic fish ponds in Port Harcourt located at D/line, Ozuboko and the UPE Sand fill Borikiri areas of Port Harcourt. Three samples were collected from each fish farm namely the raw water which is pumped into the plastic pond, the fish pond water after fish feed has been added to it and the fish pond water containing fish feed and fish excreta. For collection of the borehole water samples, the tap water was allowed to run constantly for at least 5 minutes to purge water from the plumbing and pipes and draw fresh water in from the water supply, the bottle was not overfilled and the cap secure but not over tightened. Microbial count samples were collected in sterile screw capped containers which were rinsed with the sample before collection. The samples for dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected in clean amber coloured bottles. Other physicochemical parameter samples were collected in clean plastic bottles. The collected samples were stored in an ice cooler and transported to the laboratory for analysis within 8 hours of collection. In addition, the distance between the septic tanks and borehole was measured with a measuring tape in all the three locations.

Isolation of Total Heterotrophic Bacteria (THB)

The samples of the different water samples obtained from the fish ponds were serially diluted in tenfold using physiological saline. Serial dilution was done up to 10^{-5}. 0.1ml aliquot was taken from 10^{-3} dilution and plated in triplicates on already prepared aseptic nutrient agar plates, a sterile hockey stick was used in spreading the water sample over the surface of the sterile agar plates. The plates were incubated at 37^0 C for 24 hours. Discrete colonies were counted and subsequently subcultured in order to obtain pure cultures which were stored in nutrient agar slants and frozen at 4^0C. The number of colony forming units per ml (cfu/ml) was calculated by dividing the number of colonies formed by the dilution factor and the volume plated.

Isolation of Salmonella/Shigella

The *Salmonella/Shigella* agar (SSA) (Oxoid limited, Wade Road Basingstoke Hampshire United Kingdom) was prepared according to the manufacturer's instruction. 0.1ml aliquot of each of the three water samples from the three ponds was introduced onto the surface of dried sterilized SSA plates, a sterile hockey stick was employed in spreading the inoculums on the plate after which the plates were inverted and incubated at 37^oc for 24-48hours. Pure cultures were obtained after 48 hours. Discrete colonies were counted and the number of colony forming unit per ml was calculated.

Isolation of Vibrio species

The thiosulphate citrate bile salts agar (TCBS) (Acumedia Neogen. Lasher Place, Lasing USA) was prepared according to the manufacturer's instruction and poured into sterilized Petri dishes. Upon solidification and drying, 0.1ml of each of the pond water samples was transferred onto the dried agar plates in triplicate using a 1ml pipette and spread evenly with a hockey stick. The cultures were incubated at 35^oC for 24-48 hours. After incubation, *Vibrio* colonies were counted and identified using biochemical reactions

Isolation of Coliforms

An aliquot (0.1ml) of pond water was plated on dried sterilized Mac Conkay agar plates using the spread plate technique and incubated at 35^oC for 24 - 48 hrs.

Characterization and identification of bacterial isolates

The purified bacterial isolates were characterized culturally, morphologically and biochemically based on the Bergey's manual of determinative Bacteriology (Holt *et al*., 1994).

The tests include Gram reaction, motility, catalase, urease, indole, oxidase, methyl red, Voges Proskauer (MR-VP) Reactions, sugar fermentation, citrate utilization, starch hydrolysis, salt tolerance tests.

Determination of Physico-chemical parameters

An array of the physiochemical parameters of the three water samples from each of the ponds was investigated which include temperature, dissolved oxygen, pH, turbidity, salinity, electrical conductivity, biological oxygen demand, total hardness, total dissolved solids (TDS), phosphates, nitrates, sulphates and chloride. Other parameters examined were colour, odour and appearance. Winkler's solution 1 and 11 were added *in situ* to the water samples which were collected in Amber bottles for dissolved oxygen and kept under laboratory conditions at 30^{o}C. Conductivity and salinity was determined using Horiba water checker U-10. Turbidity was determined using Lamotte TC 3000WI, Trimeter 1969-iso while Extech Dissolved oxygen meter (Water proof series) DO 700 was used to determine pH and total dissolved solids (TDS), biochemical oxygen demand was determined using the 5 days method. Nitrate was determined using the Brucine method, sulphate was determined using the turbidimetric method, phosphate was determined using the stannous chloride method; chloride was determined by the Argentometric methods. Total alkalinity was determined by the Acid-Base titration method, calcium was determined by the EDTA titration method and ammonia was determined by the phenate method. Heavy metals (Pb, Cu, and Fe) were analyzed using Atomic Absorption Spectrophotometer.

