Freshwater Source Suitability for Aquaculture: A Case Study of Ikpoba Reservoir, Edo State, Nigeria

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ARTICLE INFO

Article history:
Received: 24 June 2021
Received in revised form: 21 September 2021
Accepted: 4 October 2021
Published: 25 February 2022
Edited by DSI Iiyambo

Keywords:
Water quality
Aquaculture
Fisheries
Ikpoba Reservoir
Nigeria

ABSTRACT

The study examined the Ikpoba Reservoir water quality suitability as source water for aquaculture. Sixteen (16) water physico-chemical parameters were monitored for a duration of eighteen (18) months from February 2018 to July 2019, and analyzed according to standard methods. Concentration values were compared with the International Standard Water Quality Criteria for fisheries. Results showed that mean water temperature ($27°C$), electrical conductivity (100.46 μS/cm), chloride (27.08 mg/L), potassium (3.40 mg/L), calcium (25.16 mg/L), magnesium (15.56 mg/L) values were favourable for aquaculture. While mean water pH (5.78), turbidity (24.59 NTU), total suspended solids (23.70 mg/L), dissolved oxygen (4.36 mg/L), biochemical oxygen demand (4.16 mg/L), nitrate (15.67 mg/L) and ammonium (1.63 mg/L), iron (0.95 mg/L), copper (1.37 mg/L) and zinc (1.23 mg/L) concentrations were unsatisfactory for the breeding and survival of fish. The unsatisfactory levels of several physico-chemical parameters and their attendant effects on the development of fishes makes the reservoir water source unsuitable for use in freshwater aquaculture.

1 Introduction

Globally, aquaculture has been acknowledged as a major contributor to food security, particularly in the provision of inexpensive sources animal protein for human nutrition. Aquatic pollution which has increasingly threatened fish production from inland water resources e.g. rivers, lakes and streams(Gupta, 2006); and the deficit in the supply of fish and fish products from capture fisheries due to increasing demand has created the needed market niche for aquaculture production (Makhamisi, 2019; Oboh and Egun, 2017; Zweig *et al*, 1999). Also, aquaculture practice has contributed to the efficient utilization of water and land resources.

Fishes are totally dependent on water and so information on water quality (physico-chemical) and quantity of source water are indispensable in choosing a location for an aquaculture facility. Water quality in aquaculture refers to anything in the water, be it physical, chemical or biological that affects the fish normal health and production performance (Balogun, 2015). Fishes have a limited range of concentration values for physico – chemical properties of freshwater in which they can grow optimally (Zweig *et al*, 1999). Studies have shown that a special set of water chemistry requirements, and optimal water quality is essential to a healthy, balanced, and successful freshwater fisheries (Abubakar, 2013; DeLong *et al*, 2009).

As water quality directly affects the fishes' feed efficiency, growth rates, optimal survival, growth, and reproduction of fishes (ACTFR, 2002). Many undesirable chemical and environmental factors associated with certain

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fish farms have been linked to the absence of background information on the source of water used. Hence the screening of source water for its physico-chemical properties is an important initial step in assessing the source water suitability for aquaculture. In recent times, there has been an increase in the establishment of earthen fish ponds within the watershed of inland freshwater bodies in Nigeria. As these water bodies such as rivers, streams and reservoirs offer a readily and inexpensive source of water for aquaculture. Although the use of natural surface freshwater sources have been shown to be good sources of zooplanktons for fishes in aquaculture (Abo-Taleb, 2019), the increasing decline in their water quality due to anthropogenic activities (Anyanwu, 2012; Arimoro *et al*, 2006; Egun and Ogiesoba-Eguakun, 2018; Oboh and Agbala, 2017; Omoigberale and Ogbeibu, 2007) has necessitated the need to ascertain their present suitability for continuous use in aquaculture.

The Ikpoba reservoir which was established in 1977 due to the impounding of Ikpoba River at Okhoro in Benin City, has over the years witnessed the deposit of effluents containing a wide range of pollutants which has impacted negatively on the water quality and biodiversity (Tawari-Fufeyin and Ekaye, 2007; Wangboje and Oronsaye, 2012). Presently, several earthen fish ponds have be located in close proximity to the reservoir which rely on the reservoir as source of water for commercial aquaculture.

Therefore, the aim of this study is to ascertain the reservoir's water physico-chemical parameters, namely: water temperature, pH, electrical conductivity (EC), turbidity, total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), alkalinity, calcium, magnesium, nitrate, ammonium, potassium, chloride, iron and zinc suitability for aquaculture.

