Bima Journal of Science and Technology, Vol. 8(1B) Apr, 2024 ISSN: 2536-6041

DOI: 10.56892/bima.v8i1.625

An Assessment of Groundwater Quality of Ashaka and Environs, Gombe, North Eastern Nigeria, Using Water Quality Index Technique

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ABSTRACT

This study assesses the quality of the groundwater in Ashaka and environs using the Water Quality Index (WQI) with a view of determining the suitability of the water for public use.. WQI is a technique that uses numbers to portray the quality of water of a given area within a given time based on the level of concentration of selected water quality parameters. This research considered fifteen (15) parameters, including pH, TH, EC, TDS, Mg^{+2}, Ca^{+2}, K^{+}, Na^{+}, SO_4^{-2}, Fe^{2+}, HCO_3^{-}, Cl^{-}, NO_3^{-}, PO_4^{-}, and F^{-}, for the computation of the WQI. Fifty water samples were utilized for the WQI and the values were in the range of 34.78 to 820.76, with an average of 122.40. Fourteen percent (7 samples) of the samples exhibited excellent water quality, Thirty-six percent (18 samples) were classified as good quality water, Forty-four percent (22 samples) were categorized as poor quality water, Four percent (2 samples) were identified as very poor quality water, and Two percent (1 sample) were deemed unfit for consumption. the good water quality are found around northern part where as the poor quality water are mostly concentrated at the southern portion of the study area. The poor WQI observed in the area can be a result of high levels of TDS, and elevated concentrations of Magnesium, Sodium, Potassium, Chloride, Sulphate, Nitrate, and TH, exceeding the WHO recommended values for drinking water. The presence of these ions in high concentrations could be a result of applications of fertilizer for agricultural activities and limestone blasting for industrial activities.

Keywords: Groundwater quality, Assessment, WQI, Ashaka and Gombe

INTRODUCTION

Water is a crucial need required by all living thing on the earth and is essential for sustaining life. The increasing growing of the world population resulted to the pressing needs of safe water worldwide (Dos Santos *et al.,* 2017; Rahman *et al.,* 2020). These high needs challenged researchers to be more exhilarated to advance new models of water quality prediction (Kwami 2019a, Uddin *et al.,* 2021). Groundwater represents the most widely used source of water for domestic, agricultural and industrial purposes worldwide (Mukkafa *et al.,* 2019b; Kwami 2019a Pal *et al.,* 2022). It is chiefly sourced from precipitation which penetrated down through soil and subsoil to geologic materials. Being a significant component of the water cycle and source of water for drinking, safe groundwater becomes a concern under an enormous pressure in the world (Ahmed *et al.,* 2019; Kwami *et al.,* 2018; Saha *et al.,* 2020). Hence, evaluating water quality is of paramount important.

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The quality of Groundwater is largely dependents on its chemical constituents (Wadie and Abduljalil, 2010, Kwami *et al.,* 2019c) which is altered through natural and anthropogenic activities. Open waste disposal practices and industrial activities in Nigeria affected the readiness and quality of groundwater mainly in urban areas (Kwami *et al.,* 2023). This necessitates the needs to undertake research for proper identification of safe water sources in the country. According to Word Health Organization, most human diseases are caused by consuming unsafe water. Restoring quality of groundwater once it is contaminated from the source is a very difficult task. It is therefore very vital to monitor groundwater quality regularly and to strategize ways of protecting it from contamination.

WQI is a technique that defines overall quality of water at a certain time and location by a single number that is coherent and usable by the public, considering several water quality parameters (Kwami *et al.,* 2018). This concept was first proposed by Horten, 1965, and was adopted by many recent researchers (Kwami *et al.,* 2018, Mukkafa *et al.,* 2019b, Kouadri *et al.,* 2021, Yusuf *et al.,* 2022).

Whilst very little information on groundwater quality of Ashaka and the surrounding areas exist there is a strong need to evaluate its suitability for domestic used. This study tends to provide a detail baseline information regarding groundwater quality for human use, and aid policy makers and government for effective planning, monitoring and assessment to certify sustainable exploitation of water resource.