The chemical analysis was done using standard laboratory methods suggested by the American Public Health Association (APHA, 1995)

Statistical analysis

The results obtained in the course of the study was subjected to statistical analysis using the computer based program SPSS. Analysis of variance (ANOVA) and the Duncan's multiple range tests were used to test for significance and mean separation respectively at 5% level of confidence.

Results

Table 1: Mean Values of Physiochemical Constituents of Three Fish Ponds

PARAMETER		POND LOCATION								
		D-LINE Fish pond			OZUBOKO Fish pond			UPE Fish pond		
	Unit	BH	BHF	BHFE	BH	BHF	BHFE	BH	BHF	BHFE
Appearance	-	Clear	Clear	Clear	Clear	Clear	Slightly turbid	Clear	Cloudy without particles	Clear
Colour	-	2	40	75	3	42	550	0	0	0
Odour	Hazen	Slightly offensive	Slightly offensive	Slightly offensive	Slightly offensive	Slightly offensive	Offensive	Odourless	Odourless	Slightly offensive
Pb	Mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	Mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fe	Mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
pH		6.39	6.11	6.44	6.72	5.70	6.27	3.79	4.46	6.33
EC	uS/cm	620	587	690	124.5	135.4	801	896	824	125.5
Turbidity	NTU	0	1.98	4.98	0	0	62	0	1.02	19.40
Salinity	mg/L	0.285	0.275	0.33	0.05	0.06	0.377	0.426	0.422	.616
Temperature	^oC	31.5	31.7	31.8	31.6	32.0	32.1	31.3	32.1	31.9
TDS	mg/L	420	409	483	84.7	94.7	557	616	575	875
PO^{3-}	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
NO^{4-}	mg/L	1.88	0.86	0.19	2.02	0.17	0.16	0.79	0.21	1.04
SO_3^{2-}	mg/L	7.71	9.48	12.21	<1.00	<1.00	6.69	8.15	11.45	12.15
Cl^-	mg/L	24.7	29.64	27.17	7.41	6.42	32.11	88.92	83.98	16.79
Total Alkalinity	mg/L	4	4	4	4	2	4	2	2	4
TH	mg/L	38.4	32.6	30.7	11.52	13.4	53.76	34.56	49.92	11.52
Ca^{2+}	mg/L	11.52	9.98	10.75	3.07	2.30	18.43	11.52	18.43	3.07
Mg^{2+}	mg/L	2.34	1.87	0.93	0.93	1.87	1.87	1.40	0.93	0.93
DO	mg/L	5.68	3.24	2.43	8.93	5.68	1.62	7.30	3.24	2.43
BOD_5	mg/L	4.87	2.43	0.81	8.12	1.62	18.27	4.06	2.43	18.27

KEY: BH= Bore hole water, BHF= Borehole water and fish feed, BHFE= Bore hole water and fish feed and fish excreta

Table 2: Mean total heterotrophic bacteria count, coliform, *Salmonella/Shigella* count and *Vibrio* count of the borehole water

Location	THC (cfu/ml)	Coliform (cfu/100ml)	*Salmonella/Shigella* (cfu/ml)	*Vibrio* (cfu/ml)
D/line Pond	1.8×10^5	0	0	0
Ozuboko Pond	4.1×10^5	0	0	0
U P E Sandfill	3.6×10^5	0	0	0

Table 3: Mean total heterotrophic bacteria count, Coliform, *Salmonella/Shigella* and *Vibrio* count of the borehole water plus fish feed

