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Suitability of Surface and Groundwater for Pisciculture in Maiduguri Metropolis, North-East Nigeria

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ABSTRACT

Background and Objective: Water is the basis for fish farming and understanding its physical and chemical qualities is critical to successful and profitable aquaculture. Hence, the physic-chemical and heavy metal contents of surface and groundwater sources in Maiduguri Metropolis, Nigeria were assessed for pisciculture. **Materials and Methods:** Water samples from treated surface water (TSW), Fori River (FRW), gwonge sabolahi wash borehole (GWB) and gwonge sabolahi deep borehole (GDB) were collected and analyzed for selected physic-chemical and heavy metal parameters following standard procedure. Data gathered were analyzed using descriptive statistics and ANOVA at $\alpha = 0.05$. **Results:** All the physic-chemical parameters examined from all the water sources were within the desirable limit, except dissolved oxygen in GDB (3.76 ± 0.39 mg L^{-1}) and GWB (4.45 ± 0.21 mg L^{-1}). Meanwhile, most of the water sources investigated were contaminated with lead, cadmium and iron. **Conclusion:** The investigated water sources are not safe for pisciculture in terms of heavy metal proliferation, except if there is proper treatment.

KEYWORDS

Boreholes, river, water quality, heavy metal, fish farming, Maiduguri Metropolis, Nigeria

INTRODUCTION

Water is essential for aquaculture and it constitutes a major limiting factor in commercial fish production. The quality and quantity of a particular water source determine its suitability for fish farming operations. Aquaculture will therefore be impossible without an adequate supply of good-quality water. The most common sources of water for aquaculture are wells, groundwater boreholes, springs, rivers, lakes and municipal water. However, land use activities usually generate physical, biological and chemical pollutants that jeopardize the quality of water from any of these sources. Olanrewaju *et al.*[1] noted that water pollution may occur naturally through eroding stream banks and that most water pollutants are caused by human activities. The impact of such pollutants on aquatic life and human health was quite enormous and devastating. Hence, assessing the quality and safety of water becomes very important for the fish farming business.

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The humanitarian crisis resulting from the Boko Haram insurgency in Maiduguri, Nigeria which continues to limit fish supply from natural water bodies, especially Lake Chad has shifted the focus on aquaculture as an alternative supply channel. This has thus, created an urgent need to evaluate the suitability of all water sources particularly groundwater for the growing aquaculture enterprise. It must be emphasized that groundwater use for aquaculture is increasing worldwide. Adetunji and Odetokun[2] reported that 65–70% of people in peri-urban and rural communities in Nigeria rely on groundwater as their main source of pond water. With over 2,000 boreholes inventoried[3], groundwater remains a key water supply source for both domestic and aquaculture use in the Maiduguri Metropolis.

Groundwater and surface water vary substantially in many characteristics and most groundwater is naturally of good quality for aquaculture due to its consistent quantity and pollution-free status[4]. However, contamination due to indiscriminate dumping of untreated domestic and industrial wastes poses increasing threats to this water source[5]. Based on this fact, water quality investigation becomes important to determine its suitability for fish culture in any particular location.

Several studies on the assessment of the physical and chemical quality of borehole water sources for drinking and irrigation had been conducted so far in Maiduguri[3,6-8]. However, documented information on borehole suitability for fish farming in Maiduguri is currently scanty. Hence, this study was conducted to investigate the physic-chemical quality of surface and groundwater sources for pisciculture in Maiduguri Metropolis, Nigeria.

MATERIALS AND METHODS

Study area: The study was carried out between September and November, 2021 in the Maiduguri Metropolis, Borno State. This area extends to four local government areas, namely, Maiduguri Metropolitan, Jere, Konduga and to a smaller extent of Mafa local government areas[9]. The city is located on geographic grid reference Longitude 11°46'18"N-11°53'21"N and Latitude 13°03'23"E-13°14'19"E. It occupies a total landmass of 50,778 km^2 and is in the Sudano-Sahelian region of Northern Nigeria, having sandy loam[10].

Sample collection: Four different water sources were purposively sampled within the Maiduguri Metropolis (Table 1), taking into cognizance the location within the city center and periphery as well as residential density as highlighted by Jimme *et al*.[8]. Similarly, three samples each were taken fortnightly from each of the four sources covering September and November, 2021. The Borno State Water Treatment plant draws surface water from Lake Alau and gets it treated before releasing it to various homes within Metropolis. The plant is located some 15 km south of Maiduguri City and the water is often referred to as Mother-cat. Fori River, on the other hand, is part of the Ngadda River which passes through down to the Gamboru area and ends up in Khaddamari. The deep and wash boreholes around the Gwonge Sabolahi area of Maiduguri were also used in the study.

