WATER QUALITY EVALUATION FROM SELECTED AQUACULTURE PONDS IN BENIN CITY, NIGERIA

[1]Orobator, P. O., [2]Akiri-Obaroakpo, T. M. and [1]Orowa, R

[1]Department of Geography and Regional Planning, Faculty of Social Sciences, University of Benin, Benin City, Edo State, Nigeria
[2]Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City, Edo State, Nigeria
***Corresponding Author Email:** *orobosa.orobator@uniben.edu;* +2348077617860.

ABSTRACT
The present study evaluated water quality from selected aquaculture ponds in Benin City, Nigeria. Water samples were collected from deep concrete pond, white plastic tank, black plastic tank, black tarpaulin pond, earthen pond and surface concrete pond. Standard procedures were adopted to analyze the selected physicochemical parameters of water. The analyzed results were subjected to WHO (2009) and FEPA (1993) permissible limits for aquatic water quality. Pond D (black tarpaulin pond) had the highest concentrations of EC, Total suspended solids (TSS), Total dissolved solids (TDS), turbidity, Sulphate, Biological oxygen demand, NO_4, P, Ca, NH_4, Mg, Na, K, Zn, Cu, Cr, Pb and Cd. Pond D was more acidic and had the lowest alkalinity, Chemical Dissolved Oxygen (COD) and Dissolved Oxygen (DO) values than other fish ponds. COD and P contents in all the fish ponds were above their permissible limits. The status of TSS, TDS, and turbidity, Zn, Cu, Cr, Pb and Cd showed that these water indices were not toxic. The study recommends that fish pond water as well as water holding facilities should be monitored periodically. It also suggests that Pond D (black tarpaulin pond) should be least considered when setting up aquaculture system.

Keywords: aquaculture ponds, water quality, physicochemical parameters and permissible limits.

INTRODUCTION
Water is a natural resource and fundamental need of all organisms, plants, animals and humans; it is also the most necessary solvent for agriculture, industry, tourism and aquaculture (Aydin, 2018). Aquaculture depends predominantly on water and regular monitoring of water quality is a necessity. Fish cultivation also known as aquaculture consists of natural and artificial fish farming carried out in ponds (Akpotayire *et al.*, 2018). In addition to the use of ponds, fishes are also cultured in various water holding facilities such as pens, happas, tanks, cages, raceways, etc. Water is the environment for fishes and its quality determines its fitness for use and capacity to sustain the health of farmed aquatic organisms. Environmental pollution is a primary burden of aquaculture as poor water quality in fish ponds will result to deteriorated fish health and eventually low production. The maintenance of healthy aquatic ecosystem is dependent on the properties of water (Venkatesharaju, Ravikumar, Somashekar and Prakash, 2010). The status of various water parameters like turbidity, pH, alkalinity, hardness, ammonia, nitrite, nitrate, biochemical oxygen demand (BOD) etc. cannot be overlooked for maintaining a healthy aquatic environment (Bhatnagar and Devi, 2013). The condition of pond water quality as it imparts its physiochemical properties is fundamental to the functional state of the pond and productivity of the fish. This is a key concern for this study especially as the result will offer valuable information to fish farmers in raising fishes efficiently.

In recent years, there has been increasing interest in fish farming in the urban and rural – urban fringes of Benin City. This practice of fish farming by some of the urban populace is an integral component of sustainable urban agriculture. This will help to guarantee to some extent food security especially as the metropolitan city grows (Orobator and Asikhia, 2013). However, data from available studies (Thilza and Muhammad, 2010; Ehiagbonre and Ogunrinde, 2010; Solomon, Olatunde and Matur, 2013; Keremah, Davies and Abezi, 2014; Agbaire, Akporido and Emoyan, 2015; Mustapha, 2017; Akpotayire *et al.,* 2018 etc.) revealed that not much has been done on the assessment of the physicochemical properties of water in different fish ponds in Nigeria. These previous investigations show that quite a few of the physicochemical properties of fish pond water were examined and also the types of examined aquaculture systems were limited. This indicates a need to assess the status of various physicochemical properties of water under different fishing systems practiced by the people. Furthermore, water is the home of fish and its quality is one of the most overlooked aspects of pond management until it affects fish production (Akpotayire *et al.,* 2018). If culturists are properly guided and aware about water quality management practices, they can get maximum fish yield in their ponds to a greater extent (Bhatnagar and Devi, 2013). This also demanded the necessity for this study.