Location	THC (cfu/ml)	Coliform (Cfu/100ml)	*Salmonella/Shigella* (cfu/ml)	*Vibrio* (cfu/ml)
D/line Pond	1.3×10^5	1.47×10^2	1.86×10^2	0.096×10^2
Ozuboko Pond	4.76×10^5	0	0	0
U P E Sandfill	14.6×10^5	0	2.5×10^2	0

Table 4: Mean total heterotrophic bacteria count, Coliform, *Salmonella/Shigella* and *Vibrio* count of the borehole water plus fish feed plus fish excreta

Location	THC (cfu/ml)	Coliform (Cfu/100ml)	*Salmonella/Shigella* (cfu/ml)	*Vibrio* (cfu/ml)
D/line Pond	2.0×10^5	1.69×10^2	0.97×10^2	0.01×10^2
Ozuboko Pond	28×10^5	0.06×10^2	0	9.90×10^2
U P E Sand-fill	19×10^5	2.2×10^6	2.1×10^3	6.1×10^2

The results of the microbiological and physicochemical characteristics of the pond water samples are shown in the table. The values of the physiochemical parameters are shown in the table. The pH values ranged from 3.79 to 6.72 for the three fish ponds. The U.P.E Sand filled fish farm had the lowest pH of 3.79 which was obtained from the borehole water sample. This suggests that the water is acidic and could possibly corrode the distribution pipes, if they are metallic. The Ozuboko fish farm had the highest pH of 6.72 which was also obtained from the borehole water sample. The D/Line fish pond had pH values that read 6.39, 6.11 and 6.44 for the different samples namely borehole water, borehole water plus fish feed and borehole water plus fish feed and fish excreta. The ANOVA $P > 0.05$, showed no significant difference among the physiochemical parameters except for temperature, nitrates and turbidity. The values for temperature ranged from 31.5ºC to 32.0ºC for all the samples from the three fish ponds. The values for dissolved oxygen (DO) and biological oxygen demand (BOD) ranged from 1.62 to 8.93, 0.81 to 18.27 respectively for the three ponds. The values for phosphate, nitrate, sulphate and chloride ranged from <0.05, 0.16-2.02, <1.00-12.14, 6.42-88.92 respectively for all the three fish ponds. The values for electrical conductivity, turbidity, salinity and total dissolved solids ranged from 124.5-896, 0-19.40, 0.05-0.426, and 6.6 to 483 respectively. Total alkalinity for all the three samples from the three fish ponds ranged from 2-4.

The total heterotrophic plate mean counts for the three samples from the three fish ponds ranged from 1.3×10^5cfu/ml to 28×10^5 cfu/ml for all the three samples from the three fish ponds. The mean total heterotrophic count for the bore hole water samples for the three ponds ranged from 1.8×10^5cfu/ml to 4.1×10^5cfu/ml. The mean total heterotrophic count for the sample comprising borehole water plus fish feed ranged from 1.3×10^5cfu/ml to 14.6×10^5cfu/ml. the mean total heterotrophic count for borehole water plus fish feed plus fish excreta across the three fish ponds ranged from 2.0×10^5cfu/ml to 28×10^5cfu/ml.

Coliforms were not present in the bore hole water samples across the three ponds. The mean *coliform* count for the sample containing borehole water plus fish feed for the D/Line pond was 1.47×10^2, *coliforms* were not recorded in the same sample from the Ozuboko fish farm and the UPE sand filled fish pond. For the sample comprising the borehole water plus fish feed plus fish droppings, *coliforms* were recorded at the D/Line fish pond at $1.69x10^2$cfu/ml. while the UPE sand fill farm recorded *coliforms* at 2.23×10^6cfu/ml. the Ozuboko fish farm recorded coliforms at 0.06×10^2 for this sample.

Salmonella/Shigella were not recorded in the borehole water samples across the three fish ponds. however, in the sample containing fish pond water plus fish feed, for the Dline fish pond it was recorded at 1.86×10^2cfu/ml. *Salmonella/Shigella* counts were not recorded in the Ozuboko location but at the UPE sand fill ponds, it was recorded at 2.5×10^2cfu/ml

For the sample comprising of the borehole water plus fish feed plus fish excreta, *Salmonella/Shigella* counts were recorded at 0.97×10^2cfu/ml for the Dline fish pond, it was recorded at 2.18×10^3cfu/ml at the UPE sand fill pond but was absent at the Ozuboko fish pond.