Study Area

Ashaka and surrounding areas is located in Funakaye Local Government Area (LGA) of Gombe State, and is defined by longitude $11^0$25'E to $11^0$32'E and latitude $10^0$50'N to $11^0$00'N (Figure 1). It is about l40km North of Gombe city and can be accessed via Gombe-Bajoga-Ashaka road. It covers an area of about 25km^2. Tributaries of River Gongola flow and drain the study area following the topography of the area, along the NE-SW trend. High relief rising abruptly to about 255m elevation is observed towards the northern portion of the area, (Bassey *et al.,* 2006). This forms a very steep scarp as exemplified in the Gongila Village, from where it slopes gently southward (Bassey *et al.,* 2006). The climate of the area is characterized as sub-Sudan zone (Obaje, 2009) having two seasons in a year, with dry season starting November and ends in March, while Rainy season starts in April and lapse in October.

Geology of the Study Area

The area is underlained by sedimentary rocks of Bima and Pindiga Formations (Figure 2). The Bima Formation is the oldest rock exposed in the area covering the Northern part of the area. It is identified with low laying topography and is separated from the overlying Pindiga Formation by a thin ferruginous crust without the transitional Yolde Formation. This lithofacies is characterized by reddish sandstone with thin clay intercalations. The Pindiga Formation in the study area is represented by two sub-members namely; Kanawa and Dumbulwa Members. Kanawa member is characterized by limestone and clay intercalation and a thick clay unit. The lower parts of this members shows limestone of about 4 to 7m thick while the upper part is predominantly thick clay unit of nearly 30m. The Dumbulwa member is the dominant rock in the area which is represented by sandstone unit having intercalation of lateral extensive clay and sandstone.

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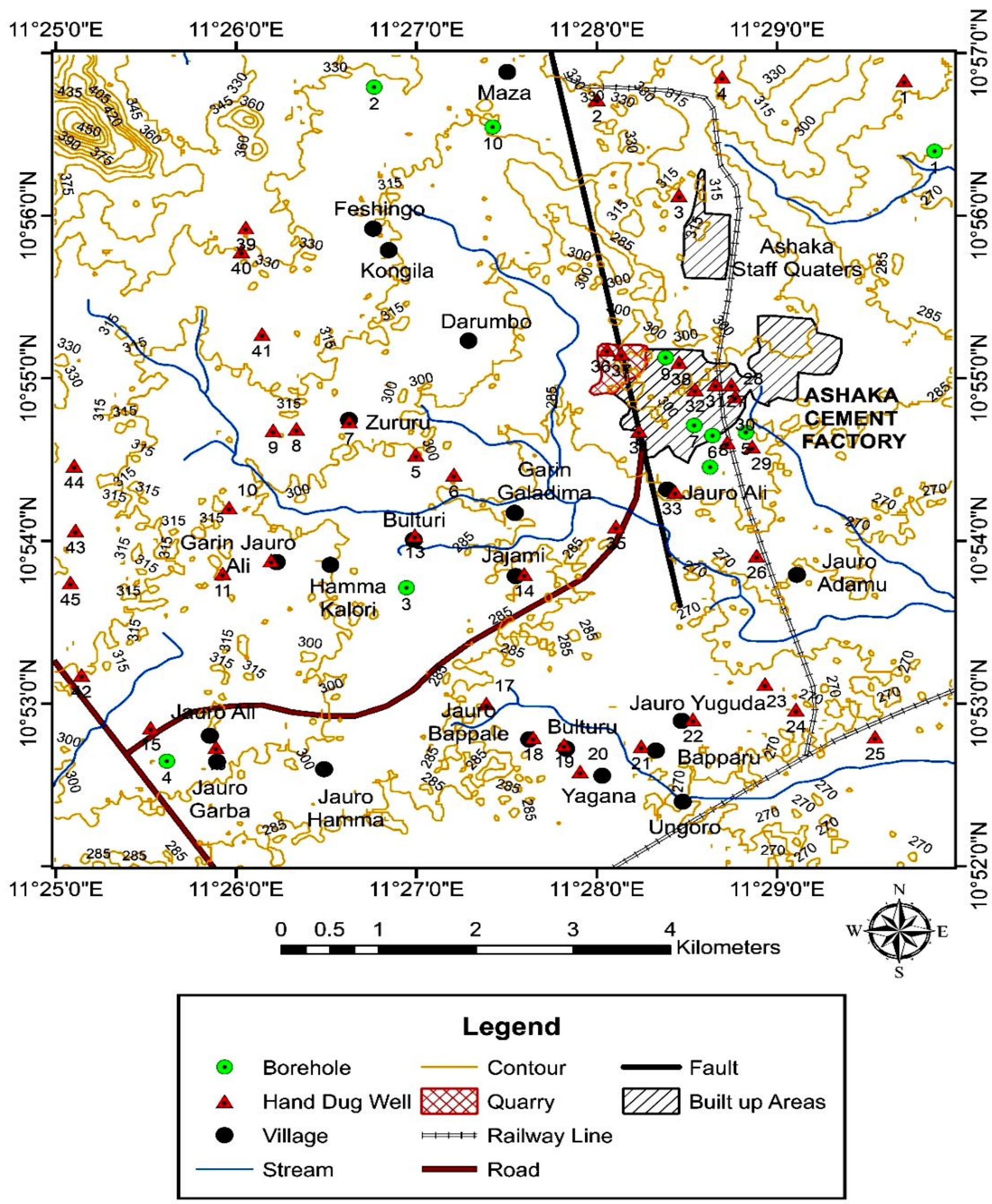

