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Quality Assessment of Groundwater in Share and its Environs, Southwestern Nigeria

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ABSTRACT

Groundwater quality assessment is of great concern for mankind due to its direct influence on human life. Increase in population of Share and its environs due to ongoing oil exploration in the Bida Basin and agricultural activities putting pressure on the groundwater resources. This study assessed the impact of human activities and urban growth on the quality of groundwater in Share and its environs, Southwestern Nigeria. Forty (40) groundwater samples were randomly taken in the study area from hand-dug wells and boreholes. Physico-chemical characteristics of the groundwater were examined. Results shows that the pH of groundwater ranges between 6.5 to 6.9 with a mean value of 6.7. The pH is acidic and falls within the world health organization (WHO) acceptable standards for domestic use. The groundwater's electrical conductivity ranges from 103 to 235 µS/cm, with a mean of 173 µS/cm. The electrical conductivity (EC) complies with WHO guidelines. Total dissolved solids (TDS) values falls between 118 and 265 with a mean of 185, which below acceptable limit of 1500 mg/l. The average mean concentrations of major ions in mg/l are (Ca^{2+} = 4.9; Mg^{2+} = 5.7; Na^{+}= 0.8; K^{+} = 1.5; SO_4^{2-} = 77.0; NO_3^{-} = 36.1; Cl^{-} = 21.3; and HCO_3^{-} = 4.1) and all are found to be within WHO standard limits. The variations of chemical parameters are in order of abundance ($Mg^{2+} > Ca^{2+} > K^{+} > Na^{+}$) and ($SO_4^{2-} > NO_3^{-} > Cl^{-} > HCO_3^{-}$) for cations and anions, respectively. The Piper's diagram characterized the hydrochemical facies of groundwater as $Mg(Ca)SO_4^{2-}$ - water type. Gibbs and Schoeller diagrams confirmed that the dominant process influencing groundwater chemistry in the study area is the interaction between water and host rock. The Wilcox diagram and Kelly's ratio indicated that groundwater in the study area is appropriate for irrigation use with values less than 1. In conclusion, findings from this study shows that the groundwater quality of the study area has not been adversely affected by the current human activities and population growth.

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1.0 Introduction

Because of its longer residence time in the ground, low level of contamination, wide dispersion, and availability within the end user's reach, groundwater is regarded as the preferred supply of water to meet home, industrial, and agricultural needs [1]. However, population increase in the urban areas due to development, industrialization, agriculture practice and climate impact have put more pressure on groundwater resources which results in decrease of groundwater availability [2].

The majority of well dwellers now rely on groundwater as their primary source of freshwater for domestic, industrial, and agricultural applications due to the failure of statutory government agencies to invest in and boost efforts in surface water infrastructure. In many regions of the world, an over-reliance on groundwater has led to excessive groundwater resource withdrawal, which has depleted its reserve [3]. Evidences have shown that groundwater gets polluted drastically by various factors either naturally or by human activities and these pollutants alter the quality of groundwater and could be many forms such as the artificial carbon-based compounds in the form of industrial, household and agricultural compounds added deliberately [4]. Others include plant nutrients such as nitrogen and phosphorous from wastewater and agricultural run-off. These wastes usually affect the quality of water [5], [6]. Human activity and / or environmental forces can also have an impact on the quality groundwater resource [7].

Characterization of groundwater hydrochemistry involves quality assessment which is another mechanism for sustainable groundwater resource development and management. Groundwater quality describes degree to which water is acceptable for specific use, including drinking, agriculture among others [4]. Groundwater quality determines level of purity and suitability of its usage for domestic, agriculture and industrial purposes. Conducting quality assessment of groundwater is essential for identifying potential contamination, understanding its suitability and environment health most especially in places where access to clean water is limited and needed for economic growth and human well – being [8]. The study area (Share) which is part of the Bida Basin has undergone rapid unprecedented urban growth because of the ongoing oil exploration and agricultural activities in the region putting pressure on the groundwater resources. However, increase in population and urbanization can influence the quality and quantity of the local aquifer systems in various ways. Population increase and other human activities can lead to the release of toxic materials into the groundwater. This study was carried out to assess groundwater quality in Share and its environs, Southwestern Nigeria for domestic and irrigation uses. Also, hydrochemical processes and hydrochemical facie of the groundwater in the study area were evaluated.

1.1 Geology and Hydrogeology of the study area

The research area is located in south of the River Niger between latitudes 80^0 48' 04" N to 80^0 51' 0" N and longitudes 40^0 57' 0" E to 500 6' 0" E in the Cretaceous-to-Upper Maastrichtian Nupe (Bida or Niger) Basin, Niger Trough, or better still, Middle Niger Valley. The research region is located in Ifelodun local government area (Figure 1). Share is located approximately 62 kilometers northeast of Ilorin in the north-central region of Kwara.