The incidences of toxic metals in fish pond water affect the lives of fish which depend upon water for their day-to-day activities. Fish can absorb heavy metals through the epithelial or mucosal surface of their skin, gills and gastrointestinal tract (Jovanovic *et al.,* 2014). The influence of heavy metal pollutants on aquatic ecosystem and its organisms is severe compared with other kinds of pollution (Aladesanmi *et al.,* 2014). For instance, chronic lead (Pb) toxicity in fish results to nervous damage which can be determined by the blackening of the fins, while acute toxicity, on the other hand causes gill damage and suffocation (Svobodova *et al.,* 1993). An inquiry into fish pond water quality should be all encompassing because of the relevance of water quality to fish survival, sustenance and productivity in developing countries. The previously mentioned studies also revealed that most culturists are not aware of the impact of different fishing ponds on the quality of its water. The physicochemical properties of water could be influenced by the culture systems (Mustapha, 2017). Beyond filling the gap in dearth of scope of inquiry into fish pond water quality, this study also aim to bring awareness to fish culturists about the vital water quality parameters that needs constant monitoring as a result of their impact on the health of fishes. Therefore, this will make the study in- depth and a major contribution to research on freshwater ecology.

MATERIALS AND METHODS

Study Area

Benin City is located in latitudes 6^o 14’, 6^o 21’ and Longitudes 5^o 34’, 5^o 44’ (Fig 1), Edo state, Nigeria. The rainy season is between March and November and the annual rainfall varies from 1500 mm to 2250 mm, with the peak between September and early October. The mean monthly temperature is generally high (27.5 ºC). The soil is lateritic (characteristically red or reddish brown in color containing clay particles) while the city is drained by two major river systems; The Ikpoba River draining the eastern portion and the Ogba River draining the western part of the city (Ogbonna, Amangabara and, Itulua, 2011).

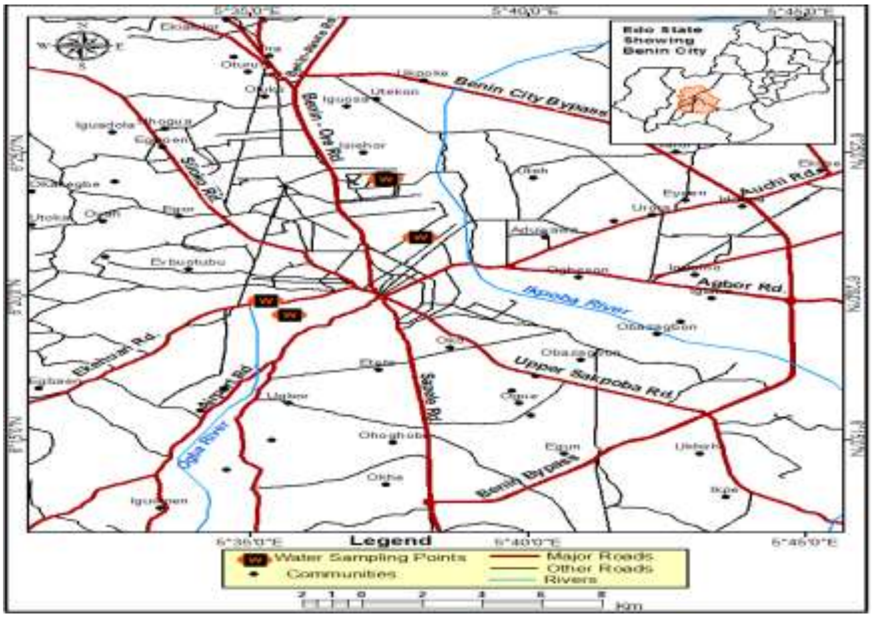

Figure 1: Benin City showing water sampling points (studied fish ponds)
Source: Compiled Using Google Earth Database (2019)

