Assessment of Shallow Groundwater Quality of Michika Area, NE Nigeria

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ABSTRACT

Groundwater forms the only reliable source of water supply and faces a growing demand for irrigated agriculture and domestic uses especially in semiarid and arid regions. The suitability of groundwater for irrigation depends on the water quality characteristics that ensure maximum yield under good soil and water management. **Objective:** The objective of this study is to assess the shallow groundwater of Michika area of Nigeria for its applicability in irrigation. **Materials and Methods:** In this study groundwater samples were collected from forty wells and were subjected to chemical analyses employing standard methods (Atomic Adsorption Spectrophotometry for cations and conventional titration for anions). The chemical parameters obtained were used to compute the irrigation indices which were interpreted using SPSSX software program indicating inter-element and irrigation indices relationship. The statistical values of minimum and maximum chemical parameters and irrigation indices were used to calculate the mean values to check the homogeneity of the irrigation and chemical data. The important constituents that influence water quality for irrigation such as Electrical conductivity (EC), total dissolved solids (TDS), sodium adsorption ratio (SAR), magnesium adsorption ratio (MAR), permeability index (PI), kellys ratio (KR) and residual sodium bicarbonate (RSBC) were assessed and compared with international standards. **Results:** The results indicate that the values of TDS are mainly (<500 mg/l), EC (< 160 µS/cm), SSP (< 80%), PI (< 50%), MAR (<50%), KR (<1), RSBC (<1) and SAR (<10) were largely within the safe limits and with few exceptions suitable for irrigation purposes. Most of the samples are slightly acidic to alkaline, largely soft with fairly low to moderate concentrations of dissolved solids that fall within the international limits for domestic and irrigation purposes. **Conclusions:** They will neither cause salinity hazards nor have an adverse effect on the soil properties and are mostly suitable for domestic and irrigation purposes. However, the concentration of iron and nitrate in less than 1% and 25% of the water samples is higher than the maximum acceptable concentration of 0.3 mg/l and 10 mg/l respectively and should be treated before use.

Keywords: cations, anions, irrigation indices, domestic purposes, Michika Area, Nigeria.

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INTRODUCTION

Groundwater is one of the most valuable natural resources, which supports human health, socio-economic development and functioning of ecosystems[34, 12,28]. Groundwater has become an important water resources issue due to rapid increase of population, rapid industrialization, unplanned urbanization and too much use of fertilizers and pesticide in agriculture[13]. It is the most reliable water resources for the survival of human beings and is widely used for drinking, irrigation and industrial purposes all over the world especially in arid and semi-arid regions where precipitation and surface runoffs are scarce[25].

The quality of groundwater is critical in the regions that are characterized by a semi-arid/arid climate and dominated by agricultural activities and where the water quality is generally affected by diffuse contamination originating from intense irrigated agriculture[25]. Rapid urbanization, especially in developing countries like Nigeria, has affected the availability and quality of groundwater quality due to its overexploitation and improper waste disposal[6]. It is therefore essential to understand the status and suitability of groundwater quality for various purposes as a first step in sustainable water resources management. The sources of water supply to the area are through hand-dug wells, boreholes and surface water. These sources of water supply especially from the hand-dug wells and surface water are polluted due to human activities such as domestic, industrial and agricultural activities. These activities include the use of pit latrines by most residents and indiscriminate dumping of household solid waste as well as the use of agricultural fertilizers in farming activities, which contribute to the contamination of water from different sources in the study area.

Most of the hand-dug wells are shallow and are often left open which renders the well susceptible to contamination by surface water during heavy rainstorms (precipitation) as well as storm runoff from fertilizers. This unfortunate situation has led to the prevalence of water borne diseases.

Furthermore, the study area is an agricultural community that largely uses shallow groundwater tapped by hand-dug well and surface water resources for irrigation purposes. It therefore becomes imperative to regularly monitor the quality of groundwater and to device ways and means to protect it. It is against this background that physic-chemical assessment of shallow groundwater of Michika Area is being carried out. Based on this study recommendation that will serve as useful guide in arresting the situation will be made.

From hydrogeochemcal point of view there is no specific pointed references to previous work evaluating the groundwater qualities in the study area. Although some regional studies were carried out namely[10,5, 8, 16] they did not give detailed information on physicochemical assessment of groundwater quality in the study area, as is detailed as in this study. These studies which discussed the geography, geology and groundwater quality of the Benue Trough were only speculative of groundwater conditions in the study area. Therefore previous work including published and unpublished are quite inadequate for physicochemical assessment of groundwater quality in the study area.

[10] carried the first reconnaissance geological mapping of Northern Nigeria during which he recognized the presence of sediments of Cretaceous and Eocene age. [5]published maps and description of the geology of the Northeastern Nigeria which includes parts of Adamawa, Bauchi and Borno Provinces in which the Basement Complex rocks of Northeastern Nigeria was grouped as Meta Sediments, Older Granites and Burashika Group.

[8]in their work on the distribution and chemical quality of groundwater in Northern Nigeria showed that these waters are calcium or sodium bicarbonate type waters. According to them deviation from the bicarbonate type are less common and suggested that regional chemical characteristics of the water are controlled by the climatic and geological conditions which cause local irregularities. [16] gave some details on the geology and chemical quality of groundwater in the Old Northern Nigeria.

A few number of literatures are also available regarding the assessment of groundwater quality data based on different irrigation indices in different parts of the world [20, 29,27,26,22].

[20]studied the irrigation water quality of some selected villages of Meherpur District of Bangladesh and argued that some of the following ions such as calcium, magnesium, sodium, bicarbonate, sulphate, chloride, potassium, boron and silica are more or less beneficial for crop growth and soil properties in little quantities.