2 Materials and methods

Study Area: This study was carried out at the Ikpoba reservoir (Latitudes $6°22'50''$N and $6°22'43''$N and Longitudes $5°38'36''$E and $5°38'46''$E) in Benin City in Edo State, Nigeria (Figure 1).

Sampling and Water Analysis: Water samples were collected in triplicates for a duration of eighteen (18) months (February 2018 to July 2019) from sampling stations along the stretch of the reservoir using the stratified random sampling approach along the downstream gradient (Averett and Schroder, 1994; USGS, 2018). Water analysis were carried out according to outlined procedures in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998). The water samples were analysed for sixteen (16) physico-chemical parameters-water temperature, pH, electrical conductivity (EC), turbidity, total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), alkalinity, calcium, magnesium, nitrate, ammonium, potassium, chloride, iron and zinc.

Data Analysis: Statistical analyses were computed using Microsoft Excel and the Statistical Package for Social Sciences (SPSS 16.0). The data are presented as means $\pm$ standard error (SE) of the triplicate samples for each physico-chemical parameter analysed.

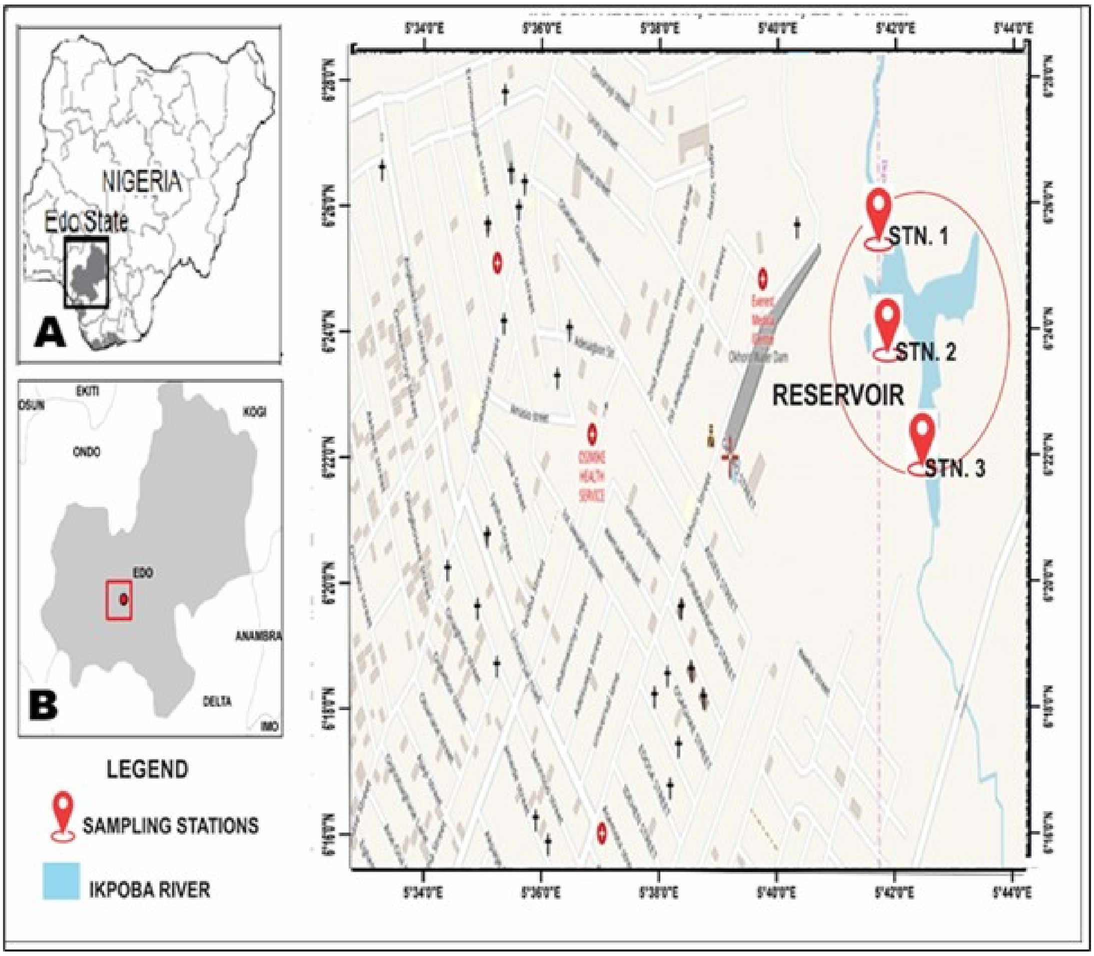

Figure 1: Map of the Benin City showing Ikpoba reservoir sampling point; Inset (A) Nigeria (B) Edo State