Water Sample collection and sampling
Water samples were drawn in sterile 500 mL bottles from six different functional fish ponds in Benin City, Edo state, Nigeria and labeled pond A, pond B, pond C, pond D, pond E and pond F (Table 1 and Plates 1, 2, 3, 4, 5 and 6). The selected fish ponds were stocked with *Clarias gariepinus* (African sharp tooth catfish) which were about four to five months old as at the time of water sampling. Water samples collected were filtered through 0.45-µm filters to remove particulate matter so as to slow down sample degradation. The fish pond water samples were transported to laboratory for physiochemical analysis. Sampling sites were determined based on the type of fishing ponds. The main source of water in the fish ponds is the underground water from the coastal plain sands of the study area. For the deep concrete pond, white plastic tank, black plastic tank, black tarpaulin pond and surface concrete pond, water was drilled from underground and stored temporarily in tanks. The water was transferred later into the various aquaculture systems while the earthen pond has underground water directly from the Ikpoba River. All the selected fish ponds are located in Benin City and their geographical locations (Fig 1) were identified with the use of Global Positioning System (GPS).

Laboratory Analysis
Fish pond water samples were analyzed for physical and chemical water quality parameters as described by Eaton (2005).The pH was measured by a multipurpose pH meter. Alkalinity was determined using the titration method. Biological oxygen demand (BOD) and dissolved oxygen (DO) was evaluated using standard titrimetric method. Total dissolved solids (TDS) were determined using standard methods 2540 B. Conductivity was analyzed using a conductivity meter in micro-siemens per centimeter (µs/cm). The turbidity was measured using nephelometric method by turbid meter. Ammonium-nitrogen was determined with Hach's Model FF-2 Aquaculture test kit. Determination of the concentrations of magnesium (Mg), lead (Pb), chromium (Cr), zinc (Zn), Ni, cadmium (Cd), copper (Cu) and iron (Fe) in the water samples was carried out using an atomic absorption spectrophotometer (AAS). Phosphate – Phosphorous was measured by the ascorbic acid method (Ayanwale *et al*,. 2012). Nitrate – nitrogen in water sample was determined using the phenoldisulphonic acid method (Paerl *et al.*, 1975). Sulphate was determined using the colorimetric method. Total suspended solids (TSS) were obtained gravimetrically (Ademoroti, 1996). Chemical dissolved oxygen (COD) was analyzed by open condensation and digestion by titration (Dinesh *et al.*, 2017). Calcium and potassium was measured using colorimetric method (Mustapha, 2017).

Statistical Analysis
This study adopted the use of descriptive statistics. However to determine the status of the examined physicochemical water parameters, results from the laboratory were compared with the permissible values given by World Health Organization (2009) and Federal Environmental Protection Agency (1993)

Table 1. Location of selected fish ponds

Sampling site	Type of fish pond	Latitude	Longitude
A	Deep concrete pond	N 06^0 19.837’	E 005^0 35. 277’
B	White plastic tank	N 06^0 19.837’	E 005^0 35. 277’
C	Black plastic tank	N 06^0 19.837’	E 005^0 35. 277’
D	Black tarpaulin pond	N 06^0 19.334’	E 005^0 35.705’
E	Earthen pond	N 06^0 22.028’	E 005^0 38.058’
F	Surface concrete pond	N 06^0 24.056’	E 005^0 37. 443’

Plate 1: Pond A (Deep concrete pond)

Plate 2: Pond B **(**White plastic tank)

Plate 3: Pond C **(**Black plastic tank)

Plate 4: Pond D (Black tarpaulin pond)

