Water Quality Index for the Evaluation of Water Quality from Different Source: A Case Study of Lafia

*** Ogah Halimat, Abdullahi Zainab Suleiman., Yusuf Gabriel**

Dept of Geography Federal University of Lafia, Nasarawa State

***Corresponding Author**

DOI: https://doi.org/10.51244/IJRSI.2025.120500170

Received: 24 April 2025; Accepted: 08 May 2025; Published: 21 June 2025

ABSTRACT

Water must be significantly free from dissolved solid, plant and animal waste and bacterial contaminants in order to be safe for human use. The Water Quality Index method was used to assess the water quality of several water sources (well and borehole) in the Lafia district of Nasarawa state. In order to determine if groundwater in the study region is suitable for residential use, the current inquiry was conducted to calculate the Water Quality Index. Numerous physico-chemical and biological data, including pH, chloride, sulphate, nitrate, calcium, feacal streptococcus, total coliform, and magnesium, were used to calculate WQI. The computed WQI result, which falls into the Good (Acceptable), Bad, and Very Bad (Rejected) classes, varies from 0 to 58.9 in one instance and from 0 to 98.0 in another, based on the empirical formulas for the groundwater samples. A distinct index range was produced by each parameter. Findings from the research revealed that all wells & borehole sampled have high faecal streptococcus above the recommended level for drinking water, thereby requiring the need for urgent public health intervention

Keywords: water quality index, physical, chemical and biological parameters.

INTRODUCTION

All living things need water, which is a vital natural resource. Humans, however, utilize water more than any other living thing for drinking, personal, household, industrial, and recreational purposes [1]. Energy generation, agriculture, and industry all depend on clean and consistent water supply. Water is essential to every environment and community on Earth for daily existence, sanitation, and hygiene. The demand for potable water for residential, agricultural, and industrial applications has rapidly expanded due to population growth.

The consequence effect of the circumstance is that some residents find other ways to get water, such as drilling wells or boreholes, while others who cannot afford it get water from water vendors that may not be of high quality [13]. Unsafe water is a global public health problem, placing persons at risk, plethora of diarrheal and other infections as well as chemical intoxication [6]. The majority of freshwater bodies worldwide are becoming contaminated, which reduces the water's potability [3].

Water quality is the term used to describe the physical, chemical and biological parameters of the water relating to its suitability for particular use [16]. Water Quality Index is an important technique for demarcating groundwater quality and its suitability for drinking purposes [2].

WQI is defined by [17] as an assessment of the physical, chemical, and biological characteristics of water in relation to its natural quality, human impacts, and intended uses. A mathematical formula is used to rate the water quality, thereby establishing whether the water is suitable for drinking and other household purposes.

According to [9], Horton originally created the index in 1965 to gauge the quality of water using the ten most often utilized water characteristics. Later, several specialists made changes to the approach. These indices made use of different types and numbers of water quality parameters. Each parameter has a weight assigned to it based on its own standards, which shows how important the parameter is and how it affects the index.

Based on a few water factors, the index gives a single value that represents the general quality of the water at a specific location and time. WQI turns a complicated dataset into information that is simply comprehensible and useful. The water quality grading system used in the WQI denotes how suitable water is for drinking [11]. The single value output of this index, derived from several parameters provides important information about water quality that is easily interpretable, even by lay people.

WQI, which synthesizes various available water quality data into an easily understandable format, provides a way to summarize overall water quality conditions that can be clearly communicated to policy makers [10]. [12]worked on the groundwater quality index using GIS, where they calculated the normalized sub-indices and then ranked them. Their study area was a few km², and the parameters they used only chemical parameters containing ions. The final index represented in percentages rather than values.

