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# Bacteriological and Physico-Chemical Assessment of Groundwater Boreholes for Aquaculture in Internally Displaced People's (IDPs) Camps in Arid Zone Nigeria

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## ABSTRACT

**Background and Objective:** The empowerment of displaced persons in fish farming in Maiduguri Metropolis requires a good water quality supply for successful operation and this is elusive in literature. This study, therefore, evaluated the physicochemical and bacteriological profile of groundwater boreholes in major IDP camps in Maiduguri, Borno State. **Materials and Methods:** Water samples from boreholes in each camp: Teacher's Village, Farm Centre, Al-Maskin, Bolori Kasua and National Youth Service Corps (NYSC) were collected in triplicate for physic-chemical and bacteriological analyses using standard methods. Data generated were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$. **Results:** The physic-chemical parameters of the water samples were within standard limit, except dissolved oxygen ($3.60\pm1.15$ to $4.50\pm0.42$ mg $L^{-1}$) and alkalinity ($30.25\pm10.18$ to $31.93\pm9.24$ mg $L^{-1}$). The cadmium ($0.01\pm0.01$ to $0.04\pm0.05$ mg $L^{-1}$), iron ($0.08\pm0.02$ to $0.15\pm0.03$ mg $L^{-1}$) and manganese ($0.10\pm0.03$ to $0.12\pm0.02$ mg $L^{-1}$) values were marginally above the threshold limit for aquaculture. However, lead content ($0.16\pm0.03$ mg $L^{-1}$) was only high at Al-Maskin Camp. Also, there is high coliform density ($4.33\pm7.50$ to $20.33\pm18.77$ CFU $mL^{-1}$) and bacteria contaminant ($33.00\pm2.64$ to $97.66\pm27.39$ CFU $mL^{-1}$) in all the borehole sampled. **Conclusion:** The water in the study area is not safe for fish culture except properly treated.

## KEYWORDS

Water quality, borehole, aquaculture, internal displaced peoples' camps, Maiduguri Metropolis, fish culture



## INTRODUCTION

Borno State is noted for its boisterous crop farming and inland fishing activities which serve as major sources of livelihood for the residents. Consequently, several thousands of tons of grains, fresh and smoked fish are supplied and distributed within and outside the state on a daily basis. However, the armed insurgency in the northeast has resulted in the disruption of agriculture and fishing livelihoods in Borno State[1]. According to Dunn[2], the incidence of this cantankerous group has resulted in the loss of

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human life, population displacement and destruction of productive assets, economic infrastructure and social services in the State. Today, several thousands of people are scattered around in Internally Displaced People's (IDPs) Camps in Maiduguri Metropolis, Borno State, Nigeria.

Owing to this fact, the Government of Nigeria and the International community have continued to provide succor for displaced people with a focus on restoring economic productivity and livelihoods in the state. Meanwhile, fish farming training and empowerment is one of the opportunities to ameliorate the suffering of the people. According to Belton and Thilsted[3], sustainable aquaculture production improves food and nutrition security, increases income and enhances livelihoods and promotes economic growth. However, the major challenge to this laudable cause apart from training in aquaculture is the availability of good quality water for aquaculture in Maiduguri.

The major source of water in Maiduguri Metropolis for drinking and farming is groundwater from boreholes (deep wells and shallow wells). According to Aniebone *et al.*[4], groundwater is naturally of good quality and viewed as the preferred source of water for fish farming due to its reliable quantity and pollution free status. Musa *et al.*[5], however, noted that groundwater is constantly under pressure due to human activities that jeopardize its quality. Meanwhile, groundwater quality differs extensively between locations, seasons and aquifers[6]. It is generally recharged by rain water infiltration and surface water percolation into the saturated zone of the water table.

Dirican[7], thus stated that water quality investigation is very important to determine its suitability either for drinking or aquacultural use. Thus, water needs to be subjected to test and found within the threshold limit that determines its suitability for a particular use. A review of literature showed scanty reports on the groundwater quality for drinking and irrigation purposes in the Maiduguri Metropolis, Nigeria[5,8-10], but there has been no documented information on borehole quality for fish farming in Maiduguri, especially in IDPs Camps. Therefore, this study investigates bacteriological and physico-chemical quality of groundwater boreholes for fish farming in IDPs Camps in Maiduguri Metropolis, Borno State, Nigeria. The present study puts an effort to assess the suitability of the groundwater boreholes available for fish farming projects in the selected IDP Camps and draw useful inferences from the findings.