[29]reported that poor quality irrigation water reduces soil productivity, changes soil physical and chemical properties, creates crop toxicity and ultimately reduces yield. [27]assessed the groundwater quality in Mymensigh District of Bangladesh and observed a linear relationship between Sodium Absorption Ratio (SAR) and Soluble Sodium Percentage (SSP). They also discovered that the groundwater could safely be used for long-term irrigation. [26]investigated the water quality of a groundwater basin in Bangladesh for irrigation purposes and observed that standard water quality indices like pH, EC, SAR. RSBC, MAR, PI, KR and TDS are within the acceptable range for crop production. [22]presented a pictorial representation of groundwater quality throughout the Sunangan

District that allowed the delineation of groundwater based on its suitability for irrigation purposes.

As at present no detailed report on the Physichochemical Assessment of groundwater quality of the study area exist. Previous geological appraisal lacked in depth geological and water quality information. This study will give new information on the suitability of shallow groundwater for domestic and irrigation purposes as well as the sources and causes of groundwater pollution in the study area.

MATERIALS AND METHODS

Study Area: The area falls within the Basement Complex of the Northeastern Nigeria and covers an areal extent of about 188.5km^2. It lies within latitudes 10^0 32'N to 10^0 14'N and longitudes 13^0 19' E to 13^0 25'E. It is bounded to the east by Republic of Cameroon, to the south by Mubi Local Government Area of Adamawa State. To the West by Askira Uba Local Government Area of Borno State and to the North by Madagali Local Government Area respectively. The area is traversed by one major highway that runs from Yola to Maiduguri and other minor roads are Michika – Yammu/ Warakanza, Michika- Kopa-kwapale/Villegwa and Michika- Moda/ Mandara roads. These roads link the villages and provide access routes to hilly areas. The study area is hilly to the eastern part and relatively flat to the west. Despite the hilly nature of some parts of the study area, there are still good road networks, foot-paths and tracks that made it accessible (Figure 1).

The study area is part of the Hawal Massif which is one of the three Massifs that occur within the eastern province of the Basement Complex of Northeastern Nigeria. The major rock type in this area includes the New Basalt, Coarse grained Biotite Granites, Coarse Porphyritic Granites and Medium Grained Granites (Figure 2).

These rocks which has been subjected to tectonism leading to the formation of fractures such as joints, faults, dykes and veins which were intruded by the New Basaltic rocks. They have undergone complete weathering, decomposition and lateritization leading to the formation of about 6 meters to 20 meters of unconsolidated weathered overburden layer consisting of gravels, clays, laterites and sands.

Two aquifer units have been identified in the study area based on geological reconnaissance and hydrolithologic analyses of borehole logs[17]. These are the unconsolidated weathered overburden aquifer and the fractured basement aquifer[17].

The fractured basement aquifer consist of rocks that has been subjected to tectonism leading fracturing and consist of jointed, fissured and faulted rocks. They are tapped mainly by deep boreholes.

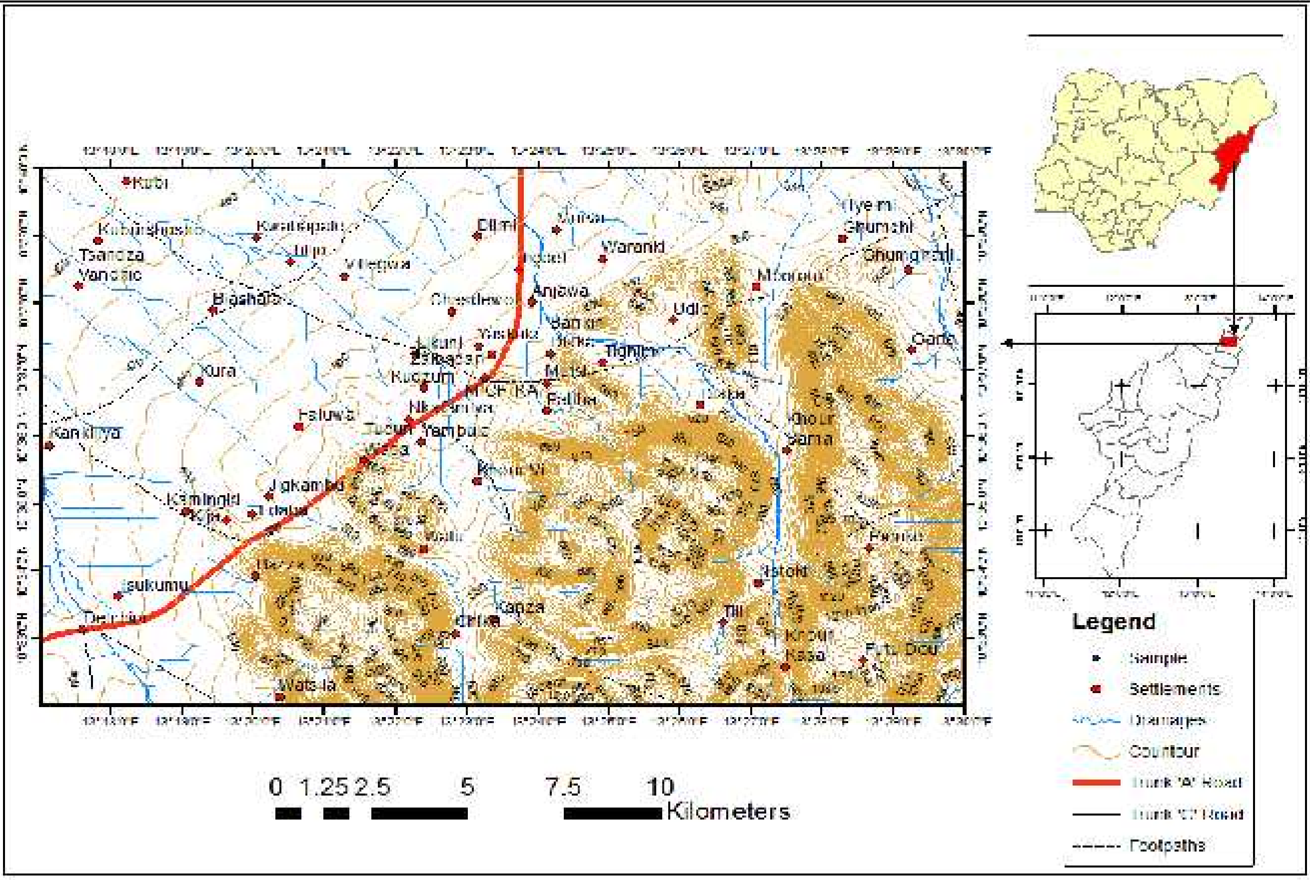

Figure 1 Topographic map of Michika and its Environs.