Plate 5: Pond E (Earthen pond)

Plate 6: Pond F (Surface concrete pond)

RESULTS

Table 2 shows the physicochemical characteristics of water of the different fish ponds and a comparison of the results of the study with standard values given by WHO (2009) and FEPA (1993). The value of pH of water samples is an indicator of its acidic or alkaline nature. Bhatnagar and Devi (2013) noted that fish have an average blood pH of 7.4; hence pond water with pH value close to the above-mentioned pH value is accepted as favorable for fish cultivation. In this study, the highest pH value (6.39) was obtained in deep concrete pond (pond A) while the lowest pH (5.74) value was recorded in black tarpaulin pond (pond D). Amongst all the fish ponds, the EC value obtained in black tarpaulin pond (pond D) was the highest (330 µs/cm) and also higher than the limit given by FEPA (1993) limit if 200 µs/cm. Therefore, the parameter gives cause for concern in this particular pond and it makes the water unsuitable for aquaculture use.

The alkalinity value was highest (12.78 Mg/l) in deep concrete pond (pond A) while it was lowest (11.48 Mg/l) in black tarpaulin pond (pond D). The high alkalinity of deep concrete pond allowed for good buffering capacity of the pond and made the pH in the pond to be basic while the low alkalinity in black tarpaulin pond could have also contributed to the slight acidity of the pond (Mustapha, 2017). The Total Suspended Solids values obtained from this study revealed that pond D had the highest value of Total Suspended Solids (6.60 Mg/l), followed by pond B (3.32 Mg/l), pond E (2.28 Mg/l), pond C (2.18Mg/l), pond F (1.90 Mg/l) and pond A (0.76Mg/l). This implies that the water in pond D is the least transparent amongst all the examined fish ponds. However, the higher transparency observed in other fish ponds may be due to the absence of algae, macrophytes, lack of wind stir to cause re-suspension of sediments and settling humic substances (Mustapha, 2017).

In this investigation, the obtained TDS values showed that pond D had the highest value of TDS (165.00 Mg/l), followed by pond B (83.00 Mg/l), pond E (57.00 Mg/l), pond C (54.50 Mg/l), pond F (47.50 Mg/l) and pond A (19.00 Mg/l). It shows therefore that the use of artificial animal feeds to complement pond nutrients in pond D by the culturist is imperative. Table 2 revealed that the values of turbidity obtained from this study was highest in pond D (19.33 NTU), followed by pond E (4.89 NTU), pond B (3.22 NTU), pond C (2.78 NTU), pond F (1.63 NTU) and pond A (0.78 NTU) respectively. Chemical oxygen demand (COD) is an significant property for establishing water quality and it defines the quantity of oxygen essential for chemical oxidation of organic and inorganic matter (Jeyaraj et al., 2014). The highest COD value (56.87 Mg/l) was recorded in pond D while the lowest value (14.35 Mg/l) was observed in pond D.

