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Original Research Article

Assessment of Water Quality Parameters in an Artificial Storage Pond for Fish Production

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ABSTRACT

Fish productivity generally depends on the physical, biological and chemical properties of the water they live in. Changes in the environmental factors can cause stress to the fish and the higher the change, the bigger the stress. The present study assessed the physiochemical and the biological water quality parameters of fish pond source water and pond water, intending to evaluate their impact on fish survival and growth. Samples were collected from the borehole that supplies water to the pond and from the fish pond effluents. Physiochemical analysis of the samples was carried out using standard methods. The average values of pH, temperature and turbidity were 7.56±0.16, 29.12±1.20 °C and 5.40±1.58 NTU in the source water and 7.24±0.10, 28.86±1.57 °C and 64±14.60 NTU in the pond water respectively. The least values of nitrate (3.16±0.60 mg/L), phosphate (13.38±5.16 mg/L) and sulphate (0±0.00 mg/L) were found in the source water while the highest values of nitrate (7.44±4.60 mg/L), phosphate (34.58±4.79 mg/L) and sulphate (39.12±13.54 mg/L) were found in the pond water. Total and faecal coliforms were determined with a standard membrane filtration method. Reduction in dissolved oxygen level and elevated levels of nitrite, ammonia, hydrogen sulphide, total and faecal coliforms as observed in pond water samples were generally an indication of poor pond water quality, and may make the water toxic and pose challenges to the fishes. Therefore, to achieve increased fish production with low input costs, these environmental factors should be regulated.

1. INTRODUCTION

Aquatic organisms live, feed and breath in water. Hence, its quality becomes imperative as it impacts directly or indirectly affect its habitants like fish and other aquatic animals. Generally, groundwater and surface water are the two main categories of source water for aquaculture. Meanwhile, groundwater is usually considered the most desirable because it is mostly free from toxic pollutants and is consistent in quality (Summerfelt, 1990). Water quality can be assessed by measuring its physical, chemical, and biological parameters. The main water quality parameters to be monitored in the fish habitat like pond are pH, temperature, hydrogen sulphide, dissolved oxygen, alkalinity, ammonia, hardness, biological oxygen demand, turbidity and phosphate (Lazur, 2007).

The quality parameters of pond water can deteriorate through accumulation of excess feed residues, fish excreta and metabolites, resulting in the accumulation of organic matter in the water and at the bottom of the pond (Datta, 2012; Otoo et al., 2019). However, the most common factors responsible for oxygen reduction are the microbial decomposition of biodegradable organic matter and high temperature since warmer water holds lesser oxygen (Ezeanya *et al.*, 2015). Nevertheless, oxygen levels in fish production ponds also depend on the inputs by the air and plants photosynthesis (Datta, 2012). The input by the plants depends on the photosynthetic activity (Summerfelt, 1990). To optimize the production of fish, an adequate understanding and maintenance of water quality are necessary. Regular monitoring is therefore crucial for ensuring a fish culture system with a well maintained and balanced physiochemical properties for fish life cycle (Collins, 2019).

In many parts of the world, fish is the preferred source of animal protein. However, among all the fish culture systems, concrete ponds are mostly used to rear fish than the earthen ponds. Previous studies showed that large numbers of fish farmers use concrete ponds than earthen ponds (Njoku et al., 2015). Pond water from these cultured controlled environments contains several harmful contaminants which could be detrimental to fish and human health. The contaminants can be traced to the pond water source, high stocking densities and feed used in feeding the fishes (Sule et al., 2016). This study seeks to evaluate the physiochemical and microbiological properties of a constructed fish pond water as a routine monitoring exercise, to determine if any potential contaminants are leading to fish health implications.

2. MATERIALS AND METHODS

2.1. Sample Collection

Samples were collected from the NWRI constructed fish pond. The pond is located within the premises of National Water Resources Institute (NWRI), Kaduna, Nigeria and lies in longitude 10°34´46" N and latitude 007°25´12" E. Water samples were collected once a week for five weeks from both the source water (borehole) and the pond water at 8:00 am. After each sample´s collection, parameters such as temperature, pH, and turbidity were determined in situ and later all samples were taken to the laboratory in cold storage for the determination of other parameters.