3 Results

The summary of the physico-chemical parameters of Ikpoba reservoir are summarised in Table 1. The range of values for water temperature ($26 - 29°C$) and electrical conductivity (40 to $275\,\mu$S/cm) were within the NESRA (2011) limits for water quality criteria for fisheries. Water pH values (4.8 - 6.6) were below permissible limits. The dissolved oxygen levels (2.8 – 5.8 mg/L) were below the minimum acceptable limits by NESRA (2011). Mean values for turbidity (24.59 NTU), total suspended solids (23.70 mg/L), BOD_5 (4.16 mg/L), nitrate (15.67 mg/L) and ammonium (1.63 mg/L) exceeded their respective permissible limits. The values for chloride (13.18 – 27.06 mg/L), potassium (0.54 – 3.40 mg/L), calcium (11.03 – 25.16 mg/L) and magnesium (4.44 mg/L) were within their various NESRA (2011) permissible limits. The range of concentration values for iron (0.31 – 2.44 mg/L), copper (1.11 – 1.81 mg/L) and zinc (0.24 – 3.43 mg/L) exceeded their respective permissible limits for surface freshwater aquaculture.

Table 1: . Summary of the Physico – chemical characteristics of Ikpoba Reservoir and Suitability for Fisheries

Parameters	Water Quality Values			Standard Water Quality Criteria for fisheries (NESRA, 2011)	Remarks
	Min.	Max.	Mean $\pm$ SE		
Water Temperature	26	29	27.00 ± 0.08	$15-30°C$	Satisfactory
pH	4.8	6.6	5.78 ± 0.04	$6.5-8.5$	Not Satisfactory
E. Conductivity	40	275	100.46 ± 6.06	400 μS/cm	Satisfactory
Turbidity	13	46	24.59 ± 1.25	< 20 NTU	Not Satisfactory
TSS	11	52	23.70 ± 1.37	0.25 mg/L	Not Satisfactory
DO	2.8	5.8	4.36 ± 0.10	≥ 6.0 mg/L	Not Satisfactory
BOD_5	2.4	6.3	4.16 ± 0.11	≤ 3.0 mg/L	Not Satisfactory
Nitrate	11.95	26.64	15.67 ± 0.56	≤ 9.1 mg/L	Not Satisfactory
Ammonium	0.76	2.84	1.63 ± 0.05	≤ 0.05 mg/L	Not Satisfactory
Chloride	13.18	27.06	19.02 ± 0.47	300 mg/L	Satisfactory
Potassium	0.54	3.4	1.82 ± 0.10	50 mg/L	Satisfactory
Calcium	11.03	25.16	16.54 ± 0.54	180 mg/L	Satisfactory
Magnesium	1.68	15.56	4.44 ± 0.40	40 mg/L	Satisfactory
Iron	0.31	2.44	0.95 ± 0.06	0.05 mg/L	Not Satisfactory
Copper	1.11	1.81	1.37 ± 0.03	$0.001-0.01$ mg/L	Not Satisfactory
Zinc	0.24	3.43	1.23 ± 0.11	0.01 mg/L	Not Satisfactory

4 Discussion

Water is always a limiting factor in commercial fish production, as many of the negative chemical and environmental factors associated with most operations have their origins in the source of water selected (Swann, 1993). This section will focus on the reservoir physico-chemical parameters whose concentration in the water was found to be unsatisfactory to the water criteria standards for fisheries (NESRA, 2011), and their attendant effect on fishes. Water pH is important in the regulation of chemical reactions in the aquatic environment (Himmel *et al*, 2010).

The most serious chronic effect of increased acidity in surface waters appears to be interference with the fish' reproductive cycle, damage to developing juvenile fish and death of adult fishes (Akintomide *et al*, 2010; Ukwe and Abu, 2016). The pH values recorded for Ikpoba reservoir indicate that a general acidic condition of the reservoir (Table 1), which requires treatment for its suitability for optimum fish production. The acidic nature of some Nigerian surface freshwater bodies had been reported by various researchers (Anyanwu, 2012; Egun and Ogiesoba-Eguakun, 2018; Imoobe and Koye, 2011; Ogbonna, 2010).

