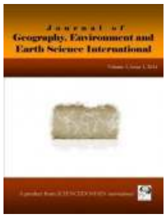

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Assessment of Water Quality for *Goro Dong* (Lake) and Its Suitability for Consumption and Domestic Use by the Immediate Lake Communities in Numan, Adamawa State Nigeria

Ezekiel Yonnana[1*], Shinggu D. Yamta[2], Iliya Kaigama[2] and Asondolo N. Bedeson[3]

[1]*Department of Geography, Adamawa State University, Mubi, Nigeria.*
[2]*Department of Chemistry, Adamawa State University, Mubi, Nigeria.*
[3]*Department of Social Development, Adamawa State Polytechnic, Numan Campus, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author EY designed the study, performed the water quality index computations and provided all tables, wrote the protocol, and wrote the first draft of the manuscript. Authors SDY and IK designed the physicochemical tests methodologies and conducted laboratory and field tests as well as results analyses of the study. Authors EY and ANB managed the literature searches and wrote on the lake's water quality status and the implications as well as the concluding part of the paper. All authors read and approved the final manuscript.

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ABSTRACT

The suitability of *Goro Dong* (Lake) water for human consumption has been examined using the Weighted Arithmetic Water Quality Index Method. Water samples were collected from the lake in the month of March 2017 and subjected to standard physicochemical tests. Parameters used for the water quality analysis include pH, Electrical Conductivity, Total Hardness, Total Alkalinity, Total Dissolved Solids, Total Suspended Solids, Sodium, Magnesium, Calcium, Chlorides, Sulfates, Nitrates, Dissolved Oxygen and Biochemical Oxygen Demand. The drinking water standards

**Corresponding author: E-mail: ezekielyonnana@gmail.com;*

employed included those of World Health Organization (WHO), Nigeria Industrial Standard (NIS) and Indian Council of Medical Research (ICMR). Results revealed that the observed values of all the parameters were within the permissible limits provided by the employed standard agencies. However, the overall Water Quality Index (62.34) indicated that the water quality is poor and thus require minor treatments before drinking.

Keywords: Goro Dong (Lake); water quality index; physicochemical parameters; drinking water quality.

1. INTRODUCTION

Access to safe water is not only essential to human health but also a basic human right [1]. However, this right is far from being attained in most rural parts of sub-saharan Africa, owing to many factors, most of which are directly or indirectly associated with anthropogenic activities and climate change. This precarious state of safe water availability in the sub-saharan Africa have since been noted and documented by numerous concerned scholars and organizations [2,3,4]. Therefore the availability of water for usage by rural communities in the sub-Saharan African region goes far beyond the quantity level to much quality status with regards to human consumption, other domestic uses and recreation.

Despite both governmental and non-governmental efforts towards rural water supply through the construction of bore holes and hand-dug well in most communities in Northeastern Nigeria, statistics revealed that about 30.8% (in 2007) and 38.3% (in 2008) of the population of Adamawa State depended on Ponds/Lakes and Streams/Rivers as sources of water for drinking and cooking [5]. Recent field studies reaffirmed the persistent dependence of some Adamawa communities on Ponds/Lakes water for drinking and other domestic uses [6,7], most especially in dry seasons, when water scarcity emerges from shortages in the existing bore holes and hand dug wells.

Goro Dong (a fluviatile lake in Numan Local Government area of Adamawa State) is a life sustaining water source for domestic use, fishing and recreation among Kodomti, Shaforon, seasonal non-indigent fishermen and nomad communities with little or no attention to its water quality status. This informs the need for the current study with an aim of proffering meaningful recommendations towards a healthy management and sustainable use of the lake.

Water Quality Index (WQI) is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues [8,9,6]. The index aims at converting complex water quality data into understandable and meaningful piece of information for usage by concerned persons. The quality status of water for domestic use is based on numerous physical, chemical and biological parameters. However, adopting a water quality index on the basis of some important parameters can provided a simple indicator of water quality [10]. This forms the conceptual underpinning of the study.

2. MATERIALS AND METHODS

2.1 Study Area

The study area comprising of Goro Dong and its immediate environs lies between Latitudes 09°23'00"N and 09°33'00"N of the Equator and Between Longitudes 11°51'00"E and 12°50'00"E of the Greenwich Meridian (Fig. 1). It is situated on left bank floodplain of the River Benue course in Numan Local government Area of Adamawa State.

Geologically, the study area situated in the Yola arm of the Benue Rift, which is a section of the West African Rift system formed in the early cretaceous period [11,12]. The major geologic structure of the area is the Bima Sandstone formation, overlain by recent alluvial sediments and few zones of laterites and limestones on the fringes.