2.2. Sample Analysis

The temperature, pH and turbidity values of both samples were determined using mobile mercury in glass thermometer calibrated in degree Celsius (°C), Hanna pH meter and Hanna turbidity meter respectively. Nitrate, phosphate, sulphate, nitrite, ammonia and hydrogen sulphide were measured according to standard methods of American Public Health Association (APHA, 2005) whereas total and faecal coliforms were determined using the standard membrane filtration method as described by (Khalil Abubakar *et al*., 2020). Dissolved oxygen on the other hand was determined in the fixed sample using Winkler's method (Shrivastava, 2018).

3. RESULTS AND DISCUSSION

The results of the physiochemical and microbiological analysis of pond source water are presented in Table 1. From these results, all the studied water quality parameters of the source water were within the standard range of drinking water quality except nitrite and phosphate that were above the limit recommended by NSDWQ (2007) and WHO (2011) (Table 1). Phosphates are derived from natural contacts such as geologic weathering. Apart from the natural factors, other anthropogenic inputs may influence the level of phosphate in groundwater. Such inputs include the application of animal manures and phosphorus based-fertilizer on farmland, domestic and animal wastes from the rural dwellers and industrial wastes (Fadiran *et al*., 2008). Nitrite, on the other hand, formed by the bacterial denitrification of nitrate or nitrification of ammonia (Gao *et a*l., 2020). However, the increased concentrations of the phosphate and nitrite here may be from the bye-product from the effluent and sewage leaching from these sites into the borehole (groundwater), since the borehole site (source water to the studied storage pond) was located close to staff quarters, sheep and goat pens and a site where the staffs dump their refuse. As a result, measures to reduce phosphorus and nitrite concentrations in the borehole should be implemented.

Table 1: Results of mean weekly physiochemical and microbiological parameters of the source water

Quality parameter	WK1	WK2	WK3	WK4	WK5	Mean concentration	NSDWQ
pH	7.3	7.5	7.6	7.8	7.6	7.56±0.16	6.5 – 8.5
Temperature (°C)	30.3	29.6	30.2	27.2	28.3	29.12±1.20	27 - 31
Turbidity (NTU)	3	7	9	6	2	5.40±1.58	5
Nitrate (mg/L)	2.8	3.30	3.90	3.60	2.20	3.16±0.60	50
Phosphate (mg/L)	4.9	13.2	20.7	12.2	15.9	13.38±5.16	0.5
Sulphate (mg/L)	0	0	0	0	0	0±0.00	100
Nitrite (mg/L)	0.03	0.05	2.0	2.07	6.0	2.03±2.18	0.2
Ammonia (mg/L)	0	0	0	0	0	0±0.00	-
Hydrogen sulphide (mg/L)	0.01	0.01	0	0.01	0.01	0.008±0.004	0.05
Dissolved oxygen (mg/L)	6.95	7.005	7.23	6.70	7.20	7.02±0.19	> 5
Total coliform (Cfu/ml)	7	7	10	6	8	7.6±1,36	10
Faecal coliform (Cfu/ml)	0	1	2	1	0	0.8±0.75	0

Table 2: Results of mean weekly physiochemical and microbiological parameters of the pond water

Parameter	WK1	WK2	WK3	WK4	WK5	Mean concentration	SON standard
pH	7.1	7.3	7.2	7.4	7.2	7.24±0.10	6.5 – 8.5
Temperature (°C)	30	29.6	30.3	26	28.4	28.86±1.57	-
Turbidity (NTU)	56	56	55	60	93	64±14.60	-
Nitrate (mg/L)	3.6	4.40	4.40	9.0	15.8	7.44±4.60	9.1
Phosphate (mg/L)	30.25	30.6	31.4	38.9	41.75	34.58±4.79	3.5
Sulphate (mg/L)	17	32.5	43	46.1	57	39.12±13.54	100
Nitrite (mg/L)	0.058	0.164	21.6	57	64	28.56±27.32	0.02
Ammonia (mg/L)	2.095	4.605	4.98	5.12	5.40	4.44±1.20	-
Hydrogen sulphide (mg/L)	0.44	0.70	2.16	2.70	2.95	1.79±1.03	-
Dissolved oxygen (mg/L)	2.54	1.685	1.04	0.89	0.58	1.347±0.70	> 6
Total coliform (Cfu/ml)	19	30	50	76	256	86.2±87.09	-
Faecal coliform (Cfu/ml)	4	8	18	23	46	19.8±14.76	-