The research area is situated in the Bida Basin, which is part of the West African rift system. The early Cretaceous and early Tertiary have a complicated history of extension, sharing, and compression. The Bida Basin's regional geology has been thoroughly examined by [9], [10], [11], [12], and [13]. A fining upward succession of Campanian to Maastrichtian rocks typically makes up the basin's sedimentary fill. The Campanian series includes the Sakpe ironstone formation and the Bida sandstone formation (Figure 2). The Bida formation, which occupies the majority of the basal regions and is the most exposed, is composed of a basal conglomeritic sandstone that fines upward into finer-grained sandstone, siltstone, and subordinate claystone.

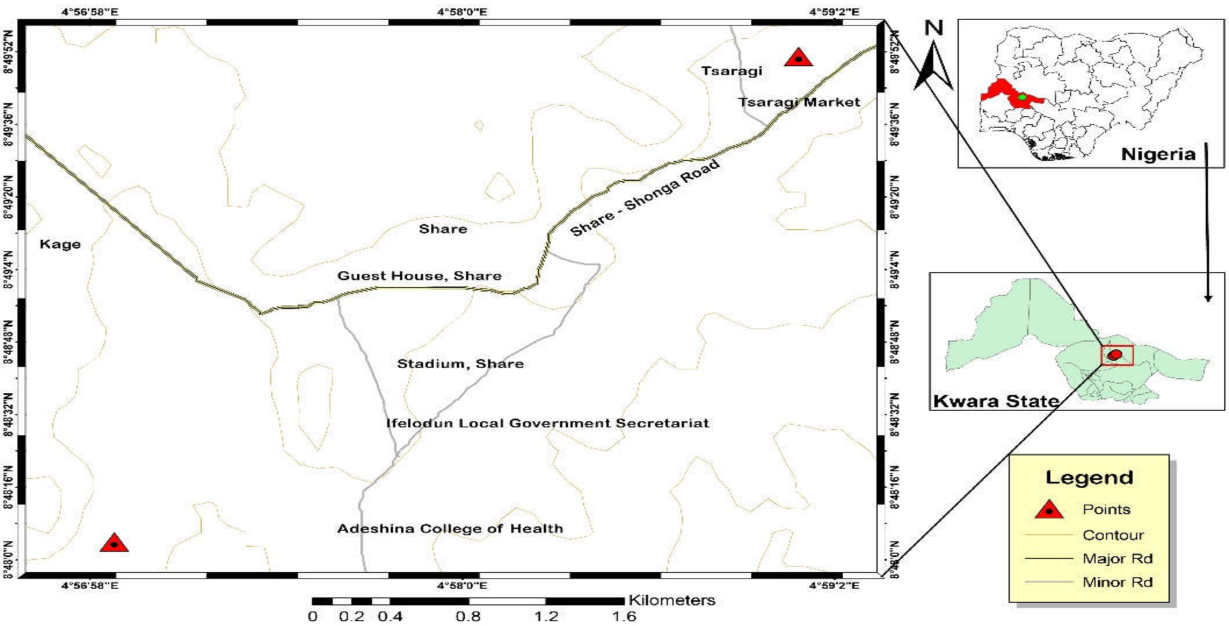

Figure 1: Location map of study area

The Sakpe formation, which is primarily composed of ooitic and pisolitic ironstone [14] above and below a silt to mudstone layer with concretions at the top, covers most of the southeast portion of the study region. The lower Maastrichtian Enagi formation's clayey sandstone and siltstone, which becomes coarser upward, predominate in the northwest of the research region [13]. Massive ironstones make up the Batati formation, which makes sharp contact with the Enagi Formation underneath it [9]. The Maastrichtian Enagi formation, which is geographically large and has numerous restricted aquifers, is the most significant aquifer in the study area. Despite having less transmissivity than the Enagi formation aquifers because to their high degree of consolidation, the Bida formation sandstone and basal conglomerate are still possess abundant aquifer systems. The Bida Basin's aquifers typically operate under confined, unconfined, phreatic, and artesian conditions, with an estimated 228.8 mm of groundwater recharge each year [2]. Also, there are some outcrops of migmatite, granite, gneiss, amphibolite found in the study area.