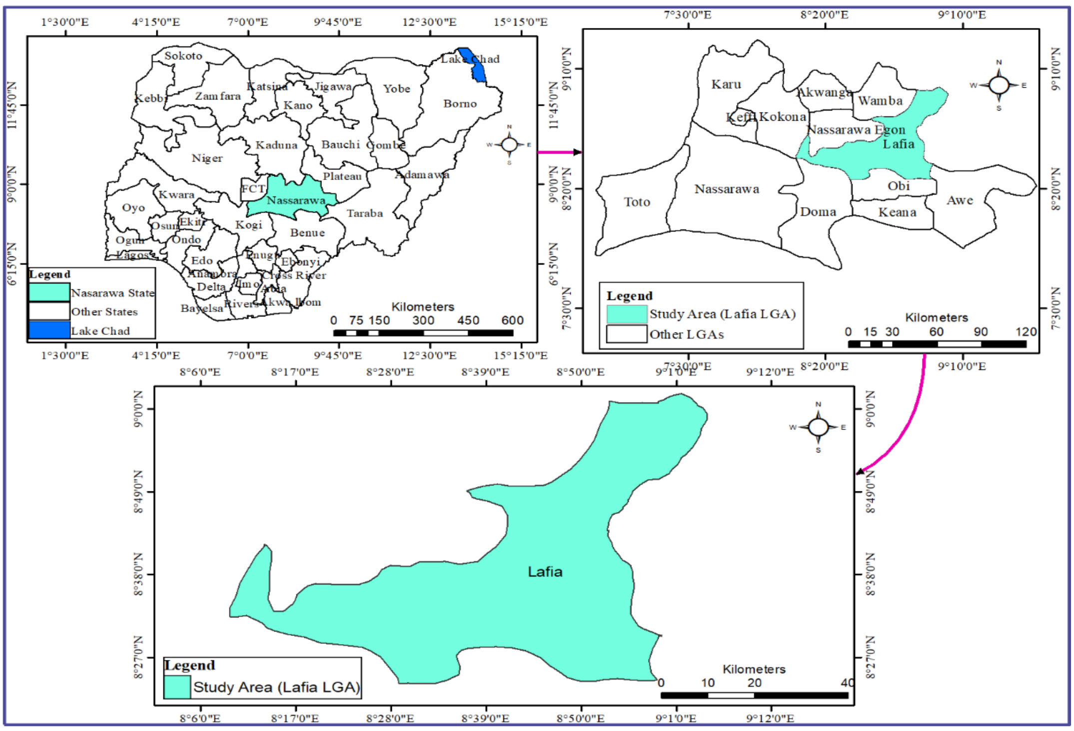
Furthermore, WQI makes it easier to compare various sample locations and occasions [5]. Therefore, a continuous periodical monitoring of water quality is necessary so that appropriate steps may be taken for water resource management practices [7]. The development of WQI is the main emphasis of this study, which is subsequently used to evaluate whether groundwater is suitable for residential use.

Description of the Study Area

Lafia is situated in central Nigeria. It is one of the 13 local government districts in the state of Nasarawa and serves as its capital. Lafia is located between Latitude $8^0$29'30"N and Longitude $8^0$31'0"E on a global scale [14]. It spans an area of around 18 km from north to south and 14 km from east to west, and it takes up about 258 km². According to [15], there are around 509,300 people living in the town. The town's geography is composed of gently sloping terrain that is typically below 400 meters, with a number of slopes down to the larger Benue plain.

The soil is predominantly sandy loam [8]. The vegetation type is guinea savanna, which is distinguished by its irregular canopy. A wet season and a dry season are its two distinct seasons [4]. Figure 1 depicts the location of Nasarawa on the maps of Nigeria and lafia on the map of Nasarawa.

Figure 1: Map showing the study area



Source: digitize and map out by Zainab.