## MATERIALS AND METHODS

**Study area:** The study was carried out from September, 2019 to December, 2019 in Maiduguri Metropolis, Borno State, Nigeria. Maiduguri is the capital city of Borno State. The geographical coordinates of Maiduguri are 11°46'18"N to 11°53'21"N and 13°03'23"E to 13°14'19"E. It is situated in the Sudano-Sahelian Region of Northern Nigeria. Maiduguri is noted for its tropical savannah climate with mane annual rainfall of about 300 to 500 mm and average daily temperature ranging from 22 to 35°C. The soil type of the area is sandy loam[11]. In this study, five major Internally Displaced People's (IDPs) Camps were selected (Table 1) as sampling sites. These were selected because they serve as temporary homes where displaced people are managing their lives.

**Water sample collection:** Water samples were collected weekly for four months (between September and December, 2019) from two randomly selected boreholes in each camp. The water samples were collected between 08:00 and 10:35 a.m. using test bottles, which were filled with water, labeled, corked and transferred to the laboratory for physicochemical and bacteriological analyses.

**Physico-chemical analysis:** Temperature, pH, conductivity, Total Dissolved Solid (TDS) and alkalinity were measured *in situ*. Digital laboratory thermometer, pH meter (HANNA HI 98107) and alkalinity meter (HANNA HI 3811) were used for the determination of temperature, pH and alkalinity. For the measurement of conductivity and TDS, an Intelligent meter (AD. 33915) was used. The water samples from boreholes in each camp were collected into separate sampling bottles and analyzed within 24 hrs after collection. In the laboratory, the analysis of dissolved oxygen, nitrate, nitrate and chloride were conducted by the use of Winkler's Method, phenoldisulfonic acid method, diazotization method and argentometric method, respectively. The total hardness, calcium and magnesium were measured through Ethylenediaminetetraacetic Acid (EDTA) titrimetric method. Also, determination of phosphate, sulphate, potassium, sodium, nitrogen, were carried out following the method used by Akpoveta *et al.*[12].

**Heavy metal analysis:** Heavy metals (lead, zinc, manganese and cadmium) were determined in water samples using a Perkin Elmer Model 306 Atomic Absorption Spectrophotometer.

**Bacteriological analysis:** Total bacteria, total and faecal coliforms were determined by Membrane Filtration Method using M-Endo-Agar Les (Difco) at 37°C and on MFC Agar at 44°C, respectively.

**Statistical analysis:** Data were analysed using descriptive statistics (means and standard deviations) and Analysis of Variance at $\alpha_{0.05}$.

## RESULTS

**Physicochemical parameters:** The concentrations of physic-chemical parameters in water samples from selected Internal Displaced People's Camps in Maiduguri were presented in Table 2. Dissolved oxygen concentration was significantly ($p<0.05$) higher in NYSC (4.50±0.42 mg $L^{-1}$) and Bakasi (4.20±0.88 mg $L^{-1}$) boreholes, than other locations. The pH values in the studied boreholes are found to be slightly alkaline, with the lowest mean reading recorded at Bakasi Camp (6.24±0.05) while the markedly maximum value was recorded at the Teacher's Village borehole (8.30±0.26). Also, water samples from Bakasi Camp had the highest ($p<0.05$) (25.33±1.53°C) temperature, followed by Farm Centre (24.20±0.20°C) and Teacher's Village Camp (23.60±0.20°C) gave the least. The mean phosphate level varied between 0.01±0.00 mg $L^{-1}$ and 0.02±0.00 mg $L^{-1}$, without significant differences between locations. The magnesium values ranged from 0.16±0.06 to 0.21±0.10 mg $L^{-1}$, with Al-Maskin samples having significant highest magnesium level (0.21±0.10 mg $L^{-1}$). Farm Centre revealed highest ($p<0.05$) potassium level (5.00±3.47 mg$L^{-1}$), followed by Teacher's Village (4.43±1.42 mg $L^{-1}$) and Al-Maskin (4.33±1.52 mg $L^{-1}$) boreholes.