From the weekly values of the pond water pH, the highest pH level was observed in week four while the lowest value was found in week one. These values are within the standard range of 6.5 - 8.5 recommended by the Standard Organization of Nigeria (SON 2007) and 6.0-9.0 suggested by Ezeanya *et al.* (2015) for fisheries. The highest value of temperature was seen in week three while the least value was recorded in week four. The standard temperature requirement for fish farming is between 25-30 °C (Ezeanya *et al.*, 2015). From these results, there was an indication that the differences in the temperature between the weeks were not sufficient enough to impact negatively on the fish. Fish is a cold-blooded animal and its temperature changes with the changes in the temperature of its surrounding. Temperature changes may affect fish metabolism and productivity (Collins, 2019).

The turbidity of the pond water was far above the recommended value of turbidity for fish pond water (5 NTU) (Table 2). Water turbidity is the result of the decomposition of organic matter in the pond which restricts light penetration into the water column thus, limiting photosynthesis by the phytoplankton population especially at the bottom of the pond (Njoku et al., 2015). Higher turbidity can cause a reduction in oxygen supply through a reduction in photosynthesis (Boyd and Pillai, 1985). On the other hand, the DO of the pond water was detected in the range far lower compared to the values of the source water and the standard value (Table 1 and 2). The acceptable value for dissolved oxygen for healthy aquatic life is > 5 mg/L (Mutlu and Kurnaz, 2018). However, air-breathing fish like catfishes can survive at 4 mg/L oxygen concentration and 5mg/L is tolerable in the fish pond (Bhatnagar and Devi, 2013). The low DO level is of major concern as it is an indication of algal blooms decomposition and may lead to a reduction in fish feeding, growth and cause stress and mortality of fish (Bhatnagar and Devi, 2013). This could explain the reason for the high mortality rate and sudden deaths of fish experiencing in the storage pond. The results of the present study indicate that the water quality from the aspect of the DO concentration is not suitable for fish production.

The results of nitrate, phosphate and sulphate from the pond water were shown in Table 2. Previous research has shown that nitrate is nontoxic to fish except at a very high concentration (Bhatnagar and Devi, 2013). For proper fish production, the maximum limit for sulphate is 90 mg/L (Mutlu and Kurnaz, 2018) or 100 mg/L according to Standard Organization of Nigeria (SON). From these results, it can be concluded that sulphate and nitrate were at low concentrations. However, they may not affect the fish negatively. Phosphate was detected in pond water at concentrations higher than the acceptable level of 0.03 - 2.0 mg/L (Bhatnagar and Devi, 2013) and 3.5 (SON). High levels of phosphates in ponds may be due to contamination of the pond source water with phosphorus based-fertilizer (Gathoni Mbuthia et al., 2019). High phosphate levels observed in the fish farms may lead to eutrophication which encourages algae growth and consequently result in depletion of oxygen supply (Njoku et al., 2015).

From the pond water samples, nitrite concentrations were far above < 4 mg/L suggested by Stone and Thomforde, (2004) and 0.02 mg/L (SON). Nitrite concentration in waters above 1mg/L is an indication of pollution (Mutlu and Kurnaz, 2018). However, nitrite sources in water are nitrogenous fertilizers and organic matter (Mutlu and Kurnaz, 2018). The higher concentration of nitrite as seen in the pond water is of great concern as it can hinder fish growth and reduces blood oxygen-carrying capacity (Ciji and Akhtar, 2020). The acceptable level for hydrogen sulphide in ponds is 0.00 - 0.02 mg/L (Bhatnagar and Devi, 2013) while a study by Lazur (2007) reported that the optimal concentration of pond hydrogen sulphide should be < 0.01 mg/L. However, according to these suggestions, the pond is not suitable for fish production on the aspect of hydrogen sulphide concentration. Bhatnagar and Devi (2013), suggested that ammonia concentration from 0.6 – 2 mg/L could be lethal for pond fish even under short-term exposure. Ammonia is the second gas of concern in the fish pond. High ammonia levels observed in this present study could be attributed to overfeeding the fish with protein feeds and excess feed decay since ammonia is produced from the metabolism of protein and microbial decomposition of organic matter (uneaten feed and waste product from (Summerfelt, 1990).