The unconsolidated weathered overburden aquifer consist of loose unconsolidated to poorly cemented materials such as gravels, sands and clays with grain-size decreasing with increasing distance from the hills. They are tapped mainly by hand-dug wells and shallow boreholes and covers about half of the study area.

This study is confined to the shallow groundwater tapped mainly by hand-dug wells and shallow boreholes which is vulnerable to pollution and used for irrigation and other domestic purposes. The depth to static water level in this aquifer varies from 2.9 meters to 9.7 meters with a mean value of 7.28.

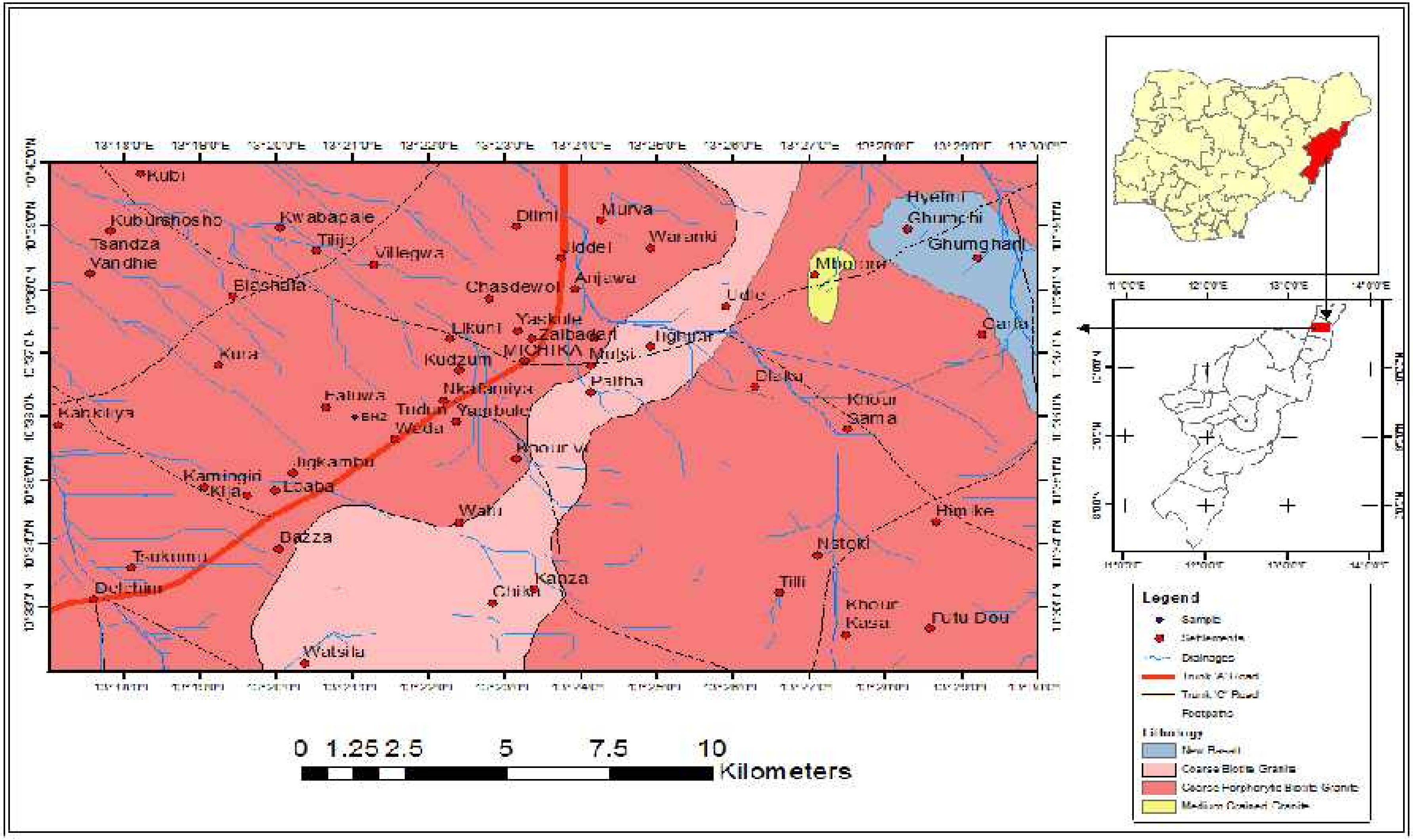

Figure 2 Geological Map of Michika and Its Environs.

Sample Collection and Preparation: For chemical analyses purpose a total of forty shallow ground water samples consisting of hand-dug wells and shallow boreholes were collected from different locations between the months of August and September 2015. The samples were filtered through a thin polycarbonate membrane with 0.45µm pore size and collected in polyethylene bottles of four litre capacity with stopper. Each bottle was washed with 2% Nitric acid and then rinsed several times with distilled water and preserved in a cool, clean place prior to analysis. The water samples were analyzed for various parameters in the newly equipped chemical laboratory of the Adamawa State Water Board Yola, Nigeria. Various physicochemical parameters like Temperature, pH, Turbidity, Total Dissolved Solids (TDS), Total Hardness, Dissolved Oxygen (DO), Electrical Conductivity (EC), Chloride, Sulphate, Total Alkalinity, Fluoride, Iron, Calcium, Magnesium, Nitrate-Nitrogen have been measured.

In general, the standard methods recommended by[1]. [31]were adopted for determination of various physico-chemical parameters. A brief description is given as follows;

Physicochemical parameters such as Temperature, pH, Turbidity, Dissolved Oxygen (DO), Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were measured using water analysis kit model (Merk, DR Spectrophotometer 2400). All multi-probes of the kit were calibrated together using the same standards and procedures.