Figure 1: Location map of the study area showing groundwater sampling points.

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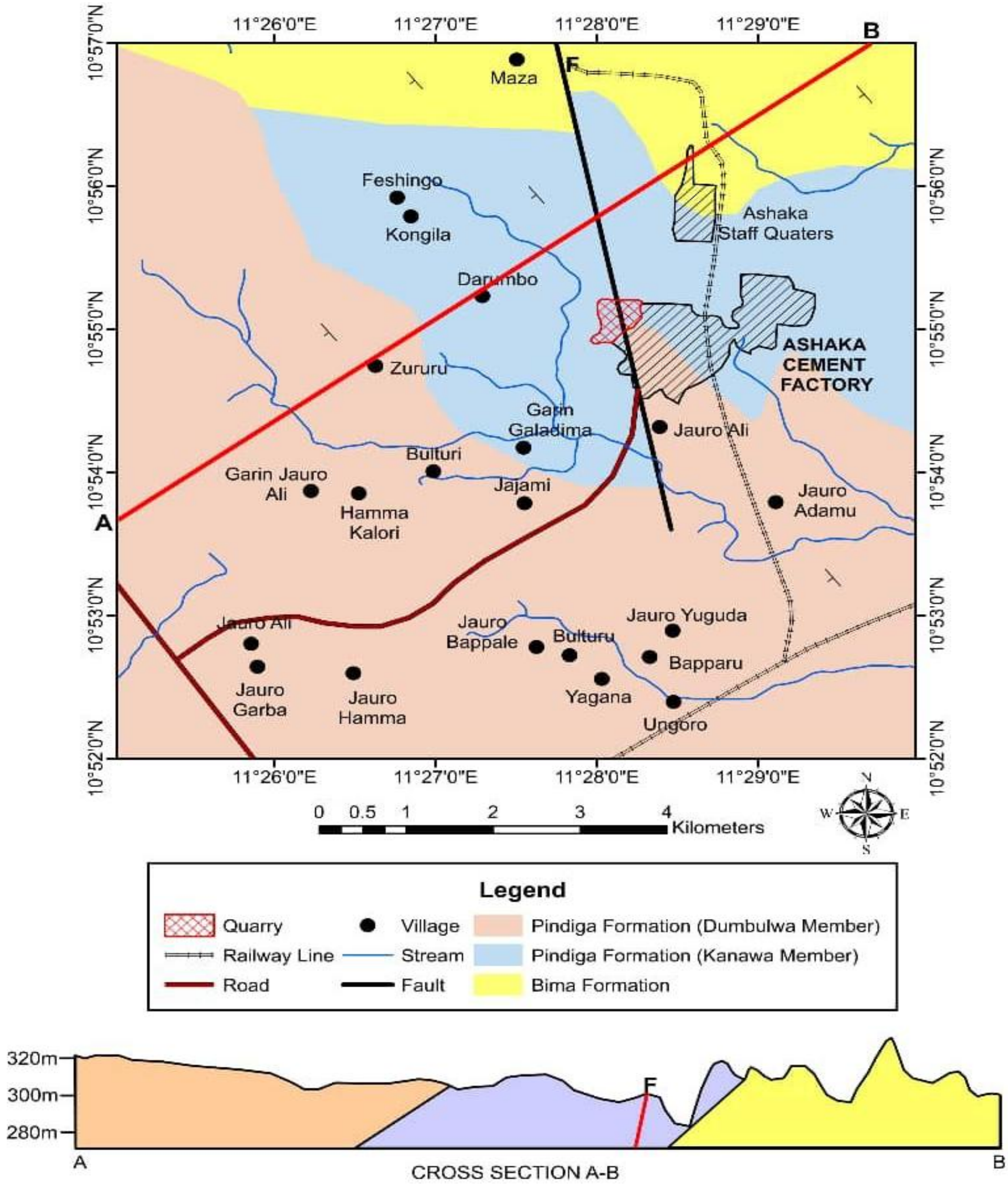