The mean sulphate and conductivity across the locations were marginally different ($p>0.05$). Al-Maskin had the highest mean sulphate of 18.66±7.02 mg $L^{-1}$ and the lowest was shown in NYSC Camp with 11.00±1.73 mg $L^{-1}$. The highest mean conductivity (0.08±0.01 dS $m^{-1}$) was found in Farm Centre while NYSC (0.05±0.02 dS $m^{-1}$) and Al-Maskin (0.05±0.03 dS $m^{-1}$) had the least. Total dissolved solid value was significant across the locations, where Farm Centre (298.33±10.02 mg $L^{-1}$) had the highest value and the lowest was shown in NYSC (215.33±73.28 mg $L^{-1}$). Alkalinity levels in the study ranged from 30.25±10.18 mg $L^{-1}$ (Teacher's Village) to 31.93±9.24 mg $L^{-1}$ (Al-Maskin) and show no significant variations ($p>0.05$). Also, the water sample from Teacher's Village showed slightly ($p>0.05$) higher hardness content (30.47±11.11 mg $L^{-1}$) than the water from other locations.

Calcium fluctuated between 1.13±0.75 mg $L^{-1}$ (Farm Centre) and 1.41±0.87 mg $L^{-1}$ (Teacher's Village) with marginal differences among the sample locations. On the other hand, Farm Centre and NYSC samples showed the highest nitrate concentrations followed in decreasing order by Bolori Kasua (2.22±0.88 mg $L^{-1}$), Al-Maskin (2.47±1.13 mg $L^{-1}$) and Teacher's Village (2.59±1.71 mg $L^{-1}$), respectively.

Similar trend was observed in nitrate content, where water samples from Al-Maskin and Farm Centre showed the lowest value (0.01±0.01 mg $L^{-1}$), compared to other sample location with similar value (0.02±0.01 mg $L^{-1}$). Significantly ($p<0.05$) higher sodium value was detected in Farm Centre (8.03±0.65 mg $L^{-1}$) while the NYSC sample shown the least (4.73±2.22 mg $L^{-1}$). No significant difference

Table 1: Sampled water sources, location and GPS points

| Sample Site | Site tag | Sample location | Coordinates | Population |
|---|---|---|---|---|
| Al-Maskin Camp | AMC | Custom Area | 11°52'33''N, 13°10'39''E | |
| Bakasi Camp | BC | Bakasi, Damboa Road | | 34,232 |
| Farm Center Camp | FCC | Ruwa Shafi, Gamboru Ngala Road | 11°51'43''N, 13°12'53''E | 9,024 |
| Teacher's Village Camp | TVC | Mala Kachala By-pass | 11°50'39''N, 13°06'00''E | 31,000 |
| NYSC Camp | NYSC | Tasan Kano, Damboa Road | 11°49'31''N, 13°07'06''E | 25,000 |

AMC: Al-Maskin Camp, BC: Bakasi Camp, FCC: Farm Center Camp, TVC: Teacher's Village Camp and NYSC: National Youth Service Corps Camp

Table 2: Physicochemical analysis of borehole water samples from selected IDP camps in Maiduguri