Table 2. Physicochemical Parameters of Fish Ponds

Parameter	Units	Pond A	Pond B	Pond C	Pond D	Pond E	Pond F	WHO	FEPA
pH		6.39	5.89	5.91	5.74	5.93	5.88	6.5-8.5	
EC	µs/cm	38.00	166.00	109.00	330.00	114.00	95.00		200
Cl	Mg/l	12.92	56.44	37.06	112.20	38.76	32.30	250	
Alkalinity	Mg/l	12.78	11.78	11.82	11.48	11.86	11.76	25-100	
Total Suspended Solids (TSS)	Mg/l	0.76	3.32	2.18	6.60	2.28	1.90	< 80	
Total Dissolved Solids (TDS)	Mg/l	19.00	83.00	54.50	165.00	57.00	47.50		500
Turbidity	NTU	0.78	3.22	2.78	19.33	4.89	1.63	5-25	
Chemical Dissolved Oxygen (COD)	Mg/l	22.65	56.87	33.62	14.35	37.98	28.44	10	
Dissolved Oxygen (DO)	ppm	7.32	2.45	3.23	0.89	3.61	6.27		8-10
Biological Oxygen Demand	Mg/l	0.24	43.87	39.21	86.38	40.11	1.05	10	
SO_4^{2-}	Mg/l	10.26	44.82	29.43	89.10	30.78	25.65	250	
NO^{3-}	Mg/l	6.84	29.88	10.90	59.40	20.52	17.10	45	
PO_4^{3-}	Mg/l	2.28	9.96	6.54	19.80	6.84	5.70	0.03-2	
Ca^{2+}	Mg/l	2.66	11.62	7.63	23.10	7.98	6.65	25-200	
NH_{3+}	ppm	0.00	2.45	0.00	5.32	0.41	0.00	0-0.05	
Mg^{2+}	Mg/l	4.56	19.92	6.54	39.60	13.68	11.40	50	
K^{+}	Mg/l	3.42	14.94	9.81	29.70	10.26	4.75	12	
Zn^{2+}	Mg/l	0.72	10.13	6.65	20.13	6.95	0.86	1500	
Cu^{2+}	Mg/l	0.16	0.63	0.45	1.35	0.47	0.39	200	
Cr^{2+}	Mg/l	0.07	0.66	4.36	13.20	4.56	0.17		50
Pb^{2+}	Mg/l	0.02	0.08	0.11	0.23	0.06	0.04	≤ 10	
Fe^{2+}	Mg/l	0.12	18.26	11.99	13.53	12.54	0.48	0.30	
Cd^{2+}	Mg/l	0.00	0.17	0.11	0.33	0.11	0.00	≤ 10	

FEPA = Federal Environmental Protection Agency. WHO = World Health Organization

Dissolved oxygen values obtained from fish ponds D (0.89 Mg/l), B (2.45 Mg/l), C (3.23 Mg/l) and E (3.61 Mg/l) were far below FEPA (1993) set limits (8 - 10 Mg/l). The values of biological oxygen demand recorded in ponds B (white plastic tank; 43.87 Mg/l), C (black plastic tank; 39.21 Mg/l), D (black tarpaulin pond; 86.38 Mg/l) and E (earthen pond; 40.11 Mg/l) were above WHO (2009) permissible limit of 10 Mg/l.

Pond D recorded the highest nitrate value (59.40 Mg/l) while the lowest was observed for pond A (10.26 Mg/l). However, only the nitrate content of pond D exceeded the limit set by WHO (2009) standard of 45 Mg/l. The maximum chloride value for this study was recorded for pond D (112.20 Mg/l) and the minimum was obtained for pond A (12.92 Mg/l). Table 2 indicates that sulphate values was highest in pond D (89.10 Mg/l), followed by pond B (44.82 Mg/l), E (30.78 Mg/l), C (29.43 Mg/l), F (25.65 Mg/l) and A (10.26 Mg/l).

The observed values of NH_4 in pond B (2.45 Mg/l), pond D (5.32 Mg/l) and pond E (0.41 Mg/l) were higher than NH_4 WHO (2009) limits of 0-0.05 Mg/l and this may affect the growth of fish. The value of Ca was highest in pond D (23.10 Mg/l) while the lowest value was recorded for pond A (2.66 Mg/l). These values were contrary to the ones obtained by Agbaire *et al.*, (2015). They observed 0.64 Mg/l as the highest Ca value while 0.04 Mg/l was the lowest Ca value. Magnesium (Mg) content of these fish ponds ranged from 4.56 Mg/l (pond A), 6.54 Mg/l (pond C), 11.40 Mg/l (pond F), 13.68 Mg/l (pond E), and 19.92 Mg/l (pond B) to 39.60 Mg/l (pond D). The result of Potassium (K) values from this study revealed that K content was highest in pond D (29.70 Mg/l), followed by pond B (14.94 Mg/l), pond E (10.26 Mg/l), pond C (9.81 Mg/l), pond F (4.75 Mg/l) and pond A (3.42 Mg/l) .The highest value of Zinc (Zn) was recorded for pond D (20.13 Mg/l), followed by pond B (10.13 Mg/l), pond E (6.95 Mg/l), pond C (6.65 Mg/l), pond F (0.86 Mg/l) and pond A (0.72 Mg/l) respectively.