Figure 1: Geological map of the study area.

METHODOLOGY

A total of 50 groundwater samples were collected from boreholes and open wells (Fig. 1) in containers after cleaning the container three times using the representative groundwater samples following standard methods. The altitude readings sampled wells and boreholes were taken using GPS (Model Garmin eTrex HC Series). Immediately following water sampling, physical parameters were measured (Pen type PH and temperature meter (Model CT6021A) was used to measure pH and temperature, conductivity was measured using Pen Conductivity meter (Model CT 3030), hand held turbidity meter (Model HAUX 2100Q) was used to measure turbidity, and Total Dissolved Solids (TDS) was measured using Pen TDS Meters (Model 21000). In order to keep ions in a

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solution the water samples collected a nitric acid was added in the water and were later analyzed for major cations and anions in Biochemistry Laboratory of Gombe State University. All other parameters were determined in the laboratory using Atomic Absorbtion Spectrometer following standards procedures.

Water Quality Index (WQI)

Water quality index can be defined as a score that reflects the combined influence of many water quality parameters on the general quality of water (Tiwari and Manzoor, 1988). The WQI is computed to gauge the fitness of groundwater for drinking purposes. WQI offers a single number (represented by grade) that prompt overall quality of water at a certain time and location that is comprehensible and usable by the public, considering several water quality parameters. The WQI was computed in four steps as follows:

Firstly, all important parameter considered for the calculations are assigned a weight (wi) to a maximum of 5 on the bases of their relative importance in the general quality of water for drinking purposes. Parameters like TDS, Chloride, Nitrate and Sulphate were assigned the highest number (i.e 5) due to their major importance in water quality assessment (Srinivasamoorthy *et al*., 2008). Some parameters that play an insignificant role in the water quality assessment are given the minimum weight of 1. Other parameters are assigned other weight values between 1 and 5 subject to their importance in the overall water quality for drinking purposes.

Secondly, the relative weight (Wi) of each parameter was determined from equation below (Tiwari and Manzoor, 1988):

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \quad (1)$$

(Where, Wi is relative weight, wi is weight of the parameter and n is total number of parameters).