Samples were collected using pre-washed polyethylene bottles (750 mL), labeled appropriately and transported in the ice-pack box to the laboratory. The physic-chemical analyses of the samples were carried out in the Water and Biological Laboratory, NAFDAC Office, Maiduguri.

Table 1: Water quality monitoring locations in Maiduguri Metropolis

Sample identification	Water source	LGA	GPS points
GWB	Gwonge sabolahi wash borehole	MMC	11°49'09"N 13°10'32"E
GDB	Gwonge sabolahi deep borehole	MMC	11°50'06"N 13°10'25"E
FRW	Fori River water	Jere	11°49'12"N 13°10'12"E
TSW	Treated surface water	Jere	11°48'48"N 13°10'51"E

LGA: Local government area and MMC: Maiduguri Metropolitan Council

Physic-chemical parameters and heavy metals analysis: Water temperature, pH and dissolved oxygen (DO) was measured *in situ* using a Celcius thermometer and pH/DO digital meter (BICASA model B.E.104). The alkalinity, conductivity, total dissolved solid, magnesium, sulphate, phosphate, nitrate, total hardness, calcium, sodium and potassium contents of the water samples were determined following the method used by Akpoveta *et al.*[11]. The heavy metal contents (lead, cadmium, manganese, iron and zinc) were determined using Atomic Absorption Spectrophotometric method[12].

Statistical analysis: Data generated were subjected to descriptive (means and standard deviations) and inferential statistics (ANOVA). Fisher's LSD was employed for mean separation using SPSS software statistical program version 20.0. (SPSS Inc., Chicago, Illinois, USA). All the statistical analyses were considered at the significance level of 5% ($\alpha_{0.05}$). The water quality parameters are expressed in mg L^{-1}, except EC, T and pH.

RESULTS

The physicochemical chemical parameters of surface and groundwater sources investigated in the study are given in Table 2. Most of the investigated parameters were significantly higher ($p<0.05$) in surface water sources (i.e., Treated surface water and Fori River) than in the groundwater sources (i.e., Gwonge Sabolahi wash and deep boreholes). The highest potassium (8.66±0.57 mg L^{-1}) and phosphate (0.20±0.02 mg L^{-1}) contents were found in the FRW ($p<0.05$), while dissolved oxygen (7.16±0.49 mg L^{-1}) and nitrate (2.11±1.42 mg L^{-1}) was markedly greater in TSW. The pH levels were significantly higher in FRW (8.52±0.34) and TSW (8.03±0.22) than in GWB (7.43±0.91) and GDB (7.06±0.58). However, no differences ($p>0.05$) were noted in temperature and magnesium concentrations among treatments. Concentrations of total dissolved solid in FRW (186.67±3.21 mg L^{-1}) and TSW (63.19±1.23 mg L^{-1}) were lower than those of groundwater sources ($p<0.05$). Total hardness was observed to be high in FRW (178.00±73.69 mg L^{-1}) and TSW (140.15±1.19 mg L^{-1}) and low in GDB (60.87±44.37 mg L^{-1}) and GWB (65.45±78.80 mg L^{-1}). Electrical conductivity value was significant across the samples, GDB had the highest value of 0.12±0.04 dS m^{-1} while the lowest conductivity was recorded in TSW (0.04±0.01 dS m^{-1}). Alkalinity (118.20±10.28 mg L^{-1}) and calcium (1.12±0.16 mg L^{-1}) concentrations were significantly higher in FRW compared to other sources ($p>0.05$). The sulphate values ranged from 15.00±3.00 to 47.33±1.52 mg L^{-1}, with samples from FRW having the highest value (47.33±1.52 mg L^{-1}). Sodium contents varied between 77.33±1.02 mg L^{-1} (TSW) and 184.20±51.36 mg L^{-1} (GDB).