Electrical Conductivity was calibrated against 0.005, 0.05 and 0.5 M standard potassium Chloride solutions. pH was calibrated with standard buffer solution at pH-4 and pH-9.2. Dissolved Oxygen was calibrated against zero solution (Sodium Sulphite) and an air saturated beaker of water checked with a Winklers's titration. Temperature is factory set and cannot be adjusted but was checked against a standard Mercury Thermometer for consistency between multi-probes. Turbidity was calibrated with standard solution of 400 NTU using Hydrazine Sulphate and Hexamethylenetetramine. Dissolved Oxygen was also measured by modified Winkler's method at the site.

For the determination of Hardness, 50 ml of sample was buffered at pH 8-10 (NH_4Cl and NH_4OH) and titrated against standard EDTA using Erichrome Black T indicator. Calcium was measured by titrating the water sample against standard EDTA using murexide indicator. Magnesium was determined by calculation method using the formular (APHA, AWWA, WPCF 1998).

$$Mg(Mg/l) = (Total\ Hardness - Calcium\ Hardness) \times 0.243 \quad (1)$$

The Total Alkalinity was measured by titrating the sample against N/50 solution of sulphuric acid using methyl orange and phenalthalein indicator respectively. Chloride content was measured by titrating against N/50 solution of silver nitrate using potassium chromate as indicator. Fluoride, Sulphate, Nitrate-Nitrogen and Iron were determined spectrophotometrically following the standard procedure recommended by APHA, AWWA, WPCF (1998). All the samples were assessed for charge balance and most of them fall within the acceptable range of ±5.

Mathematical Calculations: The Sodium Adsorption Ratio (SAR) was calculated by the following equation given by[23] as:

$$SAR = \frac{Na^+}{\sqrt{\left(\frac{Ca^{2+}+Mg^{2+}}{2}\right)}} \quad (2)$$

Where all the ions are expressed in meq/litre

The Soluble Sodium Percentage (SSP) was calculated by the following equation[30]:

$$SSP = \frac{(Na^+ + K^+) \times 100}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \quad (3)$$

Where all the ions are expressed in meq/litre

The Residual Sodium Bicarbonate (RSBC) was calculated according to[11]

3.5.11 $RSBC = HCO_3 - Ca$ (4)

Where RSBC and the concentration of the constituents are expressed in meq/litre

The Permeability Index (PI) was calculated according to[7] employing the following equation.

$$PI = \frac{Na^+ + \sqrt{HCO_3^- \times 100}}{Ca^{2+} + Mg^{2+} + Na^+} \quad (5)$$

Where all the ions are expressed in meq/litre

The Magnesium Adsorption Ratio (MAR) was calculated using the following equation[21]

$$MAR = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}} \quad (6)$$

Where all the ionic constituents are expressed in meq/litre

The Kellys Ratio was calculated employing the following equation[15] as:

$$KR = \frac{Na^{+}}{Ca^{2+}+Mg^{2+}} \quad (7)$$

Where all the ionic constituents are expressed in meq/litre

The Total Dissolved Solids (TDS) was calculated employing the following equation[23]:

$$TDS = (0.64 \; x \; EC \; x \; 106)\,(Micro-mhos/cm) \quad (8)$$

Where Electrical Conductivity (EC) and TDS are expresses in Micro-mhos/cm and mg/litre respectively.

Statistical Analyses:

Data analyses to check for statistical errors was carried out. It was done from electrical balance EB calculations since the sum of positive and negative charges in the water should be equal and expressed mathematically as follows[2]:

Electrical Balance (EB) = Sum cations- Sum anions/Sum cations+ Sum anions x 100
9

Where cations and anions are expressed as meq/l and inserted with their charge sign. The sums are taken over the cations (Na^{+}, K^{+}, Mg^{2+} and Ca^{2+}) and the anions (Cl^{-}, HCO_3^{-} and SO_4^{2-}) and were found to be within the acceptable range of ±5.

The chemical parameters obtained were used to compute the irrigation indices which were interpreted using SPSSX software program indicating inter-element and irrigation indices relationship. The statistical values of minimum and maximum chemical parameters and irrigation indices were used to calculate the mean values to check the homogeneity of the irrigation and chemical data.

RESULTS AND DISCUSSION

This study is confined to shallow boreholes and hand-dug wells because of their vulnerability to pollution from anthropogenic activities.

Assessment of physicochemical qualities of shallow groundwater

The chemical composition of the shallow groundwater is related to the solid product of rock weathering and changes with respect to time and space as well as anthropogenic activities.

Therefore, the variation on the concentration levels of the different hydrogeochemical constituents dissolved in water determines its usefulness for domestic, industrial and agricultural purposes.

However, the use of water for any purpose is guided by standard set by the World Health Organization and other related agencies. In this study, the results of the analyzed chemical parameters in the study area were correlated with those of the[33].

The analyzed physical parameters are Temperature, Turbidity, pH, EC and TDS. Results show that the temperature of the sampled water ranged between 23.7 ^{o}C to $31^{0}C$ with mean value of 29.66 ^{0}C, the least value was recorded in Michika Central (BH1) and the highest value in Huzuku (HDW1), pH ranged between 5.1 and 7.6, with the mean value of 6.26, the least value was recorded in Bize (HDW4) and the highest value in Tudunwada (HDW3), EC ranged between 25 and 165 µs/cm with the mean value 92.3 µs/cm, whereas the least and high value found in Kwatabe (BH4) and Tudunwada (HDW3) respectively. The TDS ranged between 130 to 310 mg/l with means value 192 mg/l whereas the least and high values were recorded in Kwatabe (BH4) and Futu (BH5) respectively.

The chemical parameters analyzed were the major cations (Mg^{2+}, Ca^{2+}, Fe^{2+}, Na^{+} and K^{+}.) and anions (Cl^{-}, HCO_3, NO_3^{-}, SO_4^{2-} and CO_3^{2-}). Their concentrations vary from one location to the other depending on the local geology of the area and other human related activities[18,19].