Vibrio counts were not recorded in the borehole water sample across the three ponds, however in the sample comprising of the borehole water and the fish feed *Vibrio* counts were recorded at the DLine fish pond at 0.096×10^2cfu/ml, there were no *Vibrio* counts recorded at the Ozuboko fish pond and the UPE sand fill pond. *Vibrio* counts were recorded in the three fish ponds and are as follows 0.010×10^2cfu.

For the sample comprising the borehole water plus fish feed and fish excreta, *Vibrio* counts were recorded in the three fish ponds and are as follows 0.010×10^2cfu/ml, 9.9×10^2cfu/ml and $6.1x10^2$cfu/ml for the D-Line fish pond, Ozuboko fish pond and the UPE sandfill fish pond respectively. The distance between the D-Line borehole and septic tank measured at 9m, the same was recorded for the Ozuboko borehole and septic tank. While the distance between the UPE Sand fill borehole and septic tank measured at 7m.

Discussion

The results of the microbiological profile of the three plastic fish pond in the Port Harcourt metropolis of Rivers State located at D - Line, Ozuboko and UPE sand-filled areas indicated the presence of the following genera of microorganisms *Salmonella* sp, *Shigella* sp, *Bacillus* sp, *Escherichia coli*, *Vibrio*, *Pseudomonas* sp, *Staphylococcus* sp, *Serratia* sp

Vibrio is abundant in aquatic environments as they are normal flora in such environments. *Vibrio* sp are present in fish and fish environments. Various species of *Vibrio* have the capacity to elicit serious disease both in wild and cultured fish and also elicit disease in the population of humans that consume them. Factors such as water salinity and temperature may have been responsible for the prevalence of *Vibrio* in the three fish ponds (Aleksandr *et al*., 2015). This probably accounts for the presence of *Vibrio* in the samples containing the borehole water plus fish feed and the borehole water plus fish feed and fish excreta and its absence in the borehole water.

The *Coliforms* isolated were an alert as to the possibility of faecal contamination of the water which indicates the presence of pathogenic organisms which may have been excreted into the ponds by the fish or may have arisen as a result of contaminant arising from the fish feed (Njoku *et al*., 2015). The presence of *Coliforms* in these ponds constitutes a health risk to the cultured fish in these ponds and is a possible problem in the management of fish pond effluents (Eze *et al*., 2010). According to Aleksandr *et al*., 2015, the European food safety authority lists pathogens such as *Salmonella* and *E. coli* as responsible for most of the food borne infections worldwide. Also, *Staphylococcus* sp, *Pseudomonas* sp have also been involved in food poisoning. In addition a study carried out by Adebayo *et al*., listed *Salmonella* and *Shigella* amongst organisms isolated from catfish and named *Bacillus* also as an organism isolated from fish which is responsible primarily for toxin mediated disease as opposed to infections

The total heterotrophic bacteria count, *Salmonella/Shigella* counts, *Vibrio* and *Coliform* counts were different among the three samples collected from each pond, with the counts being highest in the sample containing the bore hole water plus fish feed and fish droppings followed by the sample containing the borehole water plus fish feed and lastly the bore hole water recorded the least number of organisms. The isolates obtained from this investigation is in line with what was obtained by Adedeji *et al*., 2012 who listed *Bacillus* sp, *Salmonella* sp, *Shigella* sp and *Escherichia coli* amongst pathogens isolated from fish.

The findings of the study suggests that bacterial contamination of the borehole water fed into the plastic fish ponds is the genesis of bacterial contamination of fish ponds even before the organic components of the fish feed and fish excreta further pollute the water.