The area is characterized by the Aw climatic zone of Koppen's climatic classification, marked by wet and dry seasons controlled by the movement of the Inter-Tropical Convergence Zone [12]. The wet season lasts for about 5-6 months (May to October) with annual precipitation values 642 mm to 1407 mm. The dry season extends from November to May with February and March as the driest months. Mean Annual Temperatures range from 27.3°C to 30.7°C. While April and May are the hottest

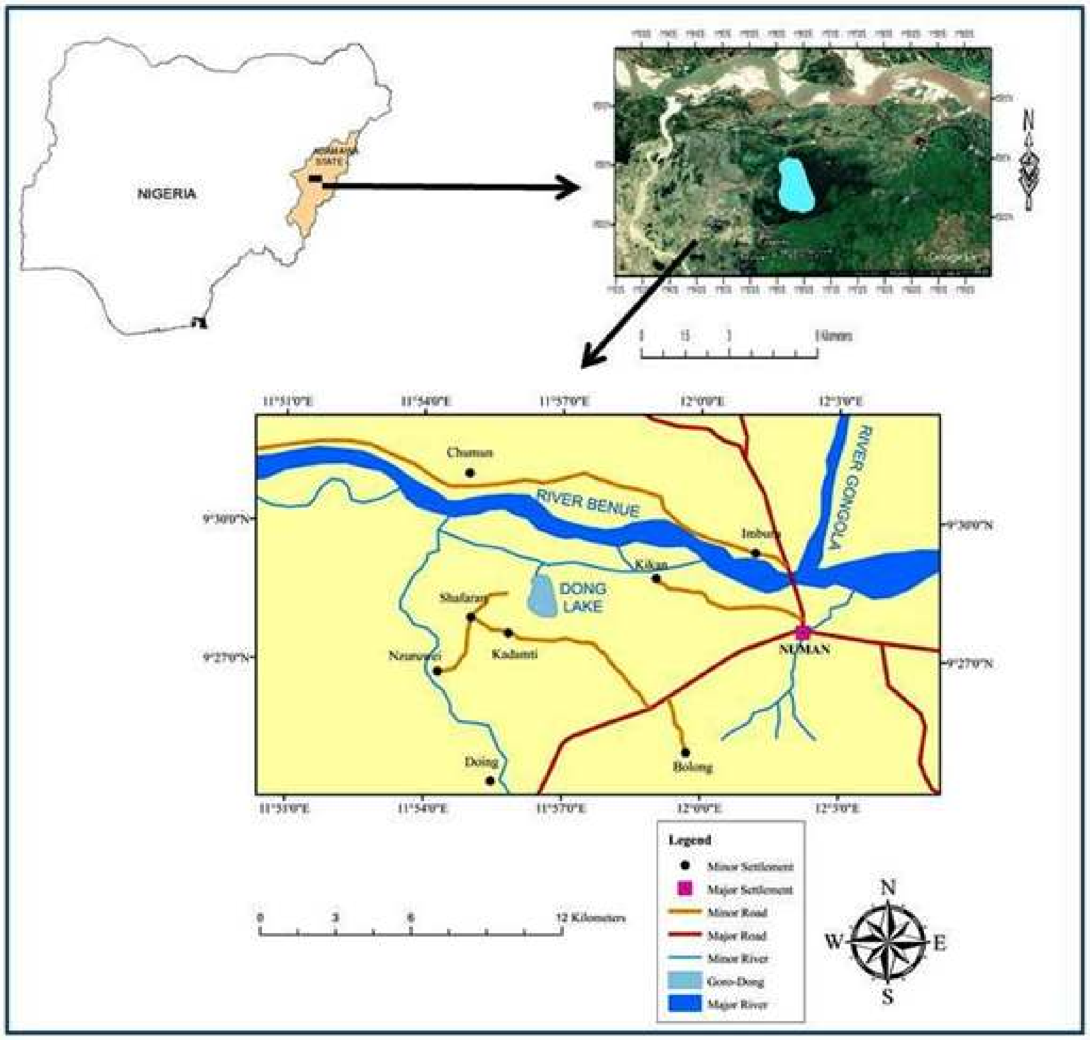

Fig. 1. The study area

months of the year, November and December make up the coolest months [13].

A larger proportion of the lake's water comes from seasonal inflow of River Benue during periods of high discharges (August to September) and rainfall. It is characterized by a Surface Area of 1.65 km^2 and a water volume of 1.98 mcm. The immediate human settlements in the vicinity of the lake are Kodomti, Shaforon and some seasonal fishermen and nomad camps.

The lake area and its littoral zone are dominated by sometropical arboreal plant species which include *Vachellia nilotica, Acacia albida, Tamarindus indica* (tamarin), *Zizipus spp and Prosopis spp*; vast species of Aquatic plant forms comprised of Emerged, Floating and Submerged Macrophytes and Phyto planktons (Alga. Spp). Common land use activities in the lake's vicinity are mainly crop cultivation and livestock rearing, beside fishing and recreation by members of nearby communities.