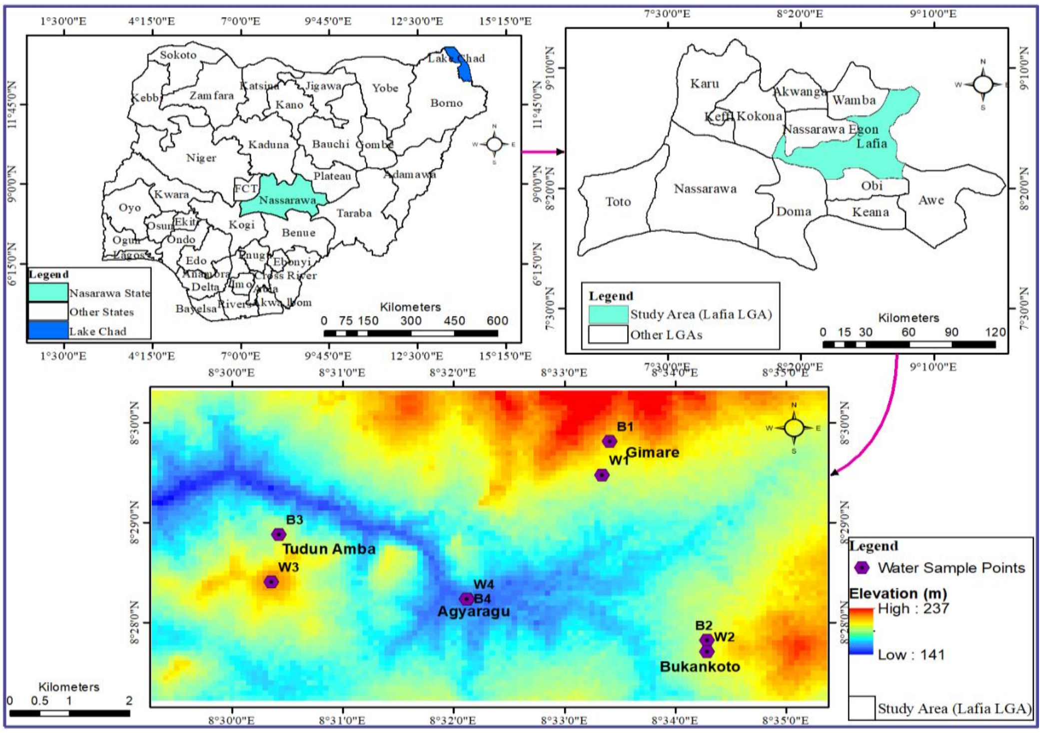
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue V May 2025

MATERIALS AND METHODS

In order to see the suitability of groundwater for domestic use in Lafia district, we therefore make use of the water quality index. WQI is considered as the most effective method of measuring water quality. A number of water quality parameters are included in a mathematical equation to rate water quality, determining the suitability of water for drinking and other domestic use. The primary data of all physico-chemical and biological parameters were collected and delivered within 48hrs of collection to federal ministry of water resources for laboratory analysis of the sample. Two sample were collected each, from different sources in the following rural areas of lafia (gimara, bukan koto, tudun amba and agyaragu tofa). Making a total of eight (8) sample, 4 from boreholes and 4 from hand dug wells. GPS was used to record the locations of the various water spots. The data generated were used to calculate water quality index (WQI). The relative weighted method was used for the calculation of the index value in this study.

RESULTS

Figure: 2. Map of the study area showing sampling points



Source: digitize and map out by Zainab.

Table 1: GPS location of the samples

No of sample	Ground position system (GPS)
Borehole 1	08^{0}29’810”N 008^{0}33’409”E
Borehole 2	08^{0}27’826”N 008^{0}34’287”E
Borehole 3	08^{0}28’883”N 008^{0}30’425”E
Borehole 4	08^{0}28’236”N 008^{0},32.123”E
Well 1	08^{0}29’475”N 008^{0}33’341”E
Well 2	08^{0}27’710”N 008^{0}34’289”E

Well 3	08^{0}28’406”N 008^{0}30’355”E
Well 4	08^{0}28’238”N 008^{0}32’120”E

Table 2: Statistical summary of physico-chemical and biological parameters of samples in the study area