The results of these chemical parameters show that the Magnesium, ranged between 5 mg/l in Thuri borehole (BH15) and 36 mg/l in Warakanza borehole (BH9) with a mean value of 14.11 mg/l. The Calcium value ranged between 36 mg/l in Minkisi borehole (BH18) and 124 mg/l in Michika Central (BH1) with the mean value of 69.68 mg/l. The Fe^{2+} ranged between 0.00 in Moda borehole (BH12) to 1.00 mg/l in Simike hand-dug well (HDW6) with a mean value of 0.26 mg/l. The total hardness ($CaCO_3$) values varied from 8.9 mg/l in Minkisi borehole (BH18) to 312 mg/l in Michika Central with the mean value of 165 mg/l. The bicarbonate values varies from 53.6 mg/l in Minkisi borehole to 361.32 mg/l in Michika Central borehole (BH1) with mean value of 152.25 mg/l. The Chloride revealed values of 31 mg/l in Garta hand-dug well (HDW5) to values of 206 mg/l in Sangere borehole (BH13) with a mean value of 85.10 mg/l. The nitrate nitrogen varied from 4 mg/l in Kubi hand-dug well (HDW8) to values of 14 mg/l in Dlaka and Warakanza boreholes (BH6 and BH9) with a mean value of 8.75 mg/l. The sulphate disclosed values of 32 mg/l in Kubi hand-dug well (HDW8) to values of 128 mg/l in Yammu borehole (BH2) with a mean value of 51.25 mg/l. The carbonate values varied from 53 mg/l in Minkisi borehole (BH18) to values of 187 mg/l in Michika Central borehole (BH1) with a mean value of 101.92 mg/l.The complete results are presented in Tables 1a,b and summarized in Table 2.

Total hardness

The water samples from all the settlements in the study area with few exceptions are moderately hard to very hard with values ranging between 8 mg/l to 312 mg/l compared to the maximum allowable limits of [33]. Standard of 150mg/l. The relatively high hardness values recorded in the water samples may be due to anthropogenic activities such as the excessive application of lime to the soils in agricultural areas.

Calcium

Calcium contributes to the hardness of water and it is the fifth most common element found in most natural waters. It is an important contributor to water hardness. The calcium concentration varies from 36 mg/l to 113 mg/l with 32.5% of the samples having values that are above the[33] recommended limit of 75 mg/l. The possible sources of this calcium in the study area are from the weathering of plagioclase feldspar as well the calc-alkaline rocks that are rich in alkaline earth metals such as magnesium and calcium.

Magnesium

Magnesium is one of the most common elements in the earth’s crust. It is present in all natural waters. It is an important contributor to water hardness.

The magnesium concentration varies from 5 mg/l to 36 mg/l with none of the samples having magnesium values that are above the[33] recommended limit of 50 mg/l. The potential sources of magnesium include weathering of ferro-magnesium igneous rocks that underlies the study area.

Table 2 Summary of Physicochemical parameters of the shallow groundwater in the Study Area.

PARAMETER	RANGE	MEAN	WHO (2011)
PH (unit)	5.1 – 7.6	6.26	6-5 – 8.5
Temperature (0/c)	23-31	29.66	-
Conductivity (µS/cm)	25- 165	92.3	140
Sodium (mg/l)	11.5-135	55.83	200
Potassium (mg/l)	0-11	2.03	55
Calcium (mg/l)	36-113	69.68	75
Magnesium(mg/l)	5-36	14.11	50
Iron (mg/l)	0-1.00	0.26	0.3
Chloride (mg/l)	31-206	85.10	250
Sulphlate (mg/l)	32-128	51.25	400
Bicarbonate (mg/l)	53.6-361.32	150.25	1000
Nitrate –N (mg/l)	4-14	8.75	10
TDS (mg/l)	130-310	192.05	1000
Total Hardness (mg/l)	8-312	165.80	500
CO_3	53-187	101.92	120
Turbidity (NTU)	1-2.4	1.40	5

Table 1a: Results of Chemical Analyses of Shallow Groundwater Samples in the Study Area.

S/NO	Sample Location	$T^{O}C$	PH	TURBID NTU	TDS Mg/l	EC. µS/cm	Total hardness	Ca^{2+} Mg/l	CO_3^{2-} Mg/l	$NaCl_2$ Mg/l	Cl^- Mg/l	Na^+ Mg/l	K^+ Mg/l	Fe_2 Mg/l	SO_4 Mg/l	NO_3 Mg/l	Mg Mg/l	Cu^+ Mg/l	$HC0_3$ Mg/l
1	Michika cent.BH1	23.7	6.8	1	240	120	312	124.8	187	211	128	83	2	0.06	67	12	34	0.02	361.32
2	Yammu BH2	25	5.5	2.2	180	95	284	113.6	170	198	180	78	3	0.12	128	10	12	0.01	346.36
3	Jidil BH3	30	6.5	1.1	200	105	244	97.6	146	105.6	64	41.6	0.8	0.08	61	8	25	0.03	256.92
4	Huzuku HDW1	31	5.8	2.4	280	140	204	81.6	122.9	95.7	58	37.7	0.9	0.04	48	6	36	0.05	267.11
5	Meze HDW2	31	6.0	2	160	80	126	50.4	76	112.7	68	44	0.4	0.03	40	12	24	0.03	163.3
6	Kwatabe BH4	27.8	6.5	1.4	130	65	144	58	86	89	54	35	0.7	0.08	46	12	18	0.02	158.2
7	Tudun Wada HDW3	26.4	7.6	1.9	210	165	121	49	72	201	122	79	0.5	0.12	54	8	10	0.03	101.8
8	Futu BH5	30	7.4	1.3	310	150	109	44	65	165	100	65	3	0.06	38	6	24	0.05	149.36
9	Dlaka BH6	31	6.3	1.2	180	85	164	56	108	66	40	22	0.6	0.13	59	14	26	0.02	116.11
10	Bize HDW4	31	5.1	2.2	140	70	176	70	106	64.6	39	25	0.7	0.17	62	9	30	0.04	202.69
11	Garta HDW5	27	5.8	1.8	260	125	146	59	87	205.5	31	11.5	0.9	0.12	46	11	25	0.03	151.31
12	Simike HDW6	27	5.5	2.4	170	90	148	65	89	73	45	34	6.8	1	39	8	15	0.04	172.18
13	Kamale BH7	30	6.9	1.2	240	120	116	52	70	86	52	40	6.6	0.06	37	10	16	0.02	145.1
14	Mbororo BH8	24	6.6	1.3	200	160	221	88	133	175	106	72	6	0.1	45	12	15	0.03	260.4
15	Warakanza BH9	24	7.4	1.1	166	85	229	91	138	191	115	76	0.4	0.3	60	14	36	0.01	261.56
16	Watsila HDW7	31	6.9	1.2	190	90	241	96	145	178.2	108	76	2	0.4	55	8	20	0.03	295.1
17	Kubi HDW8	31	6.3	1.7	260	25	144	63.6	86	73	44	35	6.4	0.09	32	4	13	0.03	170.71
18	Bazza HDW9	25.6	5.2	1	190	95	146	65.5	88	124	75	56.5	7.3	0.05	60	9	15.5	0.02	192.17
19	Viboka HDW10	31	6.2	1.2	200	100	217	96	130	75	45	39	11	0.6	55	8	19	0.01	239.23
20	Zukui BH10	31	5.5	1.4	180	90	132	59	79	150	80	56	8	1	48	12	14	0.04	137.4

