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Ground Water Quality Assessment in the Kazaure Environs for Drinking Purpose using the Water Quality Index Tool

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Abstract **—** This study presents the findings of an assessment of the ground water quality for drinking purposes using Water Quality Index (WQI). To ascertain the water quality, detailed physical and chemical analysis of water samples was carried out on samples. Samples from twelve (12) sampling points were taken and analysis was carried out on several parameters such as pH, Temperature, Electrical Conductivity (EC), total dissolved solids (TDS), Sodium, Potassium, Calcium, Fluoride, Chloride, Bicarbonates, Nitrate, Sulphate, Magnesium, Iron. Analysed parameters were compared with the World Health Organisation (WHO). It was observed that most of the water sample parameters conformed to the standards for Drinking water. The Water Quality Index values obtained ranged from 36.32 to 113.11, signifying a water quality class ranging from excellent to poor water quality. From the classification of the samples, five (5) samples indicating about 41.67% of the total water sample was classed as having "excellent" water quality (WQI < 50), Six (6) samples representing about 50.00% of the total water sample showed "good" water quality (WQI 50-100) and one (1) which is 8.33% as having "poor" water quality (WQI>100). The low values of WQI in the water samples indicate that water obtained from this area is suitable for drinking with little or no treatment.

Keywords **—** *Water Quality Index; Groundwater; Unit Weight; Physio-Chemical Parameters; Drinking Water.*

1. Introduction

Water is a natural resource on which human life and existence depends majorly upon. According to Gupta et al. (2017), water remains the main requirement for Human and Industrial growth. The obtainability of good quality water is a crucial factor for preventing disease and improving life quality (Hamaidi-Chergui et al., 2013). Between 5 million–10 million people, mostly children die from water-related diseases worldwide yearly. Consumption of water containing bacteria, viruses, or parasites causes approximately 250 million cases of water-related diseases each year, hence, making water quality control and its availability of great importance in many parts of the World. WHO (2011).

According to Selvakumar et al. (2014) groundwater quality depends on the composition of recharge water, its interaction with the soil, the soil-gas interaction, the rock which it interfaces with in the unsaturated zone, its residence time, and the reactions within the aquifer. It is also defined by both natural processes (dissolution and precipitation of minerals, groundwater velocity, quality of recharge water, and interaction with other types of water aquifer) and anthropogenic activities (Andrade et al., 2008). As competition for resources intensifies, the need for water resources information based on sustained, robust monitoring networks for tracking the quantity and quality of streamflow and ground water has never been greater (Hirsch, 2011). Aquifers in geological terms refers to bodies of saturated rocks or geological formations through which volumes of water find their way into wells and springs. Aquifers are classed into (1) confined and (2) unconfined aquifers based on water table location within the subsurface, its structure and hydraulic conductivity. They generally serve as water storing bodies and could dry up due to over abstraction. An example is the groundwater depletion in the upper aquifer of the Chad formation in the chad basin of the North Eastern Nigeria (Adamu et al.2020).

The regional aquifers in many areas of northern Nigeria are commonly associated with sedimentary strata, extending through entire zones (Kankara & Muktar, 2018). These aquifers do not need any reconnaissance and full survey before they can be dug to obtain water. According to Kankara and Idris (2020) any borehole drilled within this area is expected to have high yield than in the other geological zones/formations. Groundwater occurrence is limited to the weathered part of the basement and fractured zones. Different portions exhibit different permeability and porosity and can therefore be said to be heterogeneous. Thus, crystalline rocks are multiple aquifer system instead of a single homogenous aquifer (Ogunjobi, 1983).

1.1 The Study Area

The study area is located in northwestern part of Kano State, also covering some parts of Jigawa and Katsina States. It is part of Kazaure schist belt, north-western

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Nigeria, and lies between latitude 12º 30′ 00″ N to 12º 45′ 00″ N, and longitude 8º 15′ 00″ E to 8º 30′ 00″ E, covering an area of about 770.063 km² (Figure 1). It is accessible through major roads, like Kano-Danbatta-Kazaure-Daura road, Kazaure-Roni-Ingawa and Kazaure- Shuwaki-Lamba road. There are also numerous networks of footpath throughout the area (Kankara & Idris, 2020).