| | Site | | | | |
|---|---|---|---|---|---|
| Parameter | AMC | BKC | FCC | NYSC | TVC |
| DO (mg $L^{-1}$) | $3.80\pm1.10^{a}$ | $4.20\pm0.88^{b}$ | $3.90\pm0.65^{a}$ | $4.50\pm0.42^{b}$ | $3.60\pm1.15^{a}$ |
| Ph | $8.16\pm0.15^{b}$ | $6.24\pm0.05^{a}$ | $8.13\pm0.25^{b}$ | $7.93\pm0.15^{b}$ | $8.30\pm0.26^{b}$ |
| Temp (°C) | $24.00\pm0.22^{a}$ | $25.33\pm1.53^{b}$ | $24.20\pm0.20^{a}$ | $23.90\pm0.16^{a}$ | $23.60\pm0.20^{a}$ |
| $PO_4^{3-}$ (mg $L^{-1}$) | $0.02\pm0.00^{a}$ | $0.01\pm0.00^{a}$ | $0.02\pm0.00^{a}$ | $0.01\pm0.00^{a}$ | $0.02\pm0.00^{a}$ |
| Mg (mg $L^{-1}$) | $0.21\pm0.10^{b}$ | $0.18\pm0.11^{a}$ | $0.17\pm0.08^{a}$ | $0.16\pm0.06^{a}$ | $0.15\pm0.03^{a}$ |
| K (mg $L^{-1}$) | $4.33\pm1.52^{ab}$ | $3.57\pm1.32^{a}$ | $5.00\pm3.47^{b}$ | $3.96\pm1.77^{a}$ | $4.43\pm1.42^{ab}$ |
| $SO_4^{2-}$ (mg $L^{-1}$) | $18.66\pm7.02^{a}$ | $14.71\pm5.26^{a}$ | $13.00\pm4.58^{a}$ | $11.00\pm1.73^{a}$ | $16.00\pm3.46^{a}$ |
| EC (dS $m^{-1}$) | $0.05\pm0.03^{a}$ | $0.06\pm0.01^{a}$ | $0.08\pm0.01^{a}$ | $0.05\pm0.02^{a}$ | $0.06\pm0.02^{a}$ |
| TDS (mg $L^{-1}$) | $276.59\pm65.83^{ab}$ | $234.67\pm30.67^{a}$ | $298.33\pm10.02^{b}$ | $215.33\pm73.28^{a}$ | $287.96\pm81.53^{b}$ |
| ALK (mg $L^{-1}$) | $31.93\pm9.24^{a}$ | $30.47\pm11.11^{a}$ | $30.80\pm2.01^{a}$ | $31.30\pm8.90^{a}$ | $30.25\pm10.18^{a}$ |
| HDS (mg $L^{-1}$) | $21.58\pm8.52^{a}$ | $19.77\pm2.40^{a}$ | $23.20\pm2.65^{a}$ | $26.83\pm7.87^{a}$ | $30.47\pm11.11^{a}$ |
| Ca (mg $L^{-1}$) | $1.29\pm0.84^{a}$ | $1.37\pm0.40^{a}$ | $1.13\pm0.75^{a}$ | $1.30\pm0.40^{a}$ | $1.41\pm0.87^{a}$ |
| $NO_3^-$ (mg $L^{-1}$) | $2.47\pm1.13^{a}$ | $2.22\pm0.88^{a}$ | $2.66\pm1.60^{a}$ | $2.66\pm0.89^{a}$ | $2.59\pm1.71^{a}$ |
| $NO_2^-$ (mg $L^{-1}$) | $0.01\pm0.01^{a}$ | $0.02\pm0.01^{a}$ | $0.01\pm0.01^{a}$ | $0.02\pm0.01^{a}$ | $0.02\pm0.01^{a}$ |
| Na (mg $L^{-1}$) | $5.28\pm1.37^{a}$ | $5.77\pm0.55^{a}$ | $8.03\pm0.65^{b}$ | $4.73\pm2.22^{a}$ | $6.84\pm2.19^{ab}$ |
| N (mg $L^{-1}$) | $0.47\pm0.21^{a}$ | $0.50\pm0.20^{a}$ | $0.60\pm0.36^{a}$ | $0.60\pm0.20^{a}$ | $0.54\pm0.66^{a}$ |
| $Cl^-$ (mg $L^{-1}$) | $2.52\pm0.56^{b}$ | $0.73\pm0.29^{a}$ | $2.57\pm0.32^{b}$ | $1.90\pm0.87^{a}$ | $2.83\pm0.91^{b}$ |

AMC: Al-Maskin Camp, BC: Bakasi Camp, FCC: Farm Center Camp, TVC: Teacher's Village Camp, NYSC: National Youth Service Corps Camp, ±SD values are mean of replicates and means across the same row differently superscripted differ significantly ($p<0.05$)

was found in the nitrogen concentration of all water samples across locations ($p>0.05$). However, the nitrogen content of Farm Centre (0.60±0.36 mg $L^{-1}$) and NYSC (0.60±0.20 mg $L^{-1}$) were slightly higher compared to samples from Al-Maskin (0.47±0.21 mg $L^{-1}$), Bolori Kasua (0.50±0.20 mg $L^{-1}$) and Teacher's Village (0.54±0.66 mg $L^{-1}$). Chloride concentrations fluctuated between 0.73±0.29 mg $L^{-1}$ (Bolori Kasua) and 2.83±0.91 mg $L^{-1}$ (Teacher's Village) with significant differences among the sample locations.