The WHO (1997) standard minimum distance between boreholes and septic tanks is 30m, however in the three ponds investigated, the maximum distance measured stood at 9m. Therefore, in these ponds investigated which are all plastic ponds, it is important that farmers consider the possibility of purifying their borehole water before it is pumped into the ponds, this is because the distance between the bore holes and the septic tanks are below the recommended standard so there is the possibility of fecal contamination of the water source from the very beginning of the aquaculture process. It has also been discovered that in a bid to cut costs, some boreholes are not drilled to the depth that facilitates the collection of pure underground water, also plots of land owned by land owners are most times fragmented and the land owner usually wants to utilize the land space maximally, this leads to the less than standard distance between the boreholes and the septic tanks (Fubara and Jumbo 2014). All of these, impacts negatively on the aquaculture process, the health of the fish consumer and definitely on the economic benefits accruable to the fish farmer if such water is used for fish farming without pre-treatment.

The temperature of a pond is a reflection of the hotness or coldness of its external environment. When a pond is directly impacted by the sun, it leads to an increase in the temperature of the pond. Also, heat losses at night lead to a corresponding drop in the temperature of the pond. Generally, biologic activities have been observed to double for each 10^{o} rise in temperature. Temperature is therefore an important parameter in water as it impacts on the biotic life of the pond and also on the chemical and physicochemical characteristics of water. The best temperature that supports an increase in fish productivity according to Ntegwu and Mojisola 2008 is at the range of $20^{o}C – 30^{o}C$; however the temperature range recorded in this investigation spans from $31.5^{o}C$ to$32.0^{o}C$ which is slightly above the limit that supports optimum fish productivity. The Ozuboko fish pond recorded the highest temperature of $32.1^{o}C$, this is likely because the pond is positioned directly under the sun and did not have any form of shade or trees above it to limit the impact of the sun on the temperature of the pond.

The pH range for all the three samples in the three ponds ranged from 3.79-6.72 which is below the optimum limit for fish productivity which is pH 6-9. The pH of the D - Line fish pond fell within the acceptable range but the UPE sand filled fish pond recorded pH as low as 3.79 and 4.46 for the borehole water samples and the borehole water plus fish feed samples respectively. In order to avoid stress to fish which leaves them susceptible to infections it is important to maintain optimum pH of the fish ponds as fish can become stressed in water with a pH range of 4.0 - 6.5 (Ekubo and Abowei, 2011). Therefore for the UPE sand filled ponds, it is necessary to adjust the pH from acidic to alkaline for maximum fish productivity, this can be achieved by adding lime to the pond.

Dissolved oxygen is the most important chemical parameter in aquaculture, this is because low levels of dissolved oxygen leads to fish morbidity and mortality, the amount of oxygen that dissolves in water decreases at higher temperature and decreases with increase in altitude. Dissolved oxygen level less than 5mg/l causes stress to fish and levels less than 2mg/l will result in death. The dissolved oxygen obtained from this investigation ranged from 1.62mg/l- 8.93mg/l across the three ponds. DO was lowest in the sample containing fish pond water plus fish feed in addition to the fish droppings. The low DO could be as a result of increased organic and microbial load and a decrease in the metabolic activities of the fish in the pond (FAO, 2005). Like humans, fish need oxygen for their metabolic activities and for respiration, therefore to avoid low DO levels, the ponds should not be overstocked, the pond water should be drained sufficiently and frequently, aerators should be used to agitate the pond thereby incorporating more oxygen into the pond and also fish should not be overfed (Anita and Pooja, 2013).

Alkalinity is the ability of water to resist changes in pH, it is a measure of the total concentration of bases in water including carbonates, hydroxides, phosphates, dissolved calcium and other compounds. The desirable range of alkalinity for optimum fish productivity ranges from 20-300 mg/l. The alkalinity range obtained from this investigation across the three ponds was from 2-4mg/l which is regarded as low. Normally, lime leaches out of concrete ponds into pond water thereby boosting the alkalinity of the water (Eze and Ogbaran, 2010). However the fish ponds investigated in this study are all plastic ponds, it is therefore necessary that the alkalinity levels across the three ponds be adjusted by the addition of lime.

Nitrates are considered harmless to fish in natural systems and ponds. in closed systems however where there exists little or no water change, nitrates will accumulate and may be harmful if higher than 250mg/l. The recommended value for Nitrates according to Ezeanya *et al*., (2015) is 16.9mg/l. the nitrate range obtained from this study across the three ponds is 0.21-2.02mg/l. this concentration of nitrates in water has no adverse effect on fish. Santosh and Singh (2007) described 0.1mg/l to 4/0mg/l as the favourable range of nitrate concentration for the cultivation of fish.