Thirdly, a quality rating scale (Qi) of the parameter is calculated by dividing its concentration Ci by its respective WHO standard Si of drinking water and multiplied by 100 as shown below:

$$Qi = (Ci / Si) \times 100 \quad (2)$$

In the fourth step, the relative weight Wi is multiplied by the Quality rating Qi to get Sub index Sli of the ith parameters as shown beow:

$$SIi = Wi \times Qi \quad (3)$$

The submission of the sub index will give the overall water quality index (WQI) of each water samples:

$$WQI = \Sigma SIi \quad (4)$$

Computed WQI values are usually classified into five categories as presented in table 1. The spatial distribution map of the water quality index was plotted using surfer 13

Table 1: Water quality classification based on WQI value (Ramakrishnaiah *et al.,* 2009).

WQI Values	Rating
< 50	Excellent Water
50.1-100	Good Quality Water
100.1-200	Poor Quality Water
,h200.1-300	Very Poor Quality Water
>300	Water Unfit for drinking

RESULTS AND DISCUSSION

Geochemical Characteristics of Groundwater

Table 2 contains the values of physico-chemical results of groundwater from the study area. Based on the mean values of the chemical parameters the order of abundance of the cations concentration is Ca^{2+}>Mg^{2+}>K^{+} >Na^{+} while those of the anions are HCO_3^{-}>SO_4^{2-}>Cl^{-}>CO_3^{2-}. The results indicate that temperature ranged from 20.4°C to 27.2°C with average of 25.85°C and standard deviation of 1.48°C. pH in the area ranges from 5.81 to 8.1 with average value of 6.53 which indicate

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moderately acidic to neutral water (Ogunribido and Henry, 2018). Electrical Conductivity (EC) in the study area ranged from 189 µs/cm to 369 µs/cm with a mean of 286.92µs/cm and thus indicating less mineralized water (Ogunribido and Henry, 2108). Total Hardness (TH) was between 46.62mg/l and 73.12mg/l (as $CaCO_3$), with average of 59.93mg/l (as $CaCO_3$), thus indicating soft to moderately hard water. Total Dissolved Solids (TDS) in the area ranged from 110mg/l to 251mg/l with average of 188.40mg/l and be regarded as fresh water (Fetter 1990). Turbidity in the area ranged from 0.005 to 1.053 with average of 0.356 and standard deviation of 0.359. Calcium (Ca^{2+}) concentration in the groundwater in the study area is between 30.1mg/l and 53mg/l with average of 40.64mg/l and standard deviation of 5.07mg/l. Magnesium (Mg^{2+}) ranged from 7.49 mg/l to 31.27 mg/l with average of 18.88mg/l. Magnesium is an important contributor to water hardness. The sources of magnesium in natural water are dolomites and mafic minerals in rocks. Sodium (Na^{+}) in the study area ranged from 0.78mg/l to 2.93mg/l with average of 1.43mg/l. Potassium (K^{+}) ranged from 4.2mg/l to 13.1mg/l with average of 6.81mg/l. Sulphate (SO_4^{2-}) ranged from 23.42mg/l to 29.66mg/l with average of 27.002mg/l. Chloride (Cl^{-}) in the area was between 14.49mg/l and 30mg/l with average of 20.81mg/l. Nitrate (NO_3^{-}) ranged from 7.58mg/l to 38.42mg/l with average of 14.98mg/l. Bicarbonate (HCO_3^{-}) in the area ranged from 90mg/l to 241mg/l with a mean of 166.83mg/l. Carbonate (CO_3^{2-}) concentrations in all the water samples are extremely low (0mg/l to 3.2mg/l) Fluoride (F^{-}) range from 0.33mg/l to 0.92mg/l with mean of 0.59mg/l. Iron (Fe^{2+}) range from 0.22mg/l to 1.02mg/l with mean of 0.53mg/l, Copper (Cu^{2+}) (0.2mg/l to 1.2mg/l, mean of 0.757mg/l).