**Heavy metal contents:** The results of heavy metal analysis from borehole water samples in the study area were shown in Table 3. The cadmium content in the water samples indicate slight variations across the locations with the highest found in Al-Maskin (0.04±0.05 mg $L^{-1}$) and lowest from NYSC (0.01±0.01 mg $L^{-1}$). The lead concentration of the water samples ranged between 0.04±0.05-0.16±0.03 mg $L^{-1}$ and were significantly ($p<0.05$) different, sample from Al-Maskin was higher samples from than other locations. Iron levels however was highest in Bolori Kasua (0.15±0.03 mg $L^{-1}$) and Teacher's Village (0.15±0.02 mg $L^{-1}$), while that of the NYSC (0.08±0.02 mg $L^{-1}$) was least. The manganese value (0.10±0.03 to 0.12±0.02 mg $L^{-1}$) of the waters were not significantly ($p>0.05$) different. The zinc contents for the water samples were significantly ($p<0.05$) different, the Al-Maskin samples was the highest (0.26±0.07 mg $L^{-1}$), followed by Farm Centre (0.23±0.07 mg $L^{-1}$) and the least from Teacher's Village (0.18±0.04 mg $L^{-1}$).

**Bacteriological quality:** The bacteriological characteristics of the water samples in the study were presented in Table 4. The results indicated that the total bacteria count of the water samples ranged between 33.00±2.64-97.66±27.39 CFU $mL^{-1}$ and were significantly ($p<0.05$) different, NYSC sample was higher than samples from other locations. The total coliform count of the NYSC sample

Table 3: Heavy metal analysis of borehole water samples from selected IDP camps in Maiduguri

| | Site | | | | |
|---|---|---|---|---|---|
| Parameter | AMC | BKC | FCC | NYSC | TVC |
| Cd (mg $L^{-1}$) | $0.04\pm0.05^{a}$ | $0.03\pm0.07^{a}$ | $0.02\pm0.00^{a}$ | $0.01\pm0.01^{a}$ | $0.03\pm0.05^{a}$ |
| Pb (mg $L^{-1}$) | $0.16\pm0.03^{b}$ | $0.04\pm0.05^{a}$ | $0.08\pm0.06^{ab}$ | $0.07\pm0.05^{ab}$ | $0.04\pm0.05^{a}$ |
| Fe (mg $L^{-1}$) | $0.11\pm0.02^{a}$ | $0.15\pm0.03^{a}$ | $0.10\pm0.01^{a}$ | $0.08\pm0.02^{a}$ | $0.15\pm0.02^{a}$ |
| Mn (mg $L^{-1}$) | $0.12\pm0.02^{a}$ | $0.10\pm0.03^{a}$ | $0.11\pm0.01^{a}$ | $0.12\pm0.02^{a}$ | $0.12\pm0.01^{a}$ |
| Zn (mg $L^{-1}$) | $0.26\pm0.07^{b}$ | $0.22\pm0.05^{ab}$ | $0.23\pm0.07^{ab}$ | $0.21\pm0.06^{a}$ | $0.18\pm0.04^{a}$ |

AMC: Al-Maskin Camp, BC: Bakasi Camp, FCC: Farm Center Camp, TVC: Teacher's Village Camp, NYSC: National Youth Service Corps Camp, ±SD values are mean of replicates and means across the same row differently superscripted differ significantly ($p<0.05$)

Table 4: Bacteriological quality of water samples from boreholes in selected IDP camps in Maiduguri

| | Site | | | | |
|---|---|---|---|---|---|
| Parameter | AMC | BKC | FCC | NYSC | TVC |
| TBC (CFU $mL^{-1}$) | $64.66\pm41.42^{ab}$ | $49.38\pm5.44^{a}$ | $97.66\pm27.39^{b}$ | $92.33\pm22.36^{b}$ | $33.00\pm2.64^{a}$ |
| TCC (CFU $mL^{-1}$) | $12.66\pm21.93^{b}$ | $9.86\pm11.40^{ab}$ | $4.33\pm7.50^{a}$ | $20.33\pm18.77^{c}$ | $12.00\pm12.52^{b}$ |
| FCC (CFU $mL^{-1}$) | $17.00\pm9.64^{b}$ | $12.58\pm5.58^{b}$ | $3.33\pm5.77^{a}$ | $15.00\pm6.08^{b}$ | $14.66\pm4.93^{b}$ |

AMC: Al-Maskin Camp, BC: Bakasi Camp, FCC: Farm Center Camp, TVC: Teacher's Village Camp, NYSC: National Youth Service Corps Camp, TCC: Total coliform count, FCC: Feacal coliform count, TBC: Total bacteria count, ±SD values are mean of replicates and means across the same row differently superscripted differ significantly ($p<0.05$)

(20.33±18.77 CFU $mL^{-1}$) were significantly ($p<0.05$) highest to the rest of the samples. This was followed by Al-Maskin (12.66±21.93 CFU $mL^{-1}$) while Farm Centre (4.33±7.50 CFU $mL^{-1}$) had the least. Similarly, the feacal coliform count (3.33±5.77 to 17.00±9.64 CFU $mL^{-1}$) of the water samples were markedly ($p>0.05$) different.