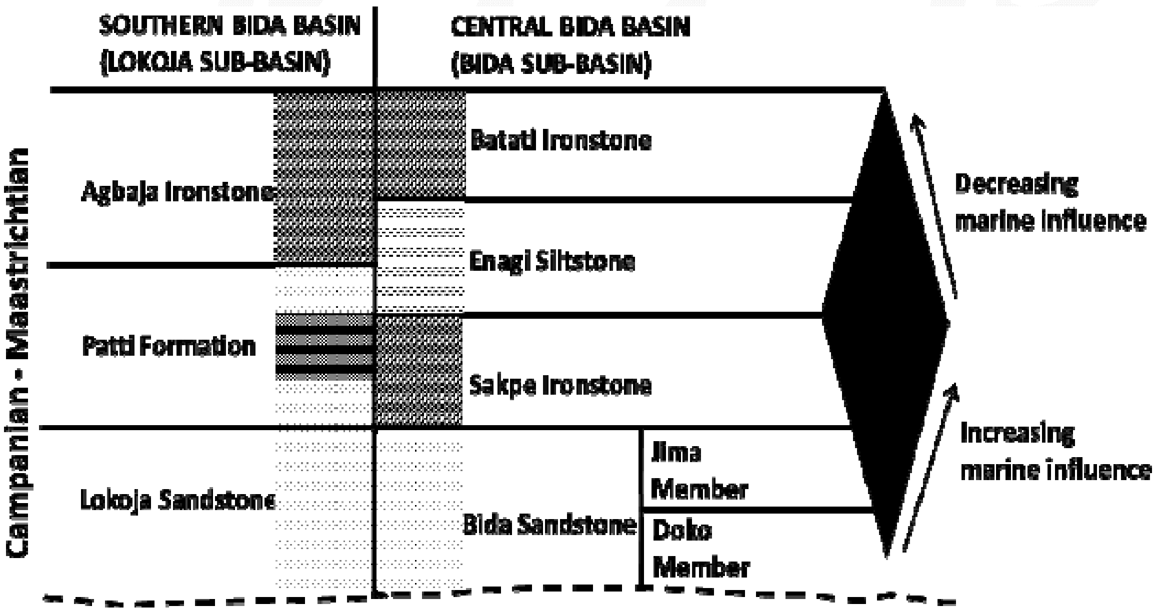

Figure 2: Stratigraphical settings of Bida Basin [12]

2.0 Materials and Method

For hydrochemical investigation, forty (40) groundwater samples were collected. ArcMap 10.7 was used to plot and digitize the sampling locations after they were identified using the Global Positioning System (GPS). Groundwater samples were randomly collected from hand-dug wells and boreholes in twenty (20) locations in the research region (Figure 3). Groundwater samples were taken in duplicate at each sampling site to make a total of forty (40) samples collected in mid-December 2024. Before being gathered, the water from hand- dug wells and boreholes were left to run for roughly few minutes. Samples were collected in one-litre polyethylene bottles and washed with the collected water. The groundwater samples were physically analysed on the spot and refrigerated. Samples were analysed for their major cation and anion concentrations using atomic absorption spectroscopy (AAS) at the Central Research Laboratory, University of Ilorin, Ilorin, and Al-hikmah University, Ilorin, Nigeria. The analyses were carried out in accordance with American Public Health Association Standards and Nigerian Standards for Drinking Water.

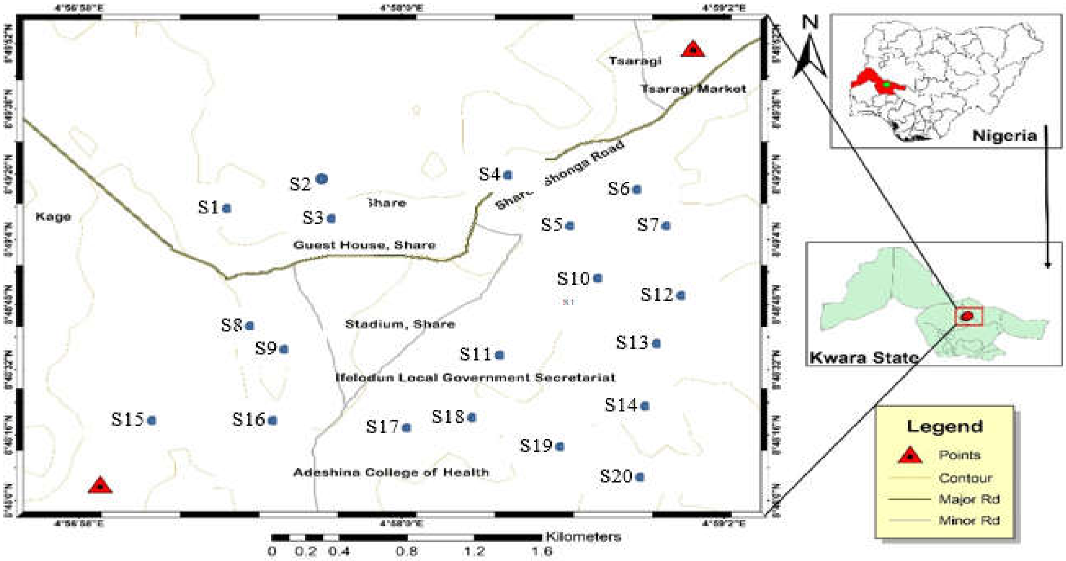

Figure 3: Map of study area showing sampling points

2.1 Quality assessment of groundwater

Results of the hydrochemical data are compared with [5] standards. Also, the results are subjected to graphical evaluation using [15], [16], and [17] to determine the quality of groundwater in the study area. The assessment also involves calculating various quality indices such as (Na%), (SAR), and (RSC) to determine the quality of groundwater for agricultural uses (Table 1).