Copper (Cu) content was highest in pond D (1.35 Mg/l) while the lowest value of Cu was recorded for pond A (0.16 Mg/l). The values of Chromium (Cr) in the different fish ponds are as follows: pond A (0.07 Mg/l), pond B (0.66 Mg/l), pond C (4.36 Mg/l), pond D (13.20 Mg/l), pond E (4.56 Mg/l) and pond F (0.17 Mg/l). The concentration of Iron (Fe) in all examined fish pond water samples was highest in pond B (18.26 Mg/l) while the lowest was in pond A (0.12 Mg/l). Lead (Pb) is a non-essential element, high concentrations can occur in aquatic organisms close to anthropogenic sources and it is toxic even at low concentrations

(Waldron and Stofen, 1974). The highest value of Pb was recorded for pond D (0.23 Mg/l), followed by pond C (0.11 Mg/l), pond B (0.08 Mg/l), pond E (0.06 Mg/l), pond F (0.04 Mg/l) and pond A (0.02 Mg/l). The result of Cadmium (Cd) values from this study revealed that Cd content was highest in pond D (0.33 Mg/l), followed by pond B (0.17 Mg/l), pond C (0.11 Mg/l) and pond E (0.11 Mg/l). Cd was not detected in ponds A (0.00 Mg/l) and pond F (0.00 Mg/l).

DISCUSSION

The pH content in pond A (6.39) was the only one closest to the range of values from 6.5 - 8.5 given by WHO (2009). It seems the pond water at deep concrete pond (Pond A) appeared more conducive (pH value of 6.39). The water in other ponds appeared slightly acidic and could need lime application. The slight acidity may have occurred from the effects of respiration and Mustapha (2017) included the decomposition between plankton, macrophytes, fish and the feed as likely causes. Keremah *et al.,* (2014) reported that pH values of 6.5 - 9.0 are good for fish production. The EC value of pond D could be a pointer to its pollution status probably caused by run-off during rains into the ponds and waste products from other insect's population within the pond (Solomon *et al.,* 2013). Pond D is the only one amid all the investigated fishing ponds that is situated very close to the wall of the building where rain water from the roof top flows directly into it. In addition, it is located very close to the moat which is known to be highly polluted with domestic wastes and dense vegetation. This may also account for the high insect population within pond D. The Benin Moat called 'Iya' in the local language was built as a defensive fortification around Benin City in the great Kingdom. It is a deep, broad ditch, either dry or filled with water that is dug surrounding Benin City which historically was to provide her with a preliminary line of defense. Presently, it is a major dumping site for the inhabitants that live around it. The result of EC obtained for water in pond D may also be due to its low pH value. Kefas *et al.,* (2015) stated that acidic waters have appreciated higher conductivity values. Similarly, the higher values of Chloride (112.20 Mg/l), nitrate (59.40 Mg/l) and phosphate (19.80 Mg/l) could account for higher EC content in pond D. Kefas *et al.,* (2015) state that increase presence of chloride, phosphorus and nitrate in water could instigate a raise in the status of EC. The values of EC observed for this investigation was lower than that reported Agbaire *et al.,* (2015). They recorded 18.00 µs/cm as the highest EC value in their study.