Table 1b Results of Chemical Analyses of Shallow Groundwater Samples in the Study Area

S/N	SAMPLE LOCATION	Temp ^{0}C	PH	TUR BNT U	TDS Mg/L	CON D μS/Cm	TOTAL HARDNESS	Ca^{2+}	CO_3	$NaCl_2$	CL	Na+	K^+	Fe^{2-}	$S0_4$	NO_3	Mg^+	CU^+	HCO_3
21	Woro Ngiki BH11	31	5.2	1.0	260	130	217	87	130	147	89	57	0.3	0.3	56	9	12	0.01	131.1
22	Moda BH12	31	5.8	1.2	180	90	146	59	87	280	170	110	1.0	0.0	52	6	8	0.00	87.7
23	Sangere BH13	31	6.5	1.2	200	98	176	70	106	339	206	133	0.3	0.1	58	8	6	0.02	106.8
24	Hausari BH14	31	5.8	1.1	170	84	126	50	76	293	178	115	0.5	0.2	39	7	10	0.01	76.9
25	Jang BH15	31	5.6	2.0	210	105	144	58	86	190	115	75	0.4	0.3	50	5	8	0.00	86.9
26	Thuri BH16	31	6.5	1.8	140	70	109	44	65	78	48	32	1.0	0.1	35	8	5	0.01	65.8
27	Kwabapale BH17	31	7.2	1.5	200	100	176	70	106	180	110	70	0.8	0.2	60	10	9	0.01	107.2
28	Minkisi BH18	31	6.8	1.0	180	90	8.9	36	53	60	36	24	0.3	0.3	48	14	10	0.00	53.6
29	Wato BH19	31	6.5	1.2	130	65	217	87	130	75	45	30	2.0	1.0	55	6	6	0.00	131.3
30	Sinagali BH20	31	5.8	1.1	160	80	13	53	79	150	80	50	1.4	0.5	48	8	12	0.01	80.1
31	Kurvi BH21	31	6.5	1.0	150	75	221	88	133	112	68	44	1.3	0.2	37	5	8	0.00	134.2
32	Kuda BH22	31	5.8	1.2	190	90	126	50	76	200	120	80	0.8	0.1	45	9	5	0.02	78.1
33	Pambila BH23	31	6.8	1.0	210	100	284	113	170	95	60	135	0.2	0.3	58	10	6	0.00	172
34	Madzi BH24	31	6.5	1.0	176	80	146	59	87	120	70	50	1.0	0.0	52	5	8	0.00	89.1
35	Rafisanye BH25	31	5.8	1.1	160	80	98	40	55	86	52	34	0.5	0.0	38	7	11	0.01	56.1
36	Luhu BH26	31	6.0	1.2	180	90	140	56	82	165	100	65	0.0	0.1	60	8	8	0.00	83.2
37	Karyanga BH27	31	7.1	2.0	220	110	145	57	85	165	64	41	0.1	0.2	42	6	10	0.00	86.8
38	Bulabuli BH28	31	6.5	1.5	140	70	125	60	77	147	89	57	0.2	0.4	40	10	8	0.01	61.3
39	Dlaka BH29	31	7.0	1.0	190	85	200	80	120	68	40	28	0.6	1.0	50	12	9	0.01	81.4
40	Kwaburshosho BH30	31	6.8	1.0	150	65	150	90	90	190	110	80	0.4	0.5	55	9	10	0.00	92.1

Iron

Iron is a very common element found in many of the rocks and soils of the earth's crust. It is also an essential trace element for animal growth. Soluble ferrous iron is present in natural water with a low Eh. The iron concentration varies from 0.10 mg/l to 1.00 mg/l with 0.23% of the samples having iron values that are above the[33] recommended limit of 0.30 mg/l. The potential sources of iron in the study area include weathering of Ferro-magnesium minerals in rocks and lateritic rock that underlies the study area.

Sulphate

Sulphate occurs in water as inorganic sulphate salts as well as dissolved gas (H_2S). It is not a noxious substance although high sulphate in water may have a laxative effect on people. The Sulphate concentration varies from 32 mg/l to 128 mg/l in study area with none of the samples having sulphate values above the[33] recommended limit of 400 mg/l.

Potential sources of sulphate include weathering of sulphate and sulphide minerals of igneous rocks that underlie the study area as well as fall out from atmospheric sources.