Table 1: Indices for estimating suitability of groundwater for irrigation use

Indices	Formula	Rate	Implication
Sodium Percentage	$Na\% = \frac{Na^{+} + K^{+}}{Na^{+} + K^{+} + Ca^{2+} + Mg^{2+}} \times 100\%$	<60%	Suitable
		>60%	Unsuitable
Kelly's Index	$KI = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$	<1	Good
		>1	Bad
Magnesium Hazard	$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}}$	<0.5	Suitable
		>0.5	Unsuitable
Sodium Adsorption Ratio	$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$	0 – 10 11 -17	Excellent Good
		- 26	Doubtful
		>26	Unsuitable

3.0 Results and Discussion

3.1. Suitability of groundwater for domestic use

The physical and chemical properties of groundwater samples from the research region are displayed in Table 2. The statistical summary of physio-chemical parameters is displayed in Tables 3 and 4. The minimum, maximum, mean, standard deviation, and maximum allowable limits are all included in the statistical summary.

Table 2: Physico-chemical parameters of groundwater in study area

S/N	pH	EC (µS/cm)	TDS (mg/l)	Turbidity NTU	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Cl^{-} (mg/l)	HCO_3^{-} (mg/l)	NO_3- (mg/l)	SO_4^{-} (mg/l)
1	6.5	122	146	0.32	2.36	0.88	0.21	1.62	18.52	3.07	50.59	99.67
2	6.7	146	118	0.22	4.72	6.44	1.32	1.27	12.62	2.06	52.94	62.63
3	6.8	132	217	0.18	1.57	5.22	0.68	2.36	18.48	3.09	42.35	94.34
4	6.4	108	256	0.22	2.85	5.46	0.74	0.97	18.52	6.12	12.94	60.62
5	6.6	113	123	0.31	4.40	6.07	2.13	1.68	18.56	5.63	11.76	51.63
6	6.7	203	164	0.12	3.72	5.69	0.42	2.38	37.03	6.21	23.53	84.61
7	6.6	198	196	0.17	3.85	6.34	0.14	2.06	55.56	3.09	38.82	86.70
8	6.8	213	233	0.12	3.29	5.52	1.62	1.46	37.03	5.06	35.29	75.82
9	6.7	116	178	0.14	8.65	6.34	1.07	0.97	16.92	5.98	54.11	62.63
10	6.6	214	167	0.23	9.36	6.12	0.23	1.43	9.26	3.36	46.47	95.93
11	6.8	164	249	0.32	7.74	6.17	0.44	1.72	13.06	5.06	58.82	98.04
12	6.6	235	233	0.13	5.62	6.11	0.32	0.86	17.06	2.07	30.59	68.04
13	6.7	205	265	0.02	2.19	5.82	1.21	0.92	15.56	6.09	32.35	86.32
14	6.5	187	244	0.13	5.01	5.22	0.43	1.66	15.07	4.65	29.41	79.12
15	6.5	173	188	0.23	6.17	6.24	0.83	1.48	18.52	4.07	18.23	41.58
16	6.9	149	124	0.04	9.33	6.44	0.23	1.29	34.07	6.72	32.41	85.71
17	6.6	207	163	0.14	1.43	5.77	1.46	0.99	15.74	3.09	47.05	82.42
18	6.5	201	127	0.33	5.97	6.15	0.73	1.08	16.67	1.03	31.76	98.14
19	6.7	168	168	0.02	6.25	6.24	0.83	2.05	27.78	2.54	23.53	62.63
20	6.8	197	143	0.32	3.53	5.90	0.52	1.95	18.52	2.63	48.23	62.38

Table 3: Statistical summary of physical parameters of groundwater samples

Parameter	Min value	Max value	Mean value	SD	WHO (2011)
pH	6.5	6.9	6.65	0.34381	6.5-8.5
EC (µS/cm)	108	235	173	102.4535	1200
TDS (mg/l)	118	265	185.1	58.93876	1500
TURBIDITY NTU	0.02	0.32	0.19	0.334812	5.0

Table 4: Statistical summary of chemical parameters of groundwater samples

Parameter	Min value	Max value	Mean value	SD	WHO (2011)
Ca^{2+}	1.43	9.36	4.90	0.517365	_
Mg^{2+}	0.88	6.44	5.71	0.380205	20
Na^{+}	0.14	2.13	0.78	0.102789	200
K^{+}	0.86	2.38	1.51	0.248542	_
Cl^{-}	9.62	55.6	21.26	1.293488	250
HCO_3^{-}	1.03	6.12	4.08	2.819952	_
NO_3^{-}	11.76	58.82	36.06	0.599226	250
SO_4^{-}	41.48	99.67	76.95	0.324087	50