The alkaline contents for this study were similar in values; this may be due to the inability of the culturists to change water in their ponds (with the exception of pond E) as a result of incessant power failure in the country and the high cost involved in using generators. Pond E (earthen pond) is readily serviced with water from rains, runoff and underground water from Ikpoba River. Alkalinity status in ponds is affected when there is no frequent change of water along with processes of respiration and nitrification by plankton and macrophytes (Mustapha, 2017). The alkalinity values obtained for all the investigated fish ponds were below WHO (2009) range (25-100 Mg/l). This implies that they cannot encourage high production in fish cultivation. The obtained values of TSS for all the fish ponds cannot affect the fish functioning and survival as they did not exceed the limit set of 80.00 Mg/l. Total Dissolved Solids (TDS) is an indication of the load of dissolved substances (Agbaire *et al.,* 2015). Ogbeibu and Edutie (2006) noted that the use of artificial animal feeds to supplement pond nutrients result to increased TDS in aquatic water. However, the values obtained for this study were low and optimum which is good for fish productivity. The values are far lesser than the FEPA (1993) limit of 500 Mg/l.

The values obtained for turbidity are also within the WHO (2009) limit (5 - 25 NTU) which makes the studied ponds fit for fish farming. This infers that the status of turbidity for all the studied fish ponds is favorable for the fish health since it does not poses severe risk to their survival. The findings of this investigation negate the result of Dinesh *et al.,* (2017) that recorded maximum turbidity value of 32.33 NTU and minimum value of 17.66 NTU. The COD values observed in pond B (white plastic pond) indicate that some amount of non-biodegradable oxygen demanding pollutants were present in it. This reflects the biodegradable nature of plastics. The COD values obtained in all the examined fish ponds were above WHO (2009) set standards (10 Mg/l). This could be harmful to the survival of aquatic life in these ponds.

The values of dissolved oxygen infer that the water in the ponds may not yield good fish productivity. It may also imply that the culturists of the selected fish ponds may be involved in either of the following; over application of fertilizers and organic manure to manage DO level, physical control aquatic plants and also management of phytoplankton biomass, recycling of water and use of aerators or artificially or manually beating of water (Bhatnagar and Devi, 2013). Low levels dissolve oxygen is a lethal concentration that can put undue stress on fish and are often linked to fish kill incidents (Danba *et al.,* 2015). However, DO contents obtained for fish ponds F (6.17 Mg/l) and A (7.32 Mg/l) were very close to FEPA (1993) set standards of 8-10 Mg/l. To make these fish ponds fit for fish farming, increasing the mixing of air and water by splashing the water with one's hands or with a broad stick or paddle should be carried out. Biological Oxygen Demand contents in ponds B, C, D and E may be due to the effects of fallen leaves and debris, and waste product of fishes and other insect population within each of the fish pond; also eutrophication resulting from unused feed present in water is another possible reason for a sudden rise in BOD (Solomon *et al.,* 2013). The occurrence of high levels of Biological Oxygen Demand can threaten the survival of fish in these ponds. The highest BOD values of fish pond water recorded for this study was 86.38 Mg/l.

Although, nitrates are not harmful to fish, it is significant that the amount of nitrate in a fish pond is regulated to avoid eutrophication (Dinesh *et al.,* 2017). The results infer that apart from pond D, all the other investigated fish ponds were suitable for fish farming. All the obtained values of phosphorus in the selected fish ponds were above the WHO (2009) set standards of 0.03-2.00 Mg/l. This infers that all the ponds are lacking in algae being that P is the main nutrient for algae in the water. The higher concentration of Cl in pond D implies that the pond water may be polluted and harmful to aquatic life (Dinesh *et al.,* 2017). However, the values of Cl observed for all the studied fish ponds were below the WHO (2009) standard for Cl (250 Mg/l). These Cl values were okay since lower concentrations are safe to aquatic life. The highest Cl content observed in black tarpaulin pond may be due to the presence of vinyl chloride (PVC) which is a major constituent of tarpaulin .Vinyl chloride migrates easily into water where it may be degraded into CO_2 and chloride ion (WHO,2009).