Bicarbonate

Bicarbonate combines with calcium carbonate and sulphate to form heat retarding, pipe clogging scale in boilers and in other heat exchange equipment. The bicarbonate concentration varies from 53.60 mg/l to 361.32 mg/l with none of the samples having bicarbonates values that are above the[33] recommended limit of 1000 mg/l. Potential sources of bicarbonate in the study area include oxidation of organic matter as well as carbon dioxide content of the atmosphere and respiration by plants and soil organisms.

Nitrate

Nitrate nitrogen concentration varies from 4 mg/l to 14 mg/l with none of the samples having nitrate values that are above the[33] recommended limit of 10 mg/l.

Sources of nitrate in water include human activity such as application of fertilizer in farming as well as human and animal wastes. The study area is highly populated and the human waste management system is poor (shallow pit toilets and open defecation in the bushes is a common practice) and also the use of nitrogenous fertilizer and animal dump in farming is rampant. The migration of the chemical in these location is facilitated by sandy nature of the superficial geology.

Chloride

A major ion that may be associated with Individual Septic Disposal System (ISDSS) is chloride[4]. Chloride is present in all natural waters but in relatively small amounts; however, chloride also can be derived from human sources such as human excreta as well as weathering of igneous rocks. Chloride is present in relatively small amounts in igneous rocks.

The chloride concentration varies from 31 mg/l to 206 mg/l with none of the samples having chloride values that are above the[33] recommended limit of 250 mg/l.

Potential sources of chloride in the study area include atmospheric sources human excreta and weathering of the underlying igneous rocks.

Total dissolved solids

Total Dissolved Solid (TDS) generally reflects the amount of minerals content that are dissolved in the water and controls its suitability for domestic, agricultural and industrial use. High concentration of total dissolved solids may cause adverse taste effects. Highly mineralized water may also deteriorate domestic plumbing appliances.

The total dissolved solids (TDS) concentration varies from 130 mg/l to 310 mg/l with none of the samples having TDS values that are above the[33] recommended limit of 500 mg/l.

The TDS of the study area falls within the[33] recommended limit of 500 mg/l and thus suitable for human consumption (domestic) and agricultural purposes.

Electrical conductivity

Electrical Conductivity (EC) is a measure of the ability of water to conduct an electric current. It is used to estimate the amount of dissolved solids. It increases as the amount of dissolved mineral (ions) increases. The EC concentration varies from 25 µS/cm to 200 µS/cm with two of the samples having EC values that are above the[33] recommended limit of 140 µS/cm (Table 6). They are thus largely suitable for domestic and agricultural purposes.

Hydrogen ion concentration

The pH is a measure of the hydrogen ion concentration in water. The pH value of water indicates whether the water is acidic or alkaline. Drinking water with a pH values of between 6.5 to 8.5 is generally considered satisfactory. Acid water tend to be corrosive to plumbing and faucets, particularly, if the pH is below 6. Alkaline waters are less corrosive whereas water with a pH above 8.5 may tend to have a biter or soda-like taste. The pH concentration varies from 5.11 to

7.60 with 47.5 % of the samples having pH values that are above the[33] recommended limit of between 6.5 and 8.5.

Assessment of Ground water Quality for domestic and irrigation purposes

Assessment of the groundwater quality of the study area was done to determine its suitability for domestic and agricultural purposes and water for each of these purposes is required to meet certain safety standards that have been set by the World Health Organization.

Domestic Purposes

All the analyzed parameters of the water samples of the study area with the exception of hydrogen ion concentration (pH) fall within the[33] recommended limits. Furthermore of these samples about 52.5% of these sample have pH values that are within the[33] recommended limits of between 6.5 and 8.5. These indicate that the samples are largely portable for human for human consumption and other domestic purposes.

The assessment of some contamination indicators such as pH, sulphate, chloride and nitrate indicate that the shallow groundwater is largely suitable for human consumption. The concentration of iron in all the analyzed samples is within the[33] recommended limits of 0.3 mg/l and thus suitable for domestic purposes.

Irrigation Purposes

Water for agricultural purposes should be good for both plant and animals. Good quality of waters for irrigation are largely characterized by acceptable range of parameters such as Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Bicarbonate (RSBC), Magnesium Adsorption Ratio (MAR), Kelly's Ratio (KR), Total Dissolved Solids (TDS), Permeability Index (PI) and Electrical Conductivity (EC). The results of the different irrigation indices for rating irrigation water quality are presented in Table 3 and summarized in Table 4.

Sodium Adsorption Ratio indicator

The sodium adsorption ratio gives a clear idea about the adsorption of sodium by soil. It is the proportion of sodium to calcium and magnesium, which affect the availability of the water to the crop. The sodium adsorption ratio of shallow groundwater obtained in the present study are generally less than 10 and fall under the category of I indicating low alkali hazards and excellent irrigation water (Table 5).

Soluble Sodium Percentage indicator

Sodium percent is an important factor for studying sodium hazard. It is also used for adjudging the quality of water for agricultural purposes. High percentage sodium water for irrigation purpose may stunt the plant growth and reduces soil permeability[14].

The soluble sodium percentage values of shallow groundwater in the study area ranges between 9.42 % and 60.10 % with a mean value of 34.81% indicating low alkali hazards and fair (Category III) to excellent (Category I) irrigation quality (Table 5)[32].