The groundwater samples' pH ranged from 6.5 to 6.9, with a mean of 6.7. The pH in the research area is acidic and it is within the acceptable allowable limits [5] standard of 6.5–8.5. The area's groundwater samples had electrical conductivity ranging from 108 to 235 µS/cm, with an average of 173 µS/cm. The EC is within the 1200 µS/cm acceptable limit for drinking water [5]. However, the existence of some metallic ore in the local foundation rocks may be responsible for certain evidence of elevated EC in groundwater. Total dissolved solids (TDS) is within the permissible range of 1500 mg/l [5], thus it is deemed safe to drink. With a mean of 4.90 mg/l, calcium readings vary from 1.43 to 9.36 mg/l. Although there are no specific limitations based on the [5] standard for calcium in drinking water, [18] states that the allowable maximum for calcium should not be greater than 75 mg/l. The mean concentration of magnesium is 5.71 mg/l, with a range of 0.88 to 6.44 mg/l. When compared to a criterion set by [5] of 20 mg/l, magnesium in the analysed groundwater is found to be appropriate for any residential use The high concentration of magnesium in groundwater may be caused by the leaching of ferromagnesian minerals found in the rocks in some parts of the study area, such as biotite and olivine. Magnesium may be produced when some kinds of rocks, particularly carbonate minerals found in natural water, come into contact with groundwater. Potassium levels in groundwater range from 0.86 to 2.38 mg/l, with a mean value of 1.51 mg/l, which is below the standard limit. However, [5] does not define a potassium permissible limit for drinking water, but [18] indicates a standard limit of 10 mg/l. With a mean of 21.26 mg/l, chloride levels vary from 9.26 to 55.56 mg/l while 250 mg/l is the highest amount of chloride that is allowed. Chloride in groundwater may also produce by weathering from the foundation rocks and replenishment from meteoric water.

Bicarbonate in groundwater samples ranges from 1.03 to 6.12 mg/l, with a mean value of 4.08 mg/l and it is within the permissible range. The groundwater samples that were examined had sulphate content levels ranging from 41.48 to 99.67 mg/l, with a mean of 76.95 mg/l. The sulphate levels fall within the permissible limit of 250 mg/l [5]. Inappropriate solid and liquid waste disposal methods, as well as fertilizer application by farmers, may have contributed to some of the sulphate residues in the groundwater. However, sulphate is also present in natural water. Nitrate concentration ranges from 11.76 to 58.82 mg/l with a mean value of 36.06 mg/. The nitrate concentration is below recommended limit of 50 mg/l [5]. Low concentration of nitrate show that local agricultural activities and sewage disposal have little impact on the groundwater in the study area.

3.2. Hydrochemical facies of groundwater

The Piper diagram developed by [15] was used to determine the hydrochemical characteristics of groundwater in the research area. Groundwater chemistry can be understood using a Piper diagram. It consists of three parts: a ternary diagram in the lower left that represents the cations, and a ternary diagram in the lower right that represents the anions and a diamond plot in the center that represents a combination of the two. Major ion relative ratios are displayed in this plot (Figure 4). It shows the mixing between two water sources and graphically depicts the variations in main ion chemistry in groundwater flow systems. The hydrochemical facies in the research region was identified using Piper's diagram as $Mg(Ca)SO_4^{2-}$ water type (Figure 4).

3.3. Hydrogeochemical processes of groundwater

Gibbs and Schoeller diagrams were used to comprehend the hydrogeochemical processes affecting the groundwater chemistry in the research area. These illustrations aid in comprehending the main elements - rock-water interaction, precipitation, and evaporation - that affect the ionic compositions of groundwater. [19] diagram showed that the groundwater falls within the rock-weathering domain (Figure 5), indicating that the interaction between the water and the host rock is the dominant process influencing groundwater chemistry. This suggests that the primary source of major ions like magnesium (Mg^{2+}), calcium (Ca^{2+}), and sulphate (SO_4^{2}) is the mineral dissolution in the aquifer as the groundwater passes through the subsurface. Also, there are other possible sources of sulphate in the groundwater which include anthropogenic sources (mining and fertilizer application) could contribute to high concentration of sulphate in groundwater. [20] The diagram was also used to further describe the research area's water chemistry (Figure 6). The relative concentrations of cations and anions are typically shown in this diagram, confirming the predominance of magnesium, calcium, and sulphate in accordance with the $Mg(Ca)SO_4^{2-}$ - water type determined from the Piper diagram. This trend also confirms that the main factor influencing the water chemistry in the studied area is rock weathering.