The level of water turbidity is a reflection of the amount suspended matter such as clay, silt, organic matter, planktons and some other microscopic organisms present in the water (Fondriest Environmental, Inc., 2014). High turbidity and total suspended solids levels in surface freshwater bodies such as Ikpoba reservoir (13 – 46 NTU and 11 – 52 mg/L) can inhibit photosynthesis resulting in decreased dissolved oxygen output (Wetzel, 2001); affect the ability of fish gills to absorb dissolved oxygen from the water and lowers their resistance to diseases and parasites (Balogun, 2015; Zweig *et al*, 1999). Adamu *et al* (2016) reported higher turbidity values (50.66 - 136.48 NTU) for Kafin-chiri reservoir, Kano State.

Dissolved oxygen (DO) is a very basic requirement for aquaculture and the first limiting factor to occur in pond aquaculture. Biochemical oxygen demand (BOD) is a key indicator of the level of organic pollution and water quality; as increase in BOD levels results in a decline in DO levels. Depletion in dissolved oxygen levels impedes fish reproduction as higher dissolved oxygen content is needed for eggs and immature development stages (Oram, 2014). Unsatisfactory mean DO levels (4.36 mg/L) and elevated mean BOD value (4.16 mg/L) for Ikpoba reservoir may be attributed to its lentic nature, and an indication of high organic pollution of the water body. Lower DO values in Kafin –chiri Reservoir (1.52 - 4.20 mg/L) and Ajiwa Reservoir (4.10 mg/L) were reported by Adamu *et al* (2016) and Usman *et al* (2017) respectively.

Natural surface freshwater ecosystems contain relatively small amounts of nitrates and ammonia. Although the toxicity of nitrates to fish is very low, increased nitrate levels in water results in eutrophication, and the excessive growth of algae and plants, which depletes dissolved oxygen and have a secondary effect on fish. Also, ammonium which is the ionized form of ammonia (NH4+) have been shown to significantly contribute to "acute ammonia intoxication" and nervous disruption symptoms such as loss of equilibrium, hyperexcitability, convulsions and coma in fishes at lower pH and dissolved oxygen levels (Oram, 2014; Randall and Tsui, 2002). Elevated water content of nitrate and ammonium in Ikpoba reservoir predisposes fishes to physiological stress and disruption when utilized for aquaculture.

Iron content is surface freshwater bodies is dependent on the on the geological area and other chemical components of the waterway (Lenntech, 2019). The toxicity of iron to fishes is dependent on the physico-chemical properties of the water such as water temperature, pH and dissolved oxygen. As low water temperature and pH results in the proliferation of iron-depositing bacteria on the gills which damage the respiratory epithelium and may thus suffocate the fish (Svobodová *et al*, 1993). The recorded acidic nature of the Ikpoba reservoir with elevated iron levels implies that the reliance of the reservoir as source water for aquaculture predisposes fishes to iron toxicity and physiological stress. Similarly, Usman *et al* (2017) reported elevated iron levels of 0.5 mg/L in Ajiwa reservoir, Katsina State, Nigeria.

Copper is highly toxic to fish resulting in copper intoxication. Although copper compounds are utilized in aquaculture as algicides and in the prevention and therapy of some fish diseases (Svobodová *et al*, 1993), the maximum admissible copper concentration in water for the protection of fish is in the range of 0.001 to 0.01 mg/L. For zinc, the principal mode of action for acute zinc toxicity to freshwater fish is inhibition of calcium uptake, and destroying of gill tissues, thereby inducing stress and death of fish (Bhateria and Jain, 2006; Giardina *et al*, 2009). High concentrations of copper and zinc in the Ikpoba reservoir implies that the water in its untreated form is unsuitable for use in freshwater aquaculture as fishes will be exposed to heavy metal poisoning.

5 Conclusion

Successful aquaculture operation is dependent on water quantity and quality. Although the Ikpoba reservoir meet the criteria of an "ideal" source of availability of large volumes of water for freshwater aquaculture; the study found that the unsatisfactory levels of several physico-chemical parameters - pH, turbidity, total suspended solids, dissolved oxygen, biochemical oxygen demand, nitrate, ammonium, iron, copper and zinc in the water and their attendant effects on the development of fishes makes the water source unsuitable for use in aquaculture.

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