S/N	PARAMETERS	Bh1	Bh2	Bh3	Bh4	W1	W2	W3	W4	NSDWQ/WHO
1	pH	7.69	7.85	7.93	7.73	7.62	8.25	8.34	7.23	6.5 – 8.5
2	TDS	742	758	683	353	459	291	283	351	500mg/l
3	Calcium	18.1	22.0	16.0	15.2	31.3	63.4	29.4	12.8	N/A
4	Nitrate	23.8	40.3	29.4	52.0	57.1	18.0	38.0	39.0	50
5	Turbidity	1.5	2.0	1.9	3.0	3.9	4.0	2.3	3.8	5NTU
6	Sulphate (mg/L)	59.0	26.0	68.0	43.0	70.0	99.3	43.2	63.4	100
7	Chloride (mg/L)	41.3	33.1	181	85.1	69.2	141	16.3	8.0	250
8	Magnesium	5.13	18.1	7.81	20.2	19.0	16.2	12.0	14.2	20
9	Fluoride (mg/L)	0.06	1.38	1.51	0.13	0.21	0.05	0.02	1.52	1.50
10	Total Coliform	11.0	10	6.0	2.0	14.0	5.0	9.0	6.0	10
11	Faecal streptococcus	100	163	87	22	144	0.1	120	56	0

Source: Field and laboratory analysis

Calculation of WQI

The WQI for the research region is determined using the parameter standard limit by Nigeria Standard for Drinking Water Quality / WHO, which is shown below. The WQI was calculated using eleven physical, chemical, and biological characteristics. Weights ranging from 1 to 5 are assigned based on the parameter values. Weight 1 is assigned if the gap between the value and the allowed value range is small (i.e if the figure between the value and the recommended standard limit after finding the difference is small then a weight of 1 is given), and weight 5 is assigned if the difference is large. The Weight (w) has been assigned according to its concentration and relative importance in the overall quality of water for drinking purposes and other domestic use. Additionally, the relative weight has been computed and is displayed in table 3 below.

Table 3. Water Quality Index

Physical, chemical and biological parameters	Standard limit NSDWQ/WHO	Weight given (Wi)	Relative weight (RW)
Turbidity (NTU)	5	1	0.0911
ph.	6.5 – 8.5	3	0.030
TDS (mg/l)	500	5	0.152

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue V May 2025

Calcium (mg/l)	N/A	0	0
Chloride (mg/l)	250	5	0.152
Nitrate (mg/l)	50	1	0.030
Fluoride (mg/l)	1.50	5	0.152
Magnesium (mg/l)	20	2	0.061
Sulfate (mg/l)	100	1	0.030
Total coliform cfu/1000m	0	5	0.152
Faecal streptococcus	0	5	0.152
		∑33	

RW = Wi/ $\sum^{n}$ Wi---1

RW = 3/33 = 0.0911

Where: RW = Relative Weight

Wi = weight given Ci = concentration of the parameters Qrs = quality rating scale

Si = sub index

Table 4. Displaying the parameters Concentration, quality rating scale and sub-index

Physical, chemical and biological parameters	Concentration of parameters (C_i)	Quality rating scale (Q_{rs})	Sub index (S_i)
Turbidity (NTU)	2.8	56.0	16.80
ph.	7.83	97.9	8.9187
TDS (mg/l)	490	98	14.8960
Calcium (mg/l)	26.025	0	0
Chloride (mg/l)	71.875	28.8	4.3776
Nitrate (mg/l)	37.2	74.4	2.2320
Fluoride (mg/l)	0.61	40.7	6.1864
Magnesium (mg/l)	14.08	70.4	4.2944
Sulphate (mg/l)	58.9875	58.9	1.7670
Total coliform cfu/1000ml	7.875	78.75	11.97
Faecal streptococcus cfu/1000ml	86.5125	0	0
			∑71.442

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue V May 2025

$Qrs = C_i / S \times 100$ -- 2

$Qrs = 2.8/5.0 = 0.56 \times 100 = 56.0$

$Si = Rw \times Qrs$ --- 3

$Si = 0.030 \times 56.0 = 16.80$

$Qi = \sum Si$ --- 4

$Qi = 71.442$

$QI = \sum Qi$ --- 5

Table 5. Show the Water quality index classification

Water quality index level	WQI status
0 – 25	Excellent water quality
25 – 50	Good water quality
51 – 75	Poor water quality
76 – 100	Very poor water quality
>100	Unsuitable for drinking