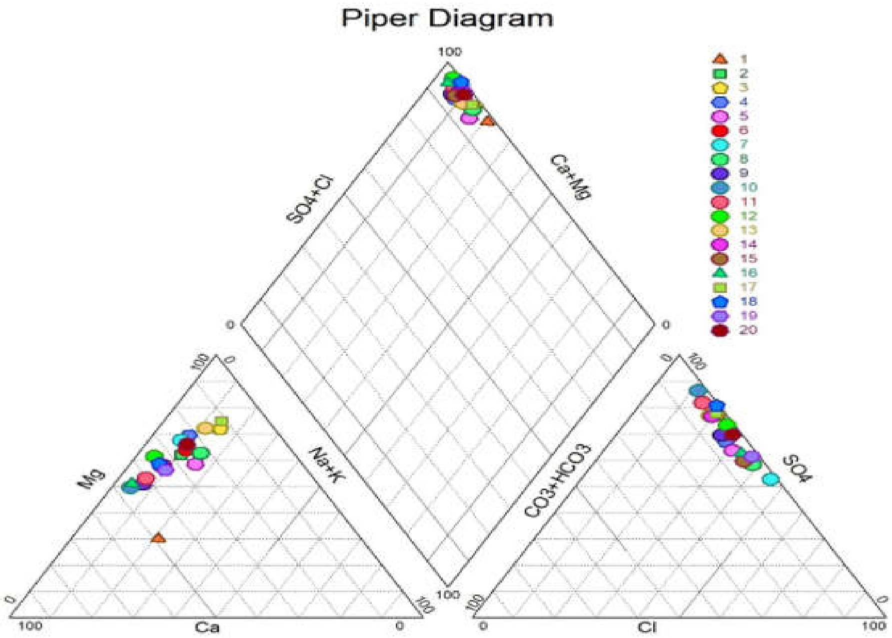

Figure 4: Piper Trilinear diagram of groundwater in study area showing water type and hydrochemical facies

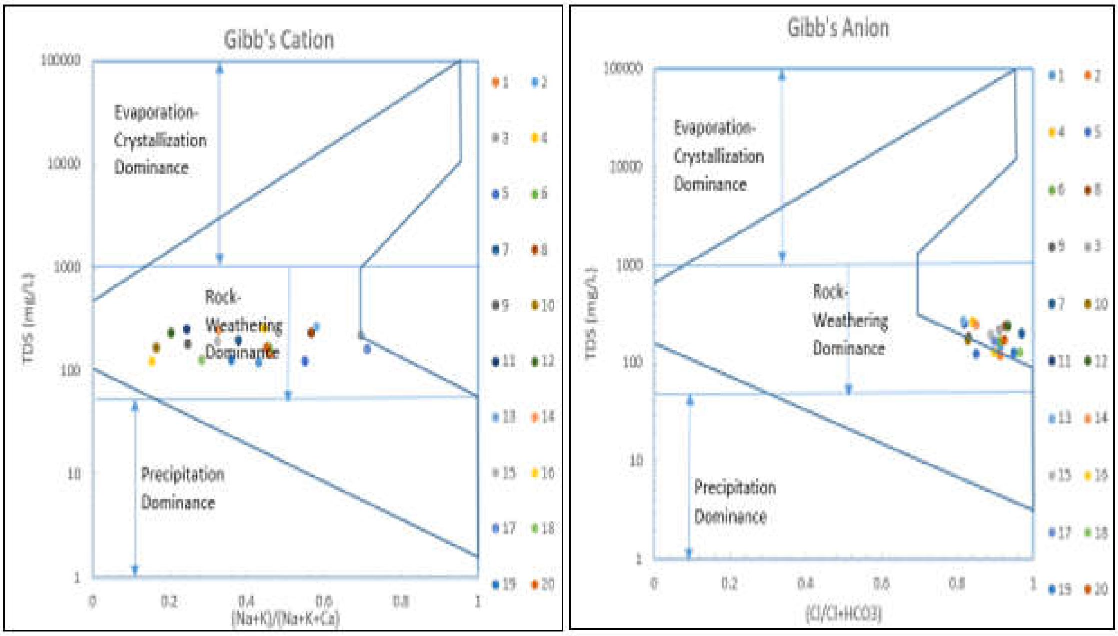

Figure 5: Gibbs diagrams showing dominant factor controlling groundwater chemistry in study area