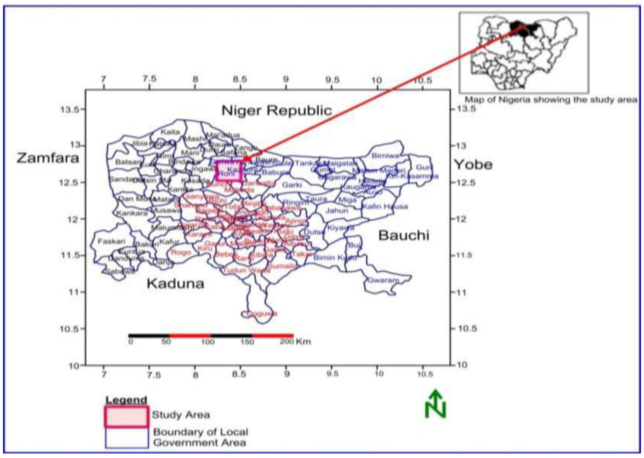

Fig. 1: Location map of the Study Area

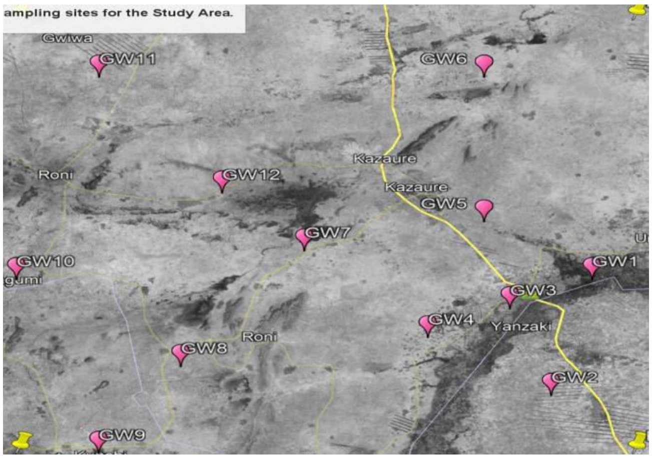

Fig. 2: Sampling locations for the Study Area

1.2 Relief and Drainage

The landforms in the area generally conform to those obtainable in many parts of northern Nigeria. It is characterized by flat to undulating relief. The geology of the area controls and influences the pattern of the drainage. Highly weathered minerals such as muscovite, biotite and feldspar of the metasediments of the area, result to the formation of secondary clay minerals (kaolinite). Alteration of these minerals favoured a relatively high storage capacity but low permeability of groundwater (Acworth, 1987). Low permeability produced fine drainage texture which indicates a high frequency of streams and its tributaries in a dendritic pattern (tree branches form), especially near metasediment ridges of Kazaure area. The area experiences an average annual rainfall of about 700mm.

Major rivers in the area include, Tuwari, Gari, Kiye, Sabke and Tagwai. The Tuwari River flow north-eastwards through a rocky terrain and turn south-eastern near Kazaure town. River Gari flows north-eastwards across regional strike to its intersection with the Tagwai River, from there it more easterly flow direction similar to that River Kiye. However, River Kiye is an important river and empties into lake Kiye. The other lakes are Dandi, Dakwat, Kwaita and Wawan-Rafi.