DISCUSSION

The World Health Organization (WHO) and individual countries have worked hard to ensure that certain standards of criteria are supplied in order to ensure the safety of water that people consume, considering the high number of diseases in the world that are brought on by contaminated water. The geological structure, urbanization and use of fertilizer in the agricultural field played a significant role in affecting water quality. Settlement pattern and land use practices in study area leaves inhabitants with limited distance between wells and sanitary structures as such; wells are often located too close to sanitation systems in households without taking water quality into cognizance. Asides the distance between wells and sewage pit and topography, other factors such as seasonal variation, inadequate hygiene and sanitation, well disinfection and well characteristics play significant role in the level of well water contamination. Based on physical criteria, the research determined the safety level of select wells and boreholes in the Lafia district. The turbidity of all wells and boreholes fell within the 5NTU National Standard limit. The wells' maximum turbidity range is 4.0, whereas the borehole's is 3.0. The borehole's lowest range is 1.5, whereas the well's is 2.3. All of the wells and boreholes had pH values between 6.5 and 8.5, which is the WHO's recommended range. With the exception of boreholes 1, 2, and 3, which surpass the limit with numbers 742, 758, and 683, respectively, all wells and boreholes fall under the limit for total dissolved solids.

The biological parameters of the study which are total coli form *and Feacal strep*, have been identified to be of high level in various boreholes & wells. A total coli form of WHO is given as 10. Looking at the analysis, all the wells & borehole analyzed are within the Nigeria standard limit. Except for borehole 1 and well 2 which has the following value 11 and 14.

The analysis gives the *feacal streptococcus* of all the samples to have exceeded the NSDWQ & WHO Standard which is 0. High value of Total dissolved solid in groundwater are generally not harmful to human beings, but high absorption of these may affect person who are suffering from kidney and heart diseases. Water containing high solid may cause laxative or constipation effects. High level of TDS are caused due to the presence of potassium, chloride, sodium and toxic ions in larger amounts, which are also observed in BH1 with the figure 742, BH2 with 758, BH3 with 683. It is also undesirable to drink as it may taste salty, metallic or bitter.

CONCLUSION AND RECOMMENDATION

The calculated WQI from the empirical formulas for the groundwater samples range from 0 to 58.9 in one case, were Bh4 has 28.0 and in another case the value ranges from 0 to 98.0 were W1 has 98.0 and falls within the Good (Acceptable), Bad and Very Bad (Rejected) class. Every parameter generated a different index range. Findings from the research revealed that all wells & borehole sampled have high faecal streptococcus above the recommended level for drinking water, thereby requiring the need for urgent public health intervention. Alongside, there is need to increase awareness of the community towards the dangers associated with the use of contaminated water; the danger in constructing septic tanks near water sources and vice versa and treatment of water by boiling and filtering before use for drinking, cooking and washing. In addition to this, there should be restrictions on the free ranging domestic animals and other domestic solid wastes which are dumped around the house; which could be possible sources of bacteria pollution of the hand dug wells and borehole. Preference should be given to water protection through well monitoring and routine analysis of well water samples over the sporadic campaigns against outbreak waterborne infections. Change assessment studies should also be conducted to evaluate the trend of the groundwater pollution over time as waterborne diseases could continue to be a health problem in study sites if appropriate measures are not taken.