Table 2: Physico-chemical parameters of water samples

	Sources				
Parameters	GWB	GDB	TSW	FRW	Desirable limits
DO (mg L^{-1})	4.45±0.21^{c}	3.76±0.39^{d}	7.16±0.49^{a}	6.38±0.25^{b}	5.0-9.5
Temperature (°C)	24.53±0.35^{a}	24.24±0.22^{a}	24.30±0.20^{a}	23.60±0.54^{a}	20.0-30.0
pH	7.43±0.91^{b}	7.06±0.58^{b}	8.03±0.22^{a}	8.52±0.34^{a}	6.5-8.5
EC (dS m^{-1})	0.09±0.03^{b}	0.12±0.04^{a}	0.04±0.01^{c}	0.08±0.06^{b}	50.0-500.0
ALK (mg L^{-1})	33.69±4.16^{bc}	36.26±3.41^{b}	38.15±9.64^{b}	118.20±10.28^{a}	20.0-150.0
TDS (mg L^{-1})	216.60±28.16^{b}	382.00±60.17^{a}	63.19±1.23^{d}	186.67±3.21^{c}	30.0-300.0
Mg (mg L^{-1})	0.22±0.11^{a}	0.21±1.00^{a}	0.26±0.02^{a}	0.21±0.03^{a}	<150.0
SO_4^{2-} (mg L^{-1})	37.40±32.25^{b}	31.40±13.15^{c}	15.00±3.00^{d}	47.33±1.52^{a}	<400.0
PO_4^{3-} (mg L^{-1})	0.01±0.01^{b}	0.04±0.05^{b}	0.01±0.00^{b}	0.20±0.02^{a}	0.12
NO_3^{-} (mg L^{-1})	0.62±0.78^{c}	0.87±0.33^{c}	2.11±1.42^{a}	1.50±0.52^{b}	0.1-3.0
TH (mg L^{-1})	65.45±78.80^{c}	60.87±44.37^{c}	140.15±1.19^{b}	178.00±73.69^{a}	20.0-150.0
Ca (mg L^{-1})	0.79±0.17^{b}	0.67±0.28b^{c}	0.57±0.01^{c}	1.12±0.16^{a}	75.0-200.0
Na (mg L^{-1})	142.80±87.96^{b}	184.20±51.36^{a}	77.33±1.02^{d}	90.25±0.65^{c}	<500.0
K (mg L^{-1})	4.46±1.54^{b}	4.32±1.04^{b}	4.50±0.50^{b}	8.66±0.57^{a}	0.5-10.0

DO: Dissolved oxygen, EC: Electrical conductivity, ALK: Alkalinity, TDS: Total dissolved solid, Mg: Magnesium, SO_4^{2}: Sulphate, PO_4^{3}: Phosphate, NO_3: Nitrate, TH: Total hardness, Ca: Calcium, Na: Sodium, K: Potassium, Values are Mean±SD and $^{a-c}$Different superscript in a row indicates significant difference ($p<0.05$) between the water sources means

Table 3: Concentrations (mg L^{-1}) of some heavy metals in water samples

	Sources				
	GWB	GDB	TSW	FRW	Permissible limits
Lead (Pb)	-0.16±0.11[b]	-0.10±0.19[b]	0.11±0.01[a]	0.15±0.06[a]	0.1
Cadmium (Cd)	0.01±0.01[a]	0.02±0.01[a]	0.01±0.00[a]	0.05±0.00[a]	0.005
Manganese (Mn)	0.15±0.03[a]	0.16±0.05[a]	0.10±0.00[b]	0.19±0.08[a]	0.5
Iron (Fe)	0.16±0.03[b]	0.11±0.02[c]	7.14±12.00[a]	0.18±0.02[b]	0.003
Zinc (Zn)	0.17±0.06[c]	0.16±0.09[c]	0.36±0.04[b]	0.81±0.07[a]	15

[a-c]Different subscript in a row indicates significant difference ($p<0.05$) between the water sources means

The heavy metal contents of the samples are summarized in Table 3. Most of the investigated parameters were significantly higher ($p<0.05$) in FRW than in other investigated water sources, i.e., lead, cadmium, manganese and zinc. The lead contents ranged from -0.10±0.19 to 0.15±0.06 mg L^{-1} in GDB and FRW, respectively. Cadmium ranged from 0.01±0.00 mg L^{-1} in TSW to 0.05±0.00 mg L^{-1} in FRW. Magnesium concentrations varied between 0.10±0.00 (TSW) and 0.19±0.08 mg L^{-1} (FRW). The iron levels also ranged from 0.11±0.02 (GDB) to 7.14±12.00 mg L^{-1} (TSW). Zinc value varied from 0.16±0.09 (GDB) to 0.81±0.07 mg L^{-1} (FRW).

DISCUSSION

The present study aimed at assessing the suitability of surface and groundwater for pisciculture in Maiduguri Metropolis, Northeast Nigeria. The findings showed that the values obtained for physicochemical parameters fell within standard limits by Anita and Pooja[13] and WHO[14]. On the contrary, parameters such as dissolved oxygen, total dissolved solids, phosphate and calcium were lower than desirable limits in some of the sources. The variations among the investigated parameters were statistically significant ($p<0.05$) except for temperature and magnesium. Similarly, most of the studied parameters were significantly higher ($p<0.05$) in surface water sources (i.e., treated surface water and Fori River). In heavy metals, TSW had significantly lower Mn (0.10±0.00 mg L^{-1}) and higher Fe (7.14±12.00 mg L^{-1}) levels, while cadmium levels showed no marked difference ($p>0.05$) among all the investigated water sources. However, Pb (0.15±0.06 mg L^{-1}) and Zn (0.81±0.07 mg L^{-1}) were significantly higher ($p<0.05$) in surface water.