The study was carried out on water samples randomly collected from different points of the lake in dry season (March) 2017. This is because the lake mostly serves as a source of drinking water to nearby communities in dry seasons when the rains are gone and their wells and bore holes yield insufficient quantities.

2.2 Physicochemical Analysis

A total of nine (9) water samples collected from the lake at different locations and depths, homogenize to make a composite sample. The water samples collected were homogenize and store in iced cooled container and transported to laboratory for analysis based on the procedures described by [14,15] and [6]. All onsite and laboratory tests were conducted as per standard procedures. The elemental parameters (Sodium, Calcium, Magnesium, Manganese, Cadmium, Lead, Zinc, and Cobalt) were tested using Air Acetylene Flame Integrated Mode (Buck 210 Model) of Atomic Absorption Spectrophotometer (AAS). The physicochemical parameters (Total Alkalinity, Total Dissolved Solids, Total Hardness, Total Suspended Solids, Sulfates, Chlorides, Nitrates, Dissolved Oxygen - DO and Biochemical Oxygen Demand - BOD) were tested as per standard procedures using the scl-04 Model of Lamotte Water Analyzer, while pH and Electrical Conductivity were tested onsite using Model 3540 of Jenway pH/Electrical Conductivity Meter.

A total of 14 parameters were used for the water quality Index determination using the Weighted Arithmetic Water Quality Index Method. The choice of this method was based on its advantages as note by [9]. The analysis employed the use of drinking water standards provided by [1,16] and [17].

2.3 Water Quality Index Computation

In the calculation procedure, water quality rating (Qn) for each parameter was calculated using the following formula:

$$Qn = \frac{Vn - Vio}{Vs - Vio} \times 100 \quad (1)$$

Where; *Qn* is Water quality rating of each parameter

Vn is Observed value of water quality parameter obtained from laboratory analysis; *Vio* is Ideal value of water quality parameter as obtained from standard tables as zero (0) for all other parameters with the exception of pH and Dissolved Oxygen (DO) having 7.0 and 14.6mg/l respectively; and *Vs* is Standard permissible value of water quality parameter as recommended by the Standard Agencies.

The relative weight for each water quality parameter ($w_{n)}$ was then calculated as a value inversely proportional to recommended standard value (v_s) of the parameter i.e.

$$Wn = K/Vs \quad (2)$$

where *K* is Constant of proportionality expressed as;

$$K = \frac{1}{\sum \frac{1}{Vs}} \quad (3)$$

The Water Quality Index(*WQI*) was then calculated by aggregating the water quality rating with unit weight linearly, using the Weighted Arithmetic Index equation:

$$WQI = \frac{\sum QnWn}{\sum Wn} \quad (4)$$

Finally, the Water Quality Suitability for drinking was determined using the quality rating adopted from [18] and [9] as shown on Table 1.

Table 1. Water quality rating

WQI value	Water quality rating	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very Poor water quality	D
Above 100	Unsuitable for drinking purpose	E

Adopted from [18] and [9]

3. RESULTS AND DISCUSSION

The observed values of the all parameters analysed (*Vn*) and there corresponding recommended standard values (*Vs*) are presented on Table 2. Dissolved oxygen (DO) is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as the self-purification capacity- a major indicator of water quality [19]. In terms of water quality for human consumption, DO is an important determinant of water taste as well as odour [20,21]. Waters with saturated level of DO taste fresh to human palates [21]. The DO level (5.11 mg/L) of the study lake was found to be adequate in comparison with the permissible level (5.00 mg/L) as provided by [19]. This DO status of the lake was also found to be similar to those of other fluviatile lakes of the Upper Benue Valley Area of Adamawa State [6] but varied substantially from values obtained for River Iju in Ogun State Western Nigeria [22]. This is an indication that the lake water is of better taste and of less prone to algal growth.

Table 2. Standard and observed values of tested parameters

S/No	Parameter	Observed value (*Vn*)	Standard value (*Vs*)	Standard agency
1	pH	6.60	6.5-8.5	WHO/ NIS
2	E.C(μS/cm)	182.20	1000	NIS
3	Total Hardness(mg/L)	102.00	150	NIS
4	Total Alkalinity (mg/L)	80.00	120	ICMR
5	TDS (mg/L)	271.00	500	WHO/ NIS
6	TSS (mg/L)	5.50	500	NIS
7	Sodium (mg/L)	133.05	200	NIS
8	Magnesium(mg/L)	2.39	50	WHO
9	Calcium(mg/L)	2.56	75	WHO
10	Chlorides(mg/L)	120.00	250	NIS
11	Sulfates(mg/L)	8.31	100	NIS
12	Nitrates(mg/L)	7.21	50	NIS
13	Dissolved Oxygen(mg/L)	5.11	5	WHO
14	BOD(mg/L)	4.02	5	WHO