Phosphate levels across the three ponds was less than 0.05mg/l. phosphates are the major food material for algae in ponds and its level must not exceed 0.03mg/l as the smallest increase can trigger an excessive algal growth which could lead to eutrophication. Phosphates are present as bound to living or dead particulate matter and play an important role in increasing aquatic productivity (Anita and Pooja, 2013). Phosphates may be introduced into the pond from the fish feed or from the materials which are used in the creation of the pond.

Sulphate levels across the ponds ranged from <1.00 to 12.2mg/l. the electrical conductivity of the water samples ranged from 124.5us/cm to 896us/cm. the FAO acceptable limit for conductivity in aquaculture is 20-1500us/cm. conductivity is an index of the total ionic content of water and therefore is used to tell the freshness or otherwise of a water source (Anita and Pooja, 2013). The electrical conductivity values were not exceeded in the three ponds and they are therefore suitable for aquaculture activities.

Total hardness described as the amount of alkaline elements such as calcium and magnesium along with other ions such as aluminum, iron in an aquatic body. Stone and Thomforde (2004) described the desirable range for total hardness in a body of water as 50- 150mg/l. from the investigation carried out in the three ponds the range across the ponds was 11.52 - 53.76mg/l. The ponds fell short of the acceptable standard. It is therefore advised that quicklime or alum be added to the pond water in order to reduce the hardness. Heavy metals lead, copper and iron were all <0.001mg/l across all the samples in the three ponds.

Turbidity is described as the ability of water to transmit the light that restricts light penetration and limit photosynthesis; it is a result of suspended clay particles, dispersion of plankton, particulate matter and the pigments caused by the breakdown of organic matter. According to Bhatnagar *et al*., 2004, acceptable turbidity range is from 30-80cm. the turbidity range recorded for the three fish ponds were from 0-62. This range is below the acceptable range for aquaculture production except for the ozuboko fish farm that recorded a turbidity of 62 NTU. Salinity is an important factor and elicits different consequences on the vitality of microorganism. The salinity level obtained from this study ranged from 0.05-0.426.

The BOD values obtained from this study ranged from 0.81 to 18.27. with the lowest BOD value found in the sample containing borehole water plus fish feed plus fish excreta obtained from the D-Line fish farm at 0.81 while the Ozuboko fish farm and the UPE sandfilled farm both recording a BOD value of 18.27. The permissible range of BOD for fish farming is <10l. The high levels of BOD at the Ozuboko and UPE sandfilled farms could be attributed to high levels of organic pollution.

Conclusion

The microbial profile of the three ponds was not significantly different. However, the study has revealed that it is important to maintain an optimum standard of the physicochemical parameters of the fish pond as a deviation from the standard causes stress to fish which makes them susceptible to infections.

It is also important that quality control measures be incorporated into the aquaculture industry in Nigeria; this should begin from the quality of the borehole water which is fed into the pond. Maximum distance between boreholes and septic tanks as recommended by WHO should be strictly followed.

In addition poor fish farm management practices such as fish being fed with more food than they can eat per time which results in the floating of fish feed on the surface of pond water and a corresponding increase in organic matter of the fish also serves as a source of bacterial contamination of fish pond water (Bhatnagah and Devi, 2013) and as such should be curtailed. Questionable water quality and high stocking densities (Bhatnagah and Devi, 2013) also serve as sources of bacterial contamination of ponds and hence should be critically monitored.

Other farm practices which must be inculcated as critical control points in the aquaculture process is the frequency of water change in ponds, it is important that water be changed every day in plastic ponds in order to prevent the possible formation of biofilms by opportunistic organisms such as *Pseudomonas* and *Serratia*.

With the deliberate inculcation of quality control and critical control points in the aquaculture process by farmers coupled with close monitoring and enforcement by policy makers such as NAFDAC, infections which could lead to economic losses to the farmer and elicit infectious disease in the population of individuals that consume such fish will be greatly reduced.

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