REFERENCES

1. Amit Kumar Mandal, and SutapaMukhopadhyay. (2018). Assessment of Suitability of Groundwater for Human Consumption in Rampurhat Subdivision of Birbhum District, West Bengal, India. (Volume 5) ISSUE 4/Oct- Dec. 2018. e/ssn 2348-1269, "International Journal of Research and Analytical Reviews.
2. Awachat Ankita R. (2017). Ground Water Quality Assessment through WQIs.International Journal of Engineering Research and Technology. ISSN 0974-3154 Volume 10, Number 1 (2017) © International Research Publication House http://www.irphouse.com
3. Arslan H (2017) Determination of temporal and spatial variability of groundwater irrigation Quality using geostatistical techniques on the coastal aquifer of Çarşamba Plain, Turkey, From 1990 to 2012. Environ Earth Sci 76:38
4. Carter, N., (2018). Commercialization of the major soil unit of Nasarawa state. Research Project, Nigeria institute of social and economic research Ibadan, Nigeria.
5. Deepa, S., Venkateswaran, S., (2018). Appraisal of groundwater quality in upper Manimuktha sub Basin, Vellar River, Tamil Nadu, India by using Water Quality Index (WQI) and multivariate statistical techniques. Model. Earth. Syst. Environ. 4, 1165-1180. https://doi.org/10.1007/s40808-018-0468-3.
6. Hughes, J. M. and Koplan, J. P. (2017). Saving Lives through Global Safe Water. Journal Of Emerging Infectious Diseases, 11(10): 1636-1637.
7. Kant, N., Singh, PK., Kumar, B., (2018). Hydrogeochemical Characterization and Groundwater Quality Of Jamshedpur Urban Agglomeration in Precambrian Terrain, Eastern India. J. Geol. Soc. India 92, 67-75. https://doi.org/10.1007/s12594-018-0954-2.
8. Kassim Abayomi Abiola and Nasiru Idris Medugu, (2016). Laterite Soil of Lafia, Nasarawa State,Nigeria International Journal of Trend in Research and Development, Volume 3(3), ISSN: 2394-9333 www.ijtrd.com
9. Mukesh Kumar Bind and Rolee Kanchan (2020). Assessing Groundwater Quality Using Geospatial Technology: A Case Study of Surat District, Gujarat, India. Journal of Global Resources Volume 6 (02) 01-19. Dio.org/10.46587/JGR.2020, V06i02.001.
10. Md. Galal Uddin, Stephen Nash, Agnieszka I. Olbert (2021). A review of water quality index models and Their use for assessing surface water quality. Journal homepage: www.elsevier.com/locate/ecolind vol.122 March 2021, 107218
11. Ruth Olubukola Ajoke Adelagun, Emmanuel Edet Etim and Oko Emmanuel Godwin (2021). Application of Water Quality Index for the Assessment of Water from Different Sources in Nigeria. Books > Promising Techniques for Wastewater Treatment and Water Quality Assessment, OPEN ACCESS PEER-REVIEWED CHAPTER, DOI: 10.5772/intechopen.98696 PUBLISHED 01

December 2021, ISBN978-1-83881-901-9 PRINT ISBN978-1-83881-900-2. EBOOK (PDF) ISBN978-1-83881-902-6.PAGES458. https://www.intechopen.com/books/9921

12. Samir Boudibi, and Almería, Bachir Sakaa (2019). Groundwater Quality Assessment Using Gis, Ordinary Kriging and Wqi in an Arid Area. International Journal of Sciences and Research, Vol. 75 | No. 12/1 | Dec 2019 https://www.researchgate.net/publication/338244055. DOI: 10.21506/j.ponte.2019.
13. Zainab, A.S., (2021) Geospatial Analysis of Groundwater Quality in some Selected Rural Areas of Lafia, Nasarawa State, Nigeria. Fulafia journal of social science (FJSS), 4(2): 59-68, ISSN: 2579-0641groundwater Quality Assessment Using Gis, Ordinary Kriging And Wqi In An Arid Area Groundwater Quality Assessment Using Gis, Ordinary Kriging And Wqi In An Arid Area
14. https://latitude.to/map/ng/nigeria/cities/lafia
15. www.geodatos.net/en/coordinate/nigeria/lafia
16. https://www.citypopulation.de>en>nigeria>admin>nasarawa.
17. https://testbook.com>civil-engineering>water...
18. https://link.springer.com>article