The values of sulphate were very low compared to 250 Mg/l which is the permissible limit according to WHO (2009). Hence, the status of S in all the investigated fish ponds needs to be enhanced. The finding of this study disagrees with that of Agbaire et al., (2015) they recorded 4.50 Mg/l as the highest sulphate value. High concentrations of NH_4 in fish ponds may cause gill damage, destroy mucous producing membranes, sub- lethal effects like reduced growth, poor feed conversion and reduced disease resistance at concentrations (Bhatnagar and Devi, 2013). The Ca content for pond D (23.10 Mg/l) was closer to WHO (2009) standard limit of 25-200 Mg/l while all other examined fish ponds were far below it. Consequently, those fish ponds would be required to have some Ca supplement introduced into them since Ca is essential for bone and scale formation. The values of Mg in ponds A, C, F, E, B and D were lesser than 50 Mg/l (WHO, 2009). The growth of aquatic plants could have been the reason for the low Ca and Mg concentrations the fish ponds as the two ions were utilized periodically by the aquatic vegetation (Mustapha, 2017).Amongst the examined fish ponds, K contents in ponds B and D were above WHO (2009) set standard of 12 Mg/l. This infers that the water quality in these two ponds is toxic with K and will have adverse effects on the fishes.

Despite the variations of Zn values recorded in the examined fish ponds, the observed Zn contents in all the fish ponds were below WHO (2009) permissible limit of 1500 Mg/l. This deduces that this particular heavy metal (Zn) is not at its toxic state making the water fit for aquaculture purposes. Generally, Cu contents in the fish ponds were below WHO (2009) set standard of 200.This implies that Cu was not toxic in the fish pond water and its fit for fish cultivation. The highest concentration of Cr was observed in pond D while the lowest was recorded for pond A. However, all Cr contents were below FEPA (1993) limit of 50 Mg/l. This suggests that Cr contents in the fish ponds are not toxic and will be ecologically fit for fish growth. Amongst all the investigated fish ponds, the contents of Fe in pond B, pond C, pond D, pond E and pond F respectively were toxic with Fe as they were greater than 0.30 Mg/l

(WHO, 2009) and would not be appropriate for aquaculture purposes. Only, pond A was not toxic with Fe concentrations as its Fe level was below 0.30 Mg/l. Notwithstanding the differences of Pb values recorded in the examined fish ponds, the detected Pb contents were far below WHO (2009) permissible limit of ≤ 10 Mg/l. This infers that Pb is not at its toxic state making the water fit for fish farming. All the investigated fish ponds were not toxic with Cd as they were below ≤ 10 Mg/l which is WHO (2009) permissible limit for Cd. This implies that the water quality in the ponds will be suitable for fish cultivation.

The concentrations of heavy metals observed in the examined fish ponds may be due to the increase in atmospheric deposition, rapid development of industrialization and anthropogenic activities around these water bodies (Aladesanmi *et al.*, 2014). Apart from Fe, pond D had the highest content of Zn, Cu, Cr, Pb and Cd than other examined fish ponds. This may be due to the presence of PVC being part of the constituents of tarpaulin. PVC contains dangerous chemical additives including phthalates, lead, cadmium and/or organotins which can easily leach out from the surface of the tarpaulin into water and it can be toxic.

CONCLUSION

The study has provided information on the evaluation of water quality from selected aquaculture ponds in Benin City, Nigeria and its suitability for fish husbandry. It revealed that black tarpaulin pond had higher contents of most water quality parameters than deep concrete pond, white plastic tank, black plastic tank, earthen pond and surface concrete pond respectively. This point to the effects of the gradual dissolution of vinyl chloride (PVC) from the interior surface of the black tarpaulin into the fish pond water. The study recommends regular monitoring of the conditions of fish culture facilities and pond water to ensure compliance with water quality standards and environmental regulations. This would help to reduce greatly the concentrations of dissolved vinyl chloride in black tarpaulin pond. It also advocates that from amongst the different types of fish ponds in Nigeria, black tarpaulin pond should be least considered when establishing one. Consistent awareness campaigns for fish culturists on the effect of the bio-accumulation of heavy metals on fish pond and application of lime to correct water pH to a more acceptable level for aquaculture use is also advocated.

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