The results of the microbiological characteristics of the pond water are shown in Table 2. The high levels of coliforms here is an indication of deterioration of pond water quality, which may indicate the possible presence of pathogenic organisms in the pond. The latter may cause disease and mortality of fish (Njoku et al., 2015).

From the result of the correlation coefficient, the pond water pH shows a significantly negative relationship with pond water temperature and dissolved oxygen and moderate positive relationship with ammonia (Table

3). However, the pond water temperature shows a positive relationship with dissolved oxygen. The dissolved oxygen on the other hand shows a negative correlation with pH, turbidity, nitrate, phosphate, sulphate, nitrite, ammonia, hydrogen sulphide, total and faecal coliforms and a positive relationship with temperature. The turbidity had an opposite behaviour with some of the above-mentioned parameters (positive correlation) except for dissolved oxygen (negative correlation) (Table 3). However, nitrate, sulphate and phosphate exhibited a strong positive correlation with each other, turbidity, nitrite, hydrogen sulphide, ammonia, total and faecal coliforms while a negative relationship was observed with temperature and dissolved oxygen. Nitrite showed a positive relationship with hydrogen sulphide, ammonia, turbidity, nitrate, phosphate, sulphate, total and faecal coliforms but established a negative correlation with temperature and dissolved oxygen. Similar relationship was observed with ammonia and hydrogen sulphide except that ammonia was not correlated with temperature and turbidity (Table 3). On the aspect of total and faecal coliforms, they both show a positive correlation with each other and with turbidity, nitrate, phosphate, sulphate, nitrite, ammonia and hydrogen sulphide but negatively correlated with dissolved oxygen.

Table 3: Correlation coefficient of the water quality parameters of the pond water

Parameters	pH	Temperature	Turbidity	NO_3^-	PO_4^-	SO_4^-	NO_2^-	NH_3	H_2S	DO	TC	FC
pH	1											
Temperature	-0.76	1										
Turbidity	-0.11	-0.26	1									
NO_3^-	0.17	-0.54	0.95	1								
PO_4^-	0.37	-0.75	0.82	0.95	1							
SO_4^-	0.43	-0.50	0.69	0.82	0.83	1						
NO_2^-	0.41	-0.75	0.72	0.89	0.97	0.88	1					
NH_3	0.63	-0.44	0.43	0.58	0.61	0.92	0.68	1				
H_2S	0.40	-0.61	0.61	0.78	0.86	0.94	0.95	0.79	1			
DO	-0.50	0.52	-0.59	-	-0.78	-0.99	-0.86	-0.94	-0.95	1		
TC	-0.02	-0.32	0.99	0.97	0.86	0.79	0.80	0.54	0.73	-0.70	1	
FC	0.14	-0.44	0.91	0.96	0.91	0.91	0.90	0.69	0.88	-0.85	0.97	1

TC= Total coliform, FC= Faecal coliform

4. CONCLUSION

Every aquatic life has its tolerable limits of water quality parameters at which they survive best of which fish is not an exception. The results of this study generally showed a deterioration of DO levels which has directly or indirectly contributed to low aquaculture production and fish mortality. It is worthy of note that as the production period proceeds as observed in Table 2, the concentrations of nitrate, phosphate, and sulphate increases, with a corresponding increase in hydrogen sulphide, ammonia, nitrite, total and faecal coliforms, and reduction in dissolved oxygen levels. This may be attributed to increased organic waste generation due to progressive increase in culture period and fish growth. To maintain a healthy aquatic environment suitable for proper fish growth and production, water quality parameters should be carefully and frequently monitored and the results of which should serve as a guide. More so, some remedial measures such as the use of aerator, regular water exchange and avoidance of overstocking are recommended to maintain a suitable pond water quality.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

APHA (2005). Standard methods for the examination of water and wastewater. 21st ed. American Public Health Association, Washington, DC, USA.

Bhatnagar, A. and Devi, P. (2013). Water Quality Guidelines for the Management of Pond Fish Culture. *International Journal of Environmental Sciences*, *3*(6), pp. 1980–2009.

Boyd, C. E. and Pillai, V. K. (1985). Water quality management in aquaculture. *CMFRI special Publication*, *22*, pp. 1-44.

Ciji, A. and Akhtar, M. S. (2020). Nitrite Implications and its Management Strategies in Aquaculture: A Review. *Review in Aquaculture*, pp. 878–908.