When the results from surface and groundwater sources were compared, it was evident that the dissolved oxygen, pH, alkalinity, nitrate, total dissolved solids, hardness and potassium were optimum in TSW and Fori River water (i.e., surface water)[15]. This might have been due to the effect of frequent precipitation which makes these water sources renewable. Based on Sawyer and McCarty[16] classification, borehole water in this study could be classified as soft while surface water swings between moderately hard to hard. This result agrees with Adetoyinbo *et al.*[17], who found the physic-chemical parameters in the stream to be optimal as compared to hand-dug wells and boreholes in Itagunmodi, Southwestern Nigeria. A similar observation was reported by Kolo *et al.*[18] on the elemental analysis of tap and borehole waters in Maiduguri, Semi-Arid region, in Nigeria. Also, the pH, alkalinity and hardness levels in surface water sources were within the ranges reported by Hyeladi and Nwagilari[6], who studied the assessment of the drinking water quality of Alau Dam Maiduguri. Jimme *et al.*[8] however reported much lower pH, hardness and nitrate values for treated surface water in Maiduguri, Nigeria.

The groundwater in this study reflected premium values for conductivity and sodium, which was similar to the findings of Adetoyinbo *et al.*[17] in Itagunmodi, Southwestern Nigeria. Similar high optimum conductivity and sodium values were documented by Kolo *et al.*[18] and Bashir *et al.*[19] for boreholes and tube wells in Maiduguri, Nigeria. The water temperature and magnesium levels were constant and not significantly different between the surface groundwater water samples. This result was similar to those reported by Al-Ghamdi *et al.*[20] from Al-Makhwah region of Saudi Arabia but differed considerably from that of Adetoyinbo *et al.*[17] in South-Western Nigeria who reported significant variations in magnesium values between surface and ground waters.

Heavy metal was one of the most important pollutants in the waters because of its toxicity and mutagenic and carcinogenic effects on animals. Abubakar *et al.*[21] noted that heavy metals constitute the most widely distributed group of highly toxic and retained substances. The variations in heavy metal, contents between the investigated water sources in this study were statistically significant ($p<0.05$). However, lead, iron and zinc were markedly higher in surface water samples. Conversely, the cadmium contents in all the water samples studied differ non-significantly. In the current study, the values obtained for manganese and zinc were in consonance with recommended limits by Saah *et al.*[22]. There is the proliferation of iron and cadmium in all the water samples while leading swings above the desirable limits in surface water sources only.

These results agreed with the finding of Adetoyinbo *et al.*[17] and Kolo *et al.*[18]. Similar results were mentioned by Hyeladi and Nwagilari[6], who found a minimal range of zinc but higher iron concentrations in surface water sources in Maiduguri Metropolis. However, this result contradicts the findings of Al-Ghamdi *et al.*[20], who reported a marginal difference in iron contents between surface and groundwater in the Al-Makhwah Region, Saudi Arabia. Cadmium and iron were not detected in treated surface water and deep boreholes in the Maiduguri metropolis which is in agreement with Jimme *et al.*[8]. The authors, however, report significantly high cadmium content (0.15 mg L^{-1}) in wash boreholes in the area.

In aquaculture, it is very important to determine the safety of water concerning its physical, chemical and bacteriological property[15]. This was because poor quality water can affect the health, growth and survival of the fish, which eventually may cause a huge loss on the investment. Ssekyanzi *et al.*[23] noted that poor knowledge and practices concerning water quality in aquaculture usually wreck the farmers and hamper fish food production in Sub-Saharan Africa. Moreover, homestead fish farming has been declining in the Maiduguri metropolis, probably due to water quality issues. Yet, there is no previously documented information on the suitability of surface and groundwater for aquaculture in the area prior to this study. Thus, the study is very unique being the first of its kind in the area. The study shows that most of the water sources investigated are contaminated with abnormal levels of Pb, Fe and Cd. Therefore, proper treatment is recommended to abate the rise of heavy metals in these boreholes. There is also a need for regular monitoring of the physicochemical parameters of these waters and taking appropriate remediation measures to control any parameters not within the threshold.

CONCLUSION

The study revealed that the physic-chemical parameters investigated in all water sources studied were within the desirable limit, except dissolved oxygen in deep and wash boreholes that will require enhancement through aeration. However, most of the water sources investigated were contaminated with lead, cadmium and iron. Therefore, these water sources may not safe for pisciculture. It could only be considered adequate for fish culture after proper treatment.

SIGNIFICANCE STATEMENT

This study is novel being the first to investigate the suitability of surface and groundwater for fish farming in the Maiduguri Metropolis. It was discovered that these waters conform with the optimum standard recommended range for fish culture. However, the study revealed the proliferation of heavy metals above the desirable limits for fish farming, which is a serious concern to both fish farmers and consumers in the area. Also, this study will create an avenue for the researchers to uncover the reasons for heavy metal proliferations in all of these waters as well as possible solutions to explore.

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