1.3 Geological/Hydrogeological Mapping

According to Kankara and Idris (2020) the Chad Formation is of lacustrine origin, and was deposited by rivers flowing towards Lake Chad on the Basement Complex during the Plio-Pleistocene. Aquifers in this area fall within the regional and localised aquifers. In the regional aquifers, the basement complex or water-bearing objects here are regional aquifers and do not exceed 90 meters. (Kankara et al., 2021). According to Kankara and Idris (2020), depths of boreholes drilled into the migmatite-gniess in around regional aquifers fall within the range of 25.0 m to 79.50 m for boreholes tapping the Biotite granite rocks. Regional aquifers in the southern parts of the study area are extended or elongated, have a high yield and cover many kilometers. The localized aquifers on the other hand have very low to moderate yield. The average yield of an aquifer here is 0.2 to 0.5 liter per second. If the aquifer is soft overbudden with very good hydrologic characteristics, the yield can stand at 0.2 l/s or more.

A few studies have been carried out in the study area. (Musa et al., 2019) conducted a hydrogeochemistry of the groundwater from this area using multivariate statistics. The study aimed at determining the groundwater geochemistry and the factors controlling the water chemistry. He reported that the physiochemical evaluation of groundwater showed evidence of local contamination and concluded that the water-rock interaction, tectonics and anthropogenic factors affected the studied groundwater. (Kankara & Idris, 2020), carried out a Mapping of the geology and structural features of the Kazaure area with a look at establishing a groundwater potential model for the area. Groundwater potential modeling of the area revealed three zones of groundwater potential. These include zones of low, medium and high potentials.

The uniqueness of this study however is based in the fact that water quality from the study area have not been determined using the Water Quality Index. This research therefore takes a look at the suitability of the ground water

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in the Kazaure area for drinking purposes using the Water Quality Index (WQI).

2. Materials and Methods

2.1 Physio-Chemical Analysis

Water samples were obtained from twelve (12) sampling points. Parameters analysed include pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Temperature, Calcium, Magnesium, Potassium, Sodium, Iron, Sulphate, Bicarbonates, Chlorine, Nitrate and Fluoride. Electrical conductivity meter was used to determine the electrical conductivity. The drying process was employed in the determination of total dissolved solids. Determination of pH Value was done using the pH meter. The Atomic Absorption Spectrophotometer (AAS) was used to determine the concentration of calcium, magnesium, potassium, sodium and iron while digital titration was used to determine the concentration of sulphate, bicarbonate, chlorine and nitrates.

2.2 Water Quality Index

Water Quality Index is a mathematical equation that provides a clear understanding of the quality of surface and groundwater (Chaudhry & Sachdeva, 2020). It is a means of integrating a wide range of information into a simpler form and as such is considered as the most effective tool in water quality assessment (Akter et al., 2016). According to Olusola. (2020) water quality index helps in better management of water quality issues and improves the effectiveness of protective measures. It is a simplified and precise means employed to verify the deficiency in the quality of water. WQI helps to evaluate the effect of each water parameter on the overall water quality by assigning weights to each water quality parameter and summarizing them into a single figure, thus giving an indication of the classification of water in terms of its quality. Several researchers have used this tool and reported on its viability in water quality assessment. Alobaidy et al. (2010); Saeedi et al. (2010); Gebrehiwot et al. (2011); Kumar and James. (2012); Tyagi et al. (2013); Batabyal and Chakraborty (2015); Akinbile and Omoniyi (2018); Kawo and Karuppannan (2018); Agrama. (2019); Ameur et al. (2019); Khan et al. (2020); Iwar et al. (2021). Recently, researchers have reported on the application of the GIS-GWQI (Adimalla and Taloor (2020)) and the Hybrid fuzzy GIS based WQI in assessing water quality (Hosseini-Moghari et al. (2015); Gorai et al. (2016); Jha et al. (2020))

2.3 Water Quality Index Computation

Computation of the Water Quality Index involves these successive steps (Ramakrishnaiah et al., 2009); (Rokbani et al., 2011); (Aly et al., 2014); (Fathi et al., 2015).

Step 1: *Assigning of weights.* Weights were assigned to the parameters according to their importance in the overall water quality, with a maximum value of five (5) and the minimum of one (1). A higher weight was assigned to the most significant parameters, and lesser weights attached to the less significant parameters (Table 2).