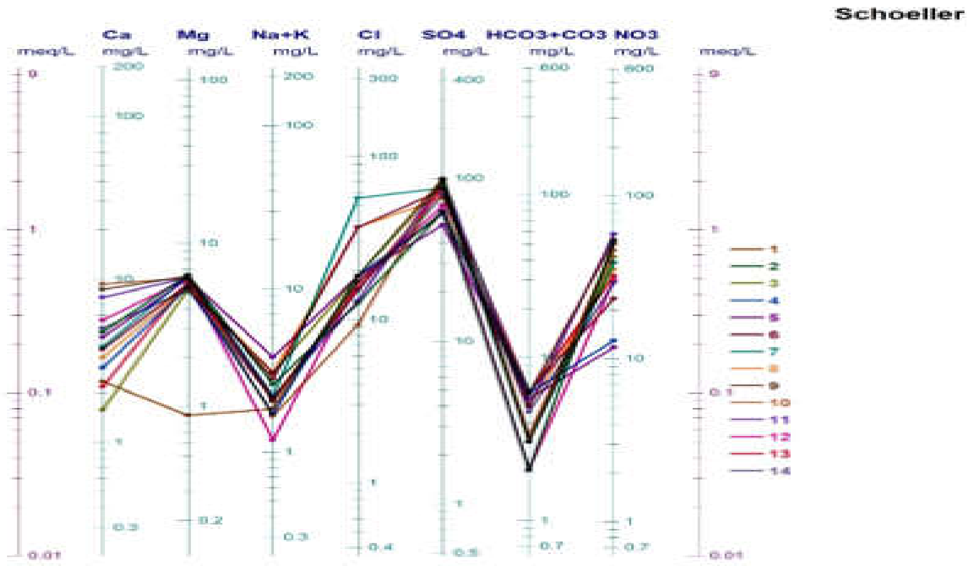

Figure 6: Schoeller diagram showing groundwater evolution

3.4 Suitability of groundwater for irrigation use

The impacts of water mineral concentrations in the aquifer determine whether groundwater is suitable for irrigation. The indices covered in table 1, such as sodium adsorption ratio, Kelly's ratio, Wilcox, percent sodium, and magnesium absorption ratio, can be used to categorize systems to assess whether groundwater is suitable for irrigation use. When the Kelly index is less than 1, the water is suitable for irrigation. From Table 5, the Kelly index values for groundwater samples are less than 1 and therefore, they are good and suitable for irrigation.

Table 5: Kelly index of groundwater samples

Samples	Na^+	Ca^{2+}	Mg^{2+}	$Ca^{2+}+Mg^{2+}$	KR
1	0.009	0.118	0.072	0.190	0.047
2	0.057	0.236	0.529	0.765	0.074
3	0.029	0.079	0.429	0.508	0.057
4	0.032	0.143	0.449	0.592	0.054
5	0.092	0.220	0.500	0.720	0.127
6	0.018	0.186	0.465	0.651	0.027
7	0.006	0.193	0.521	0.714	0.008
8	0.070	0.164	0.454	0.618	0.113
9	0.046	0.432	0.521	0.953	0.048
10	0.010	0.468	0.503	0.971	0.010
11	0.019	0.387	0.507	0.894	0.021
12	0.013	0.281	0.502	0.783	0.016
13	0.052	1.109	0.479	1.588	0.032
14	0.018	0.250	0.429	0.679	0.026
15	0.036	0.308	0.513	0.821	0.043
16	0.010	0.466	0.530	0.996	0.010
17	0.063	0.071	0.474	0.545	0.115
18	0.031	0.298	0.506	0.804	0.038
19	0.036	0.312	0.513	0.825	0.043
20	0.022	0.176	0.485	0.661	0.033

The Wilcox diagram illustrates the quality of water for irrigation. The percentage value of sodium (%Na) is plotted against electric conductance. Both the sodium percentage (%Na) and the electric conductance must be below 60% and 1500, respectively, for the water to be appropriate for irrigation.

The Wilcox diagram for groundwater samples collected in the study area is displayed in Figure 7 and all groundwater samples are classified as excellent.