Table 2: Physico-Chemical Constituents of groundwater samples in the Study Area

Parameters	Minimum	Maximum	Mean	Standard Deviation	WHO Standard (2015)
Temp (°C)	26.9	27.7	27.43	1.484418721	30-35
pH	5.04	7.52	6.35	0.621918329	6.5-8.5
EC (µs/cm)	83.4	6420	805.68	43.26277228	500
TDS (mg/l)	41.2	3260	403.55	37.01182911	500
Turbidity (NTU)	4.27	50.91	16.55	0.359512468	0-5
TH mg/l	13.08	1484.4	393.93	8.046910108	500
CO_3^{2-}	0	0	0	0.825731587	120
HCO_3^{2-}	7.18	52.05	10.87	103.3791064	500
Ca^{2+}	1.27	383.96	54.17	5.070186926	75
K^{+}	2.21	586.55	69.91	2.395990324	12
Cu^{2+}	0.0011	1.06	0.063	0.247295906	0-1.5
Na^{2+}	71.17	5023	596.15	1.263195196	200
Mg^{2+}	2.52	320.36	65.66	6.559055134	50
Fe^{2+}	0.0013	0.82	0.058	0.199804737	0.3
SO_4^{2-}	70.67	1841.75	381.65	381.65	250
F	0.02	3.68	0.5154	0.15661587	1.5
Cl^{-}	78.56	6372.66	812.028	3.612733738	250
NO_3^{2-}	5.03	76.22	26.93	6.064048624	50
Mn^{2-}				0.01026643	0-0.4
PO_4^{2+}	0.87	71.59	10.82	0.199006615	0-10

Water Quality for Drinking (Water Quality Index)

The Water Quality Index (WQI) was calculated to evaluate the suitability of groundwater for drinking purposes, and also used to access the influence of natural and anthropogenic activities on groundwater quality. The values of WQI in the study area ranges from 34.78 to 820.76 with an average

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of 122.40 (Table 10). Statistical presentation of the WQI from the fifty groundwater samples in the area revealed that fourteen (14%) of the samples are excellent quality water, Thirty Six percent (36%) are of good quality water, forty four percent (44%) depicted poor quality water, Four percent (4%) represent very poor-quality water and Two percent (2%) are unfit for drinking (Fig 3). The map of the study area showing spatial distribution of WQI (Fig 3) shows that Good to Excellent quality water are found around Hamma Kalorin, Feshingo Bawa, Gongila, Jajami, and Ashaka estate vilages which are largely concentrated at the Northern and towards the south western portions of the study area. Poor to Very Poor and unfit water are observed around the central part of the study area which is largely west of the limestone quarry, another poor to very poor WQI are also observed along the eastern and southern portion of the limestone quarry, which represent the south-eastern portion of the study area. In addition, the poor to very poor-quality water were found in localities such as Jururu, Bulturi, Jauro Bappa, Jauro Ali, Anguwan Jalingo, Jauro Yuguda and Dayayi. This shows that groundwater in the study area around the eastern and south eastern portion are unfit for drinking, and this corresponds to the direction of the general ground water flow of the area and thus require treatment before consumption. The poor values of water quality index of the study area are largely due to the high concentrations of TDS, and this could be attributed to the presence of relatively high content of Magnesium, Sodium, Potassium, Chloride, Sulphate, Nitrate, TH, and some trace metals beyond WHO standards limits for drinking water. Presence of high concentration of these ions in the water could be as a result of industrial activities in the study area.