Step 2: *Relative weight computation.* Relative weight (W_i) was obtained using the formula:

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

Where,
W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters (Table 1).

Step 3: *Quality rating scale (qi) computation. qi* was obtained for each parameter using the equation;

$$qi = \left(\frac{Ci}{Si}\right) x\ 100 \qquad (2)$$

Where,
q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample (mg/L), S_i is the WHO standard for each chemical parameter (mg/L) WHO (2018).

Step 4: *Calculation of the Water Quality Index (WQI).* W_i and q_i used to compute the *SLi* for each chemical parameter. WQI was finally obtained from Equation (4) below:

$$SLi = Wi * qi \qquad (3)$$

$$WQI = \sum_{i=1}^{n} SLi \qquad (4)$$

Where SLi is the sub-index; Wi is the relative weight. The WQI for a sample is therefore finally obtained by summing SLi for all the parameters. WQI values computed is then used to classify water into five types: “Excellent”, “Good”, “Poor”, “Very Poor” and “Unsuitable” (Table 4).

3. Results and Discussion

The values obtained from the physiochemical analysis of the parameters measured and the statistical descriptive analysis are as presented in Table 1. The values obtained were compared with the World Health Organisation (WHO) standard.

The pH values of samples from this area ranged from 4.90 – 6.08 with a mean and standard deviation of 5.57 ± 0.39. This indicates that the samples were acidic and below the recommended levels of the World Health Organisation (WHO) of 6.5 – 8.5. The range, mean and standard deviation for the other parameters presented in (table 1) shows TDS (0.00 – 230 and 100 ± 75.00) mg/L, Temperature (28.80 – 33.40 and 30.53 ± 1.25) ^{o}C, EC

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(10.00 – 390.00 and170.83 ± 113.10) µS/cm, Na^{2+} (0.00 – 90.00 and 35.00 ± 23.98) mg/L, K^{+} (5.00 – 165.00 and 38.98 ± 44.12) mg/L, Ca^{2+} (4.00 – 15.00 and 6.92 ± 2.75) mg/L, Mg^{2+} (0.00 – 22.10 and 4.30 ± 5.50) mg/L, Fe^{2+} (0.52 – 1.90 and 1.16 ± 0.45) mg/L, F^{-} (0.46 – 0.58 and 0.53 ± 0.04) mg/L, Cl^{-} (28.40 – 85.20 and 55.63 ± 14.83) mg/L, HCO_3^{-} (30.50 – 345.00 and 106.53 ± 82.11) mg/L, NO_3^{-} (10.00 – 18.60 and 14.47 ± 2.95) mg/L and SO_4^{2-} (1.90 – 9.52 and 4.43 ± 2.18) mg/L respectively.

Table 1: Statistics of the Parameters analysed and Comparison with (WHO, 2018)

Parameter	*Unit*	*Min*	*Max*	*Mean*	*St.Dev*	*WHO (2018)*
pH		4.90	6.08	5.57	0.39	6.5-8.5
TDS	*mg/L*	0.00	230.00	100.83	75.00	500 [a]
Temp.	*°C*	28.80	33.40	30.53	1.25	25
EC	*µS/cm*	10.00	390.00	170.83	113.10	1000 [a]
Na^{+}	*mg/L*	0.00	90.00	35.00	23.98	200
K^{+}	*mg/L*	5.00	165.00	38.98	44.12	12 [a]
Ca^{2+}	*mg/L*	4.00	15.00	6.92	2.75	75 [a]
Mg^{2+}	*mg/L*	0.00	22.10	4.30	5.50	50 [a]
Fe^{2+}	*mg/L*	0.52	1.90	1.16	0.45	0.3
F^{-}	*mg/L*	0.46	0.58	0.53	0.04	1.5
Cl^{-}	*mg/L*	28.40	85.20	55.63	15.83	250
HCO_3^{-}	*mg/L*	30.50	345.00	106.53	82.11	120 [a]
NO_3^{-}	*mg/L*	10.00	18.60	14.47	2.95	50
SO_4^{2-}	*mg/L*	1.90	9.52	4.43	2.18	250

[a] *WHO (2011)*

Table 2 shows the parameters and the weights assigned according to the importance of each parameter in drinking water. Parameters which are considered most significant were assigned a higher weight while those considered less important in drinking water were assigned a lower value. The relative weights used in this study are also as presented.