## DISCUSSION

**Physico-chemical parameters:** In aquaculture, one of the most critical aspects to ensuring success is having good quality supply of water, however, physic-chemical properties and supply differs extensively between locations due to many factors including land use activities. Meanwhile, the superior quality and suitability of groundwater for fish culture is well acknowledged by Bhatnagar and Devi[13], since its quality does not fluctuate like surface water and is rarely get polluted. Anne *et al.*[14], however, states that it is very important to judge the safety of water with respect to its physical, chemical and bacteriological property. In the present study, all the physico-chemical parameters explored were in consonance with the optimum range for survival and growth of fish[13,15], except few parameters including dissolved oxygen, alkalinity, conductivity, hardness and calcium. This observation corroborates the previous report by Mustapha *et al.*[16], who investigate the the water supply system from Maiduguri water treatment plant. These authors found similar temperature, pH, sodium, potassium and magnesium range values that fell within the standard recommended range for aquaculture.

Similar to this study, Mustapha *et al.*[16] and Hyeladi and Nwagilari[9] found the total hardness groundwater boreholes in Maiduguri to be less than 50 $CaCO_3$ mg $L^{-1}$ and classified as soft water based on the classification of Hori *et al.*[17]. Jimme *et al.*[8], however, reported that deep and wash boreholes in Maiduguri based on total hardness varied from slightly hard (105.0 mg $L^{-1}$) to very hard (519.0 mg $L^{-1}$) as classified by Hori *et al.*[17]. The variations in the results could be due to differences in time of sampling and soil types between studied locations. The result also corresponds with the finding of Biu *et al.*[10], who investigate the physicomicrobiological properties of domestic water used by the community of College of Agriculture and its environs, Maiduguri, North-Eastern Nigeria. The selected water parameters studied by these authors were found optimum for fish culture except for for few parameters. The results in this study also compared well with the findings of Musa *et al.*[5] on groundwater wells in Maiduguri.

**Heavy metal contents:** In this study, heavy metals were of particular concern due to their toxicity and ability to be bioaccumulated in aquatic ecosystems[18], as well as persistence in the natural environment. Hence, concentrations of five heavy metals were determined in borehole water samples in the study area. Lead and zinc content variations between the investigated sources were statistically significant ($p<0.05$), while cadmium, iron and manganese were marginally different ($p>0.05$) between sources. Meanwhile, the range values obtained for heavy metals in this study were incongruence with standard recommended limits by Taylor and McLennan[19], except zinc. Also, these metal levels show disparity with the recommended limits for aquaculture[20], except manganese and lead.

The results in previous literatures were somewhat closer to or higher than our obtained data for similar water source and study area. Jimme *et al.*[8] recorded contamination levels of domestic water in Maiduguri Metropolis, Borno State, Nigeria. These authors reported cadmium level (0.15 mg $L^{-1}$) much higher than those recorded in study area of the current work. In addition, Hyeladi and Nwagilari[9] recorded higher Iron levels (0.01 to 0.09 mg $L^{-1}$) than range levels obtained in the present study Hyeladi and Nwagilari[9] however, reported lower concentrations of Zinc (0.01 to 0.09 mg $L^{-1}$) in the same study area. Zinc, manganese and lead contents observed in the present study was comparatively higher that those reported by Musa *et al.*[5] in Gwange and Bulumkutu Wards, Maiduguri. Also, the manganese levels in this study compared well with other similar boreholes outside Maiduguri as reported by Ahmed and Eyaife[21] in Bauchi and Olorunfemi *et al.*[22] in Ejigbo town and environs, Osun State, Nigeria.