Table 3: Water Quality Index Rating of water from the Study Area

SAMPLES	LOCATION	WQI	RATING
Sample 1	GANGAREN KATSINAWA	53.83	Good
Sample 2	GANGARE 2	40.81	Excellent
Sample 3	GONGILA	93.07	Good
Sample 4	FUNA GONGILA	46.02	Excellent
Sample 5	FESHINGO 1	58.99	Good
Sample 6	FESHINGO 2	50.81	Good
Sample 7	WURO MODIBBO	169.56	Poor
Sample 8	GARIN GALADIMA	84.43	Good
Sample 9	WURO ORFE	44.99	Excellent
Sample 10	JURURU (JAURO ABDU)	820.76	Unfit for Drinking
Sample 11	JURURU(JAURO JABEN)	181.77	Poor
Sample 12	JAURO MUSA	62.27	Good
Sample 13	JAURO SOGIJI	34.78	Excellent
Sample 14	HAMMA KOLON	45.07	Excellent
Sample 15	BULTUN	98.06	Good
Sample 16	MAAJA	83.24	Good
Sample 17	JAJAMI	59.09	Good
Sample 18	SHUWARIN FULANI	86.05	Good
Sample 19	SHUWARIN JAURO GARBA	89.17	Good
Sample 20	SHUWARIN JAURO MADAKI	134.09	Poor
Sample 21	GARI JAURO HAMMAN	166.72	Poor
Sample 22	GARI JAURO DALA	191.38	Poor
Sample 23	BULTURIYEL	140.7	Poor
Sample 24	JAUN YAGANA	67.88	Good
Sample 25	JAURO YUGUDA	222.39	Very Poor
Sample 26	MALARI	137.61	Poor

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Sample 27	JAURO MANU	125.23	Poor
Sample 28	JAURO BAPPA	122.3	Poor
Sample 29	JAURO ALI	131.35	Poor
Sample 30	MAZA MALLAM MEDU	144.97	Poor
Sample 31	ANGUWAR ALHERI	101.55	Poor
Sample 32	ANGUWAR ABIYOLA	130.61	Poor
Sample 33	BAKIN TUKA	159.79	Poor
Sample 34	BUNGUMYEL	105.64	Poor
Sample 35	TSOHUWAR KWATA	45.61	Excellent
Sample 36	DAYAYI	180.56	Poor
Sample 37	ANGUWAN KARA 1	142.37	Poor
Sample 38	ANGUWAN KARA 2	146.42	Poor
Sample 39	DAYAYI 2	109.18	Poor
Sample 40	DAYAYI 3	97.05	Good
Sample 41	MAZAN FULANI	122.35	Poor
Sample 42	WURO IBBA	182.56	Poor
Sample 43	PESHINGO ASHAKA	85.44	Good
Sample 44	SHUWARI JAURO MOH'D	267.29	Very Poor
Sample 45	FESHINGO BAWA 2	44.71	Excellent
Sample 46	JALINGO BH	157.28	Poor
Sample 47	GIDDE BAGE	63.62	Good
Sample 48	ASHAKA ESTATE EDGE	76.75	Good
Sample 49	GUDUBAM	69.48	Good
Sample 50	GUDUBAM 2	44.46	Good
	MINIMUM	**34.78**	
	MAXIMUM	**820.76**	
	AVERAGE	**122.402**	