Table 2: Assigned weights and relative weights of parameters considered

Chemical Parameters	*Weights (w_i)*	*WHO 2018 (Si)*	*Relative Weights (W_i)*
pH	4	6.5-8.5	0.08
TDS	4	500	0.08
EC	3	1000	0.06
Na^{+}	5	200	0.10
K^{+}	2	12	0.04
Ca^{2+}	5	75	0.10
Mg^{2+}	4	50	0.08
Fe^{2+}	2	0.3	0.04
F^{-}	5	1.5	0.10
Cl^{-}	5	250	0.10
HCO_3^{-}	4	120	0.08
NO_3^{-}	4	50	0.08
SO_4^{2-}	3	250	0.06
Total	$\sum_{i=1}^{n} wi = 50$		$\sum Wi = 1.0$

Table 3 presents the classification of the various water samples. The results show that GW2, GW5, GW8, GW9, GW10 showed "excellent" water quality, GW3, GW4, GW6, GW7, GW11, GW12 exhibited "good" water quality, while GW1 has "poor" water quality. Fig 1 shows a pictorial representation of the classification and WQI values for the water samples.

Table 3: Water Quality Index values obtained

Water sample ID	*Water Source*	*WQI obtained*	*Class*
GW1	BH	113.11	Poor
GW2	BH	45.41	Excellent
GW3	BH	51.77	Good
GW4	W	69.20	Good
GW5	W	39.81	Excellent
GW6	BH	70.17	Good
GW7	W	56.52	Good
GW8	BH	46.44	Excellent
GW9	W	44.57	Excellent
GW10	W	36.32	Excellent
GW11	W	53.73	Good
GW12	W	51.75	Good

BH=Bore hole, W=Well

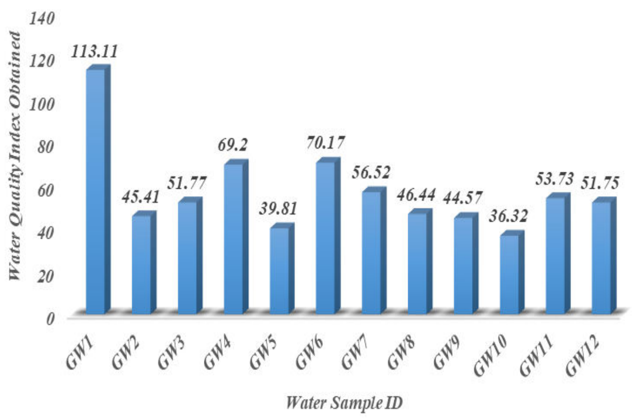

Fig.3: Water Quality Index Obtained for each Water Sample ID

Table 4: Water Quality Classification

Index Values obtained	*Water Quality Class*	*No. of Samples*	*Percentage*
< 50	Excellent	5	41.67%
50 – 100	Good	6	50.00%
100 – 200	Poor	1	8.33%
200 – 300	Very poor	-	0%
> 300	Unsuitable	-	0%

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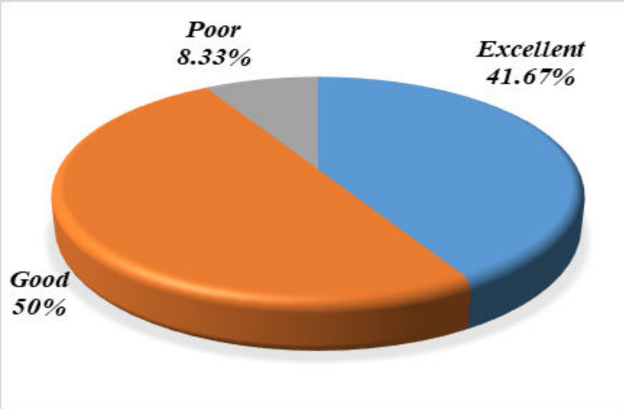