**Bacteriological quality:** Coliform bacteria are commonly-used bacteria indicator of water pollution because their presence in potable water may indicate a possible presence of harmful, disease-causing organisms[21]. In this study, the total bacteria count varied from 33.00±2.64 to 97.66±2.39 CFU $mL^{-1}$, though there were significant variations across the sampling camps ($p<0.05$). These values were far above the World Health Organization and Nigeria Standard for Drinking Water Quality acceptable standard of 0 CFU $mL^{-1}$. Some of the reasons to this poor water quality can impugned on improper construction, animal waste, proximity to toilet facilities, sewage, refuse dump site and various anthropogenic activities.

Antony and Renuga[23], apprise that total coliforms are reflective of overall cleanliness state of the water and imminent danger of communicable disease from water. In this exploration, all the water samples except Farm Centre have Total Coliform Count (TCC) above the standard requirement of 10 total coliform counts per 100 mL[24]. This is however, an indication that all the water samples in this study were higher in TCC when compared with the permissible standard (0 CFU $mL^{-1}$) of Meride and Ayenew[18]. Similar observations have been reported by Jimme *et al.*[8] and Biu *et al.*[10] for borehole waters samples in Maiduguri, Nigeria. According to Getachew *et al.*[25], the increase in the coliform count may be as a result of fecal contamination of the water source. This result therefore suggests that the water from the samples boreholes is polluted and neither safe for human consumption nor fish farming without processing.

Faecal contamination is considered as the most critical form of water pollution derived from different sources[26]. The main cause of this problem ensues from poor sanitary and hygiene, non-compliance to best waste disposal and environmental sanitation. According to Cabral[27], their existence in drinking water suggests the possibility of pathogenic organisms being present in the water system, which may likely constitute imminent threat to the water and by extension to the life and wellbeing of the consumers. The faecal coliform count in the study ranged from 3.33±5.77 to 17.00±9.64 CFU $mL^{-1}$ which is higher than the standard range of 0 CFU $mL^{-1}$ cited by Oyedum *et al.*[24] and Meride and Ayenew[18]. Thus, the result clearly shows that the water from the sampled boreholes is faecally contaminated. Biu *et al.*[10], who examined the quality of ground water in Maiduguri, Nigeria found unacceptable levels of faecal coliform present in borehole water of Maiduguri Metropolis. In another similar work, Sabo and Christopher[21] obtained faecal coliform count of 199 CFU $mL^{-1}$ for borehole water samples in Bauchi Metropolis of Nigeria. However, the consequence of this findings is the possibility of the presence of pathogens that may cause acute intestinal illness[24].

This exploration stands to complement the government efforts toward empowering the displaced people in fish farming business. By implication, the study realised that poor knowledge and practices regarding water quality in fish farming can wreck the farmers and hamper the business. The data generated in the study have application in the area of monitoring the quality and safety of groundwater boreholes for pisciculture in the selected IDP camps. Meanwhile, the study recommends appropriate remediation measures to control the proliferation of cadmium, lead and manganese in the water. There is also need for proper treatment to avert high coliform density and bacteria contaminant found in the water. Nonetheless, the limitation in this study is mostly the insufficient resources to garner more sample for extensive coverage of the site.

## CONCLUSION

Water quality assessment in the selected IDPs revealed that all the physico-chemical chemical parameters explored were in consonance with the standard recommended limits for fish culture, except dissolved oxygen and alkalinity. Water samples from the various IDPs camps in the study could be classified as soft in terms of total hardness values. There is proliferation of cadmium, lead and manganese in all the water examined. Also, there is high coliform density and bacteria contaminant in all the borehole water samples in the study area. Hence, these water in the study area could only be considered satisfactory for fish culture after proper treatment. Also, there is need for regular monitoring of the physico-chemical and bacteriological constituents of these boreholes and take appropriate remediation measures to control any parameters that are not within the threshold.

## SIGNIFICANCE STATEMENT

The study is very unique and critical to the fish farming empowerment and settlement of displaced persons in banditry-prone areas like Borno State, Nigeria. It was discovered that the physico-chemical parameters of water in the selected IDPs were optimum, except the rise in cadmium, lead and manganese. More so, the study revealed high coliform density and bacteria contaminant which rendered the water undesirable for fish farming. Therefore, this study has shown the need for proper water treatment in these IDPs Camps before it can be used for fish farming venture. It has also raised concern for policy makers and researchers on the socio-economic danger of using such unhealthy water for aquaculture.

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