WHO = World Health Organization; NIS = Nigeria Industrial Standard; ICMR = Indian Council of Medical Research

Another key water quality parameter is the five-day Biological Oxygen demand (BOD) level. BOD is the measure of the oxygen required by bacteria and other microorganisms to break down organic matter in a water body [21]. Though not a direct measure of water pollution, a normal unpolluted or less polluted water body is expected to have a BOD value of less than 5.00 mg/L [19,21]. High BOD levels indicates decline in DO because the oxygen that is available in the water is being consumed by existing microorganisms in the water. The BOD value (4.02 mg/L) obtained from the study lake was less than 5.00 mg/L, indicating that the lake is not much affected by microbial pollution.

The amount of solids present in a water body is an important estimator of pollution load owing to the presence of both organic and inorganic contaminants. The higher the amount of solids in the water, the more contaminated the water may be not minding the sources. The total alkalinity, total hardness, calcium and magnesium contents of the lake showed no indication of anthropogenic input. The total hardness of the water (102 mg/L) was observed to be within the permissible limit (150 mg/L) of [23]. The value for Total Dissolved Solids (TDS) for the study lake was 271 mg/L, while that of Total Suspended Solids (TSS) was 5.50 mg/L; all within permissible limits (Table 2). A study by [24] showed the occurrence of high TSS in Asa River (Kwara state) while [25] also reported similar findings for Rivers Ona and Alaro in Ibadan. Such elevated values of TSS are capable of shielding harmful organisms in drinking water [26]. TSS could also act as a vector of nutrients such as phosphorus [27], and toxic compounds such as pesticides and herbicides from the land surface to the water body [28] leading to proliferation of phytoplankton in rivers. In surface water, TSS could cause drift in invertebrate population [29]. Results of this study clearly showed that the study lake (Goro Dong) lake is not much susceptible to diseases as compared with similar previous studies mentioned above. Besides, All heavy metals tested (Manganese, Lead, Cadmium, Zinc, Cobalt, Nickel and Copper) were beyond detection limits.

Even though levels of all the tested physicochemical parameters in the lake water were found to be within the permissible limits of the standard organizations used, the Weighted Arithmetic Water Quality Index computation (Table 3) indicated a poor water quality status for drinking, taking into consideration the combined effect of the tested parameters. The lake's water quality status may also be considered as moderate based on the grading on Table 1. This implies that the contamination status of the lake is mild and as such could be managed. Thus the quality level of the water could be improved by minor treatments before consumption. However, the lake water could be regarded as suitable for other domestic uses as bathing, washing, fishing and irrigation.

Table 3. Weighted arithmetic water quality index computations

S/No	Parameter	Observed value (V_n)	Standard value (V_s)	Unit weight (W_n)	Quality rating (Q_n)	W_nQ_n
1	pH	6.60	6.5-8.5	0.161	-0.267	-0.043
2	E.C	182.20	1000	0.001	18.22	0.018
3	Total Hardness	102.00	150	0.009	68.00	0.612
4	Total Alkalinity	80.00	120	0.011	66.70	0.734
5	TDS	271.00	500	0.003	54.20	0.163
6	TSS	5.50	500	0.003	1.10	0.003
7	Sodium	133.05	200	0.007	66.75	0.457
8	Magnesium	2.39	50	0.027	4.78	0.129
9	Calcium	2.56	75	0.018	3.41	0.061
10	Chlorides	120.00	250	0.005	48.00	0.240
11	Sulfates	8.31	100	0.014	8.31	0.116
12	Nitrates	7.21	50	0.027	14.42	0.389
13	Dissolved oxygen	5.11	5	0.274	98.85	27.08
14	BOD	4.02	5	0.274	80.4	22.03
				$\sum W_n$=0.834	$\sum Q_n$=532.873	$\sum W_nQ_n$=51.989 WQI=62.34 (Poor Water Quality)

4. CONCLUSION

Despite the finding that all the tested parameters fell within permissible limits of the Standard Agencies employed, the study lake was found to be slightly polluted by microbial activity as evident in high mean value BOD. Besides, the combined impact of the tested parameters as portrayed by the calculated Water Quality Index indicted a poor water quality that could be made consumable with light treatments such as boiling, sieving and slight chlorination. Findings of the study also imply that though the water quality is poor, users can use the lake water for domestic for domestic purposes (drinking, cooking bathing and washing) as well as fishing and farming are not likely exposed to severe public health risks. Therefore, proper conservation of the lake against contamination which may rise from excessive anthropogenic activities within its catchment area is recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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