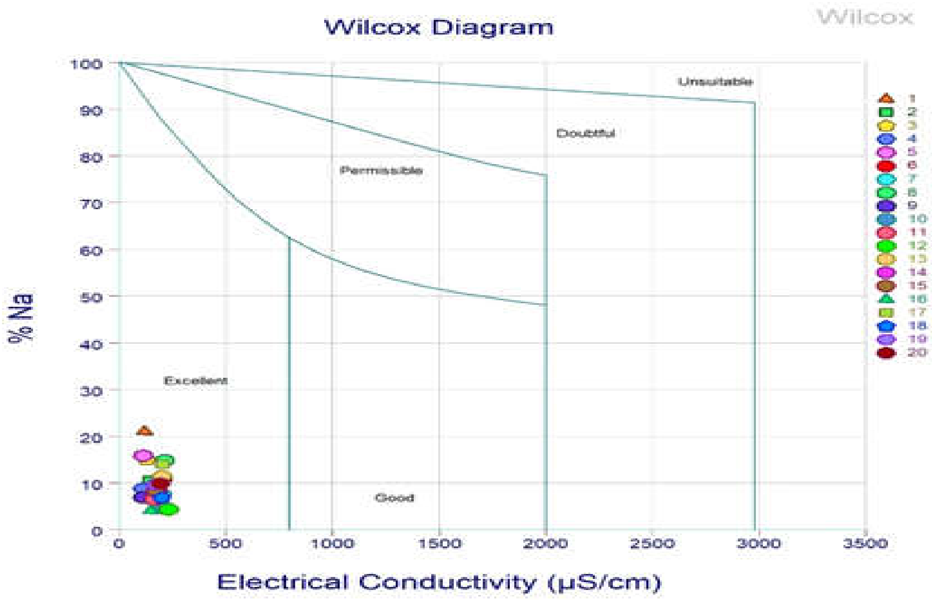

Figure 7: Wilcox diagram of groundwater samples for irrigation use

The ratio of sodium (a harmful element) to the combination of calcium and magnesium (a beneficial element) is known as the sodium absorption ratio (SAR). The concentration of sodium in relation to calcium and magnesium is expressed mathematically as SAR. According to the interpretation of results (Table 6 and Figure 8), the groundwater in the region is appropriate (falls under excellent category) for irrigation because the groundwater samples have SAR values less than 1.

Table 6: Sodium absorption ratio (SAR) values of groundwater samples

Samples	EC (μS/cm)	Na^+	Ca^{2+}	Mg^{2+}	$Ca^{2+}+Mg^{2+}$	SAR
1	122	0.009	0.118	0.072	0.190	0.029
2	146	0.057	0.236	0.529	0.765	0.092
3	132	0.029	0.079	0.429	0.508	0.057
4	108	0.032	0.143	0.449	0.592	0.058
5	113	0.092	0.220	0.500	0.720	0.153
6	203	0.018	0.186	0.465	0.651	0.031
7	198	0.006	0.193	0.521	0.714	0.010
8	213	0.070	0.164	0.454	0.618	0.125
9	116	0.046	0.432	0.521	0.953	0.066
10	214	0.010	0.468	0.503	0.971	0.014
11	164	0.019	0.387	0.507	0.894	0.028
12	235	0.013	0.281	0.502	0.783	0.020
13	205	0.052	1.109	0.479	1.588	0.058
14	187	0.018	0.250	0.429	0.679	0.030
15	173	0.036	0.308	0.513	0.821	0.056
16	149	0.010	0.466	0.530	0.996	0.141
17	207	0.063	0.071	0.474	0.545	0.120
18	201	0.031	0.298	0.506	0.804	0.048
19	168	0.036	0.312	0.513	0.825	0.056
20	197	0.022	0.176	0.485	0.661	0.038

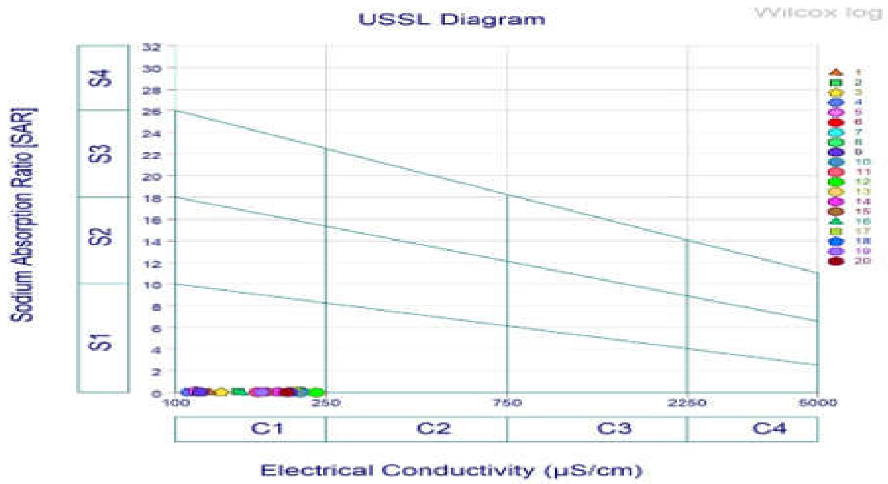

Figure 8: SAR for groundwater samples in the study area

4.0 Conclusion

The findings from this study shows that the studied area's groundwater quality has not been adversely affected by the ongoing oil exploration activities and population growth. This study also shows that pH of groundwater in the area is acidic and falls within the acceptable and recommended limits for domestic use. Other physical and chemical parameters (electrical conductivity, total dissolve solid, turbidity, anions and cations) are within the permissible limits. Hydrochemical facies of groundwater is characterized as $Mg(Ca)SO_4^{2-}$ - water type from interaction between water and host rock. The results indicate that groundwater in the studied area is good and suitable for irrigation, though there are possibilities of some anthropogenic influences, therefore, regular monitoring of the groundwater is necessary in the region.

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