Fig. 4a: Pie chart of water quality percentage in each class

Fig. 4b: Bar chart of water quality percentage in each class

Table 4 presents the classification by percentage. The results show that five (5) sampling points representing about 41.67% have "excellent" water quality, six (6) sampling points representing 50% have "good" water quality while one (1) sampling point representing 8.33% has "poor" water quality. Fig 2a and b gives a pictorial representation of the water samples classification by percentage.

The Physiochemical parameters were analysed using the Pearson Correlation Coefficient to determine the relationship between these parameters. Table 5 shows the interrelationship of these groundwater parameters. A high correlation is observed between EC and TDS (r = 0.914). This suggests that ions which are necessary for electrical conductivity in water increases with increase in dissolved solids.

Significant positive correlation was observed between EC and TDS with Na^+, K^+, Cl^-, HCO_3^- and SO_4^{2-}. Significant positive correlation was also observed between some chemical parameters notably, Mg^{2+} and Ca^{2+} (0.929), Cl^- and K^+ (0.795), HCO_3^- and K^+ (0.71), HCO_3^- and Na^+ (0.586), Fe^{2+} and NO_3^- (0.578) and Fe^{2+} and Ca^{2+} (0.531)

Table 5: Correlation Matrix for the considered parameters

	pH	*TDS*	*EC*	*Na^+*	*K^+*	*Ca^{2+}*	*Mg^{2+}*	*Fe^{2+}*	*F^-*	*Cl^-*	*HCO_3^-*	*NO_3^-*	*SO_4^{2-}*	*WQI*
pH	1													
TDS	0.123	1												
EC	-0.014	***0.914***	1											
Na^+	0.001	***0.54***	***0.653***	1										
K^+	-0.371	***0.656***	***0.635***	0.088	1									
Ca^{2+}	0.329	-0.541	-0.61	-0.6	-0.341	1								
Mg^{2+}	0.244	-0.42	-0.41	-0.443	-0.215	***0.929***	1							
Fe^{2+}	-0.245	-0.584	-0.644	-0.756	-0.122	***0.531***	0.392	1						
F^-	0.156	-0.686	-0.625	-0.102	-0.704	0.428	0.263	0.058	1					
Cl^-	-0.308	***0.569***	***0.509***	0.014	***0.795***	-0.138	-0.009	-0.055	-0.504	1				
HCO_3^-	-0.169	***0.624***	***0.739***	***0.586***	***0.71***	-0.268	-0.048	-0.464	-0.442	0.463	1			
NO_3^-	0.018	-0.122	-0.304	-0.446	-0.069	0.475	0.361	***0.578***	0.031	0.025	-0.327	1		
SO_4^{2-}	0.07	***0.638***	0.374	0.103	0.48	-0.241	-0.371	-0.179	-0.294	0.46	0.167	0.372	1	
WQI	-0.452	0.377	0.373	-0.189	0.889	-0.006	0.092	0.288	-0.596	0.783	0.565	0.159	0.305	1

4. Conclusion

The quality of life of a group of people depends largely on the quality of water they have access to. The water quality for the purpose of drinking in the Kazaure area was investigated using the water quality index (WQI). The physio-chemical parameters assessed was compared with the WHO standards and most of the parameters measured were found to be within limits. The water quality index values obtained show that the water is generally of good quality with about 91.67% having values below 100 (WQI < 100). The water quality index ranged between 36.32 to 113.11. It can therefore be concluded based on the study that the water in this area is generally good for drinking with little to no treatment.

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