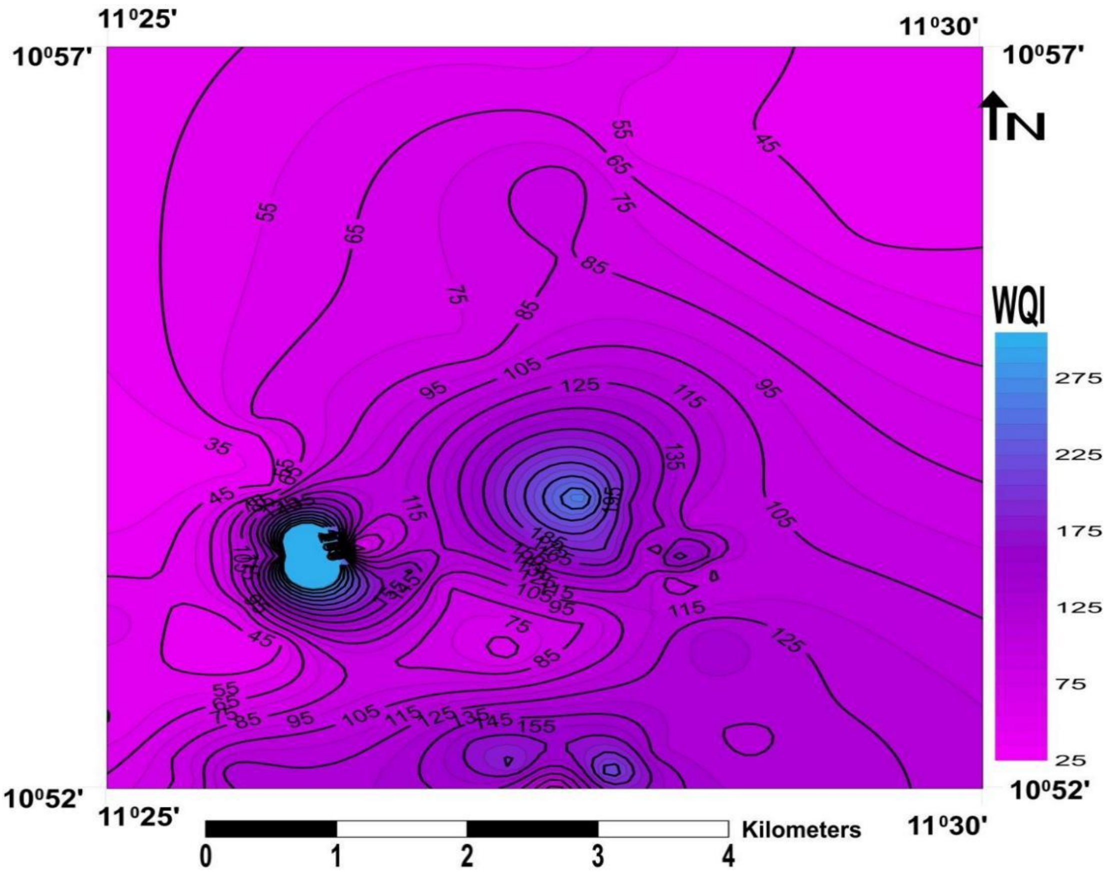

Figure 3: Spatial distribution of Water Quality Index in the Study Area

CONCLUSION

In this study the quality of groundwater in Ashaka and its surrounding areas was assessed using the Water Quality Index (WQI) technique. Fifty groundwater samples were used for the study and considered fifteen (15) parameters, including pH, TH, EC, TDS, Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, HCO_3^{-}, $SO4^{2-}$, NO_3^{-}, Fe^{2+}, F^{-}, $PO4^{-}$, for the computation of the WQI. The calculated WQI values ranged from 34.78 to 820.76, with an average of 122.40. Fourteen percent (14%) of the samples exhibited excellent water quality, Thirty-six percent (36%) were classified as good quality water, Forty-four percent (44%) were categorized as poor-quality water, Four percent (4%) were identified as very poor-quality water, and Two percent (2%) were deemed unfit for consumption. Areas with good to excellent quality water were predominantly found in Hamma Kalorin, Feshingo Bawa, Gongila, Jajami, and Ashaka estate villages, mainly concentrated in the Northern and south-western regions of the study area. On the other hand, poor to very poor-quality water, as well as water unfit for consumption, were observed in the central and south-eastern parts of the study area. Specifically, localities such as Jururu, Bulturi, Jauro Bappa, Jauro Ali, Anguwan Jalingo, Jauro Yuguda, and Dayayi exhibited poor to very poor water quality. This indicates that the groundwater in the eastern and south-eastern parts of the study area is not suitable for drinking. The poor WQI observed in the area can be a result of high levels of TDS, and elevated concentrations of Magnesium, Sodium, Potassium, Chloride, Sulphate, Nitrate, and TH, exceeding the WHO recommended values for drinking water. The presence of these ions in high concentrations could be a result of applications of fertilizer for agricultural activities and limestone blasting for industrial activities.

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