Collins, O. O. (2019). Determination of Some Physiochemical Parameters and Selected Heavy Metals from Water Collected from Concrete Fish Ponds in Ozoro Town. *International Journal of Advances in Scientific Research and Engineering*, 5(5), pp. 266–274.

Datta, S. (2012). Management of water quality in intensive aquaculture. *Respiration*, *6*, p. 602.

Ezeanya, N. C., Chukwuma, G.O., Nwaigwe, K.N. and Egwuonwo, C.C. (2015). Standard Water Quality Requirements and Management Strategies for Fish Farming (a Case Study of Otamiri River). *International Journal of Research in Engineering and Technology*, *04*(03), pp. 1–5.

Fadiran, A. O., Dlamini, S. C. and Mavuso, A. (2008). A comparative study of the phosphate levels in some surface and ground water bodies of Swaziland. *Bulletin of the Chemical Society of Ethiopia*, *22*(2), pp. 197–206.

Gao, X. Q., Fei, F., Huo, H. H., Huang, B., Meng, X. S., Zhang, T. and Liu, B. L. (2020). Effect of acute exposure to nitrite on physiological parameters, oxidative stress, and apoptosis in Takifugu rubripes. *Ecotoxicology and Environmental Safety*, *188*, p. 109878.

Gathoni Mbuthia, M., Esther Lesan Kitur, K. C., Koske, J., Milkah Gathoni Mbuthia, C. and Lesan Kitur, E. C. (2019). Assessment of Water Characteristics in Aquaculture Ponds in Tigoni, Limuru Sub-County, Kenya. *International Journal of Fisheries and Aquatic Studies*, *7*(3), pp. 121–127.

Khalil Abubakar, I., Abubakar, M. M. and Abubakar, M. M. (2020). Assessment of the Coliform Bacterial Load of Some Drinking Water Sources in Dutse Metropolis of Jigawa State Nigeria. *Scientific Review*, *6*(66), pp. 48–52.

Lazur, B. A. (2007). Good Aquacultural Practices Program Growout Pond and Water Quality Management. *Joint Institute for Food Safety and Applied Nutrution*, pp. 6-17

Mutlu, E. and Kurnaz, A. (2018). *Assessment of physicochemical parameters and heavy metal pollution in Çeltek Pond water*. *Indian Journal of Geo-Marine Sciences*, 47(6), pp. 1185–1192.

Nigerian Standard for Drinking Water Quality (NSDWQ) (2007). Ministry of Water Resources, Nigeria, pp. 1 – 2

Njoku, O. E., Agwa, O. K. and Ibiene, A. A. (2015). An Investigation of the Microbiological and Physicochemical Profile of Some Fish Pond Water Within the Niger Delta Region of Nigeria. *African Journal of Food Science*, *9*(3), pp. 155–162.

Otoo, N. E. G., Sanful, P. O., Iddrisu, W. A., Amfoh, S. and Boateng, O. K. (2019). Uderstanding Water Quality Dynamics in Sunyani, Ghana: Insights from Partial Least Squares (PLS) - Path Modeling. *Journal of Fisheries and Aquaculture Research*, *4*(1), pp. 28–42.

Shrivastava, S. (2018). Analysis of Pond Water Quality OF Raipur Chhatishgarh (India). *European Journal of Physiochemical and Heavy Metal*, pp. 450–454.

Standard Organization of Nigeris (SON) (2007). African Forum for Utility Regulations and Nigeria Industrial Standards (NIS), 5542

Stone, N. M. and Thomforde H. K., (2004). Understanding Your Fish Pond Water Analysis Report. Cooperative Extension Program, University of Arkansas at Pine Bluff Aquaculture/Fisheries. *International Journal of Environmental Sciences*. 3 (6), pp. 1980-1996

Sule, I., Agbabiaka, T., Ahmed, R., Saliu, B. and Olayinka, K. (2016). Bacteriological and physicochemical analysis of waste water from fish ponds. *Ethiopian Journal of Environmental Studies and Management*, *9*(2), pp. 167-178

Summerfelt, R. C. (1990). Water Quality Considerations for Aquaculture. *Department of Animal Ecology*, *50*, pp. 11–21.

World Health Organization (WHO) (2011). Drinking Water Standard.