Table 3: DIFFERENT PARAMETER INDICES FOR RATING SHALLOW GROUNDWATER IN THE STUDY AREA

S/N	Location	Well No	SAR	SSP (%)	MAR (%)	KR	PI (%)	TDS Mg/l	RSBC (Meq/l)	EC (μS/cm)
1	**Michika Central**	**BH1**	1.70	28.77	31.27	0.40	47.69	240	3.06	120
2	**Yammu**	**BH2**	1.86	34.21	14.99	0.51	57.40	180	4.68	95
3	**Jidil**	**BH3**	0.97	20,84	29.96	0.26	44.07	200	2.13	200
4	**Huzuku**	**HDW1**	0.87	19.03	42.42	0.23	42.84	280	1.40	140
5	**Meze**	**HDW2**	1.27	29.27	42,30	0.42	55.21	160	0.70	80
6	**Kwatabe**	**BH4**	1.03	25.95	34.95	0.35	52.94	130	1.07	65
7	**Tudunwada**	**HDW3**	2.68	57.69	25.41	1.05	70.28	210	0.72	165
8	**Futu**	**BH5**	1.95	41.02	47.66	0.67	62.53	310	0.42	150
9	**Dlaka**	**BH6**	0.61	16.38	43.68	0.19	39.37	180	0.54	85
10	**Bize**	**HDW4**	0.63	15.56	41.70	0.18	41.09	140	0.86	70
11	**Garta**	**HDW5**	0.32	9.42	41.44	0.10	40.84	260	0.35	125
12	**Simike**	**HDW6**	0.97	26.88	27.81	0.33	52.88	170	1.30	90
13	**Kamale**	**BH7**	1.24	32.71	33.84	0.44	57.93	240	0.79	120
14	**Mbororo**	**BH8**	1.86	36.80	22.16	0.55	60.22	200	3.06	160
15	**Warakanza**	**BH9**	1.70	30.52	39.48	0.44	49.56	166	1.35	85
16	**Watsila**	**HDW7**	2.00	38.01	30.84	0.60	62.66	190	4.19	90
17	**Kubi**	**HDW8**	1.01	26.55	25.44	0.36	55.29	260	1.41	25
18	**Bazxa**	**HDW9**	1.63	36.70	28.33	0.54	60.31	190	1.52	95
19	**Viboka**	**HDW10**	0.95	23.23	24.84	0.27	4.56	200	6.37	100
20	**Zukul**	**BH10**	1.70	39.09	28.42	0.59	60.11	180	0.77	90
21	**Wuro Ngiki**	**BH11**	1.52	31.76	18.72	0.47	50.44	260	1.14	130
22	**Moda**	**BH12**	3.56	57.11	18.47	1.32	71.26	180	0.73	90
23	**Sangere**	**BH13**	4.09	59.23	12.52	1.45	72.69	200	1.29	98

24	**Hausari**	**BH14**	3.88	60.10	25.03	1.50	73.52	170	0.80	84
25	**Jang**	**BH15**	2.44	47.88	18.73	0.92	65.30	210	0.73	105
26	**Thuri**	**BH16**	1.24	36.05	16.59	0.55	62.24	140	0.73	70
27	**Kwabapale**	**BH17**	2.09	41.93	1.77	0.72	59.96	200	1.05	100
28	**Minkisi**	**BH18**	0.91	28.57	31.68	0.40	53.83	180	0.02	90
29	**Watu**	**BH19**	0.83	21.88	10.33	0.27	45.11	130	1.65	65
30	**Sinagali**	**BH20**	1.61	37.79	27.43	0.60	57.05	160	0.30	80
31	**Kurvi**	**BH21**	1.20	27.79	13.19	0.38	40.17	150	1.57	75
32	**Kuda**	**BH22**	2.88	54.58	14.31	1.19	73.64	190	0.82	90
33	**Pambila**	**BH23**	3.35	48.90	8.14	0.96	62.87	210	2.35	100
34	**Madzi**	**BH24**	1.62	37.90	18.47	0.60	58.47	176	0.75	80
35	**Rafisanye**	**BH25**	1.22	33.86	31.47	0.74	55.50	160	0.003	80
36	**Luhu**	**BH26**	2.15	44.95	19.27	0.82	63.53	180	0.64	90
37	**Karyanga**	**BH27**	1.31	32.69	22.57	0.48	54.50	220	0.58	110
38	**Bulabuli**	**BH28**	1.83	40.41	18.22	0.68	56.69	140	-0.09	70
39	**Dlaka**	**BH29**	0.79	20.62	15.82	0.26	39.81	190	0.59	85
40	**Kwabursho**	**BH30**	2.13	39.58	15.65	0.65	53.47	150	-0.81	65

TABLE 4: STATISTICAL SUMMARY OF DIFFERENT IRRIGATION INDICES OF SHALLOW GROUNDWATER IN THE STUDY AREA

Parameter	Concentration		
	Minimum	Maximum	Mean
SAR	0.32	4.09	1.69
SSP (%)	9.42	60.10	34.81
EC (µS/cm)	25	200	97.68
MAR (%)	1.77	47.66	25.38
KR (meq/l)	0.10	1.50	0.59
P1 (%)	4.56	73.52	54.70
T.D.S (mg/l)	130	310	118.65
RSBC (meq/l)	-0.09	6.37	1.29

Residual Sodium Bicarbonate indicator

The concentration of bicarbonate and carbonate influences the suitability of water for irrigation purpose. The water with high RSBC has high pH. Therefore, land irrigated with such water becomes infertile owing to deposition of sodium carbonate[9]. The residual sodium bicarbonate values of water samples from the study area vary from -0.09 meq/l to 6.37 meq/l with a mean value of 1.29.

The residual sodium bicarbonate values are less than 3.0 meq/litre and are therefore considered safe for irrigation purposes (Table 5).

Table 5: Limits of some parameter indices for rating groundwater quality and its sustainability.

Category	EC (μS/cm)	RSBC meq/l	SAR	SSP %	Sustainability for irrigation
I	<117.509	<1.25	<10	<20	Excellent
II	117.509-509.61	1.25-2.5	10-18	20-40	Good
III	>509.61	>2.5	18-26	40-80	Fair
IV			>26	>80	Poor

Magnesium Adsorption Ratio indicator

Magnesium content of water is considered as one of the most important qualitative criteria in determining the quality of water for irrigation. Generally, calcium and magnesium maintain a state of equilibrium in most waters. More magnesium in water will adversely affect crop yields as the soils become more saline[14].

The values of The magnesium adsorption ratio of shallow groundwater in present study varies from 1.77 % to 47.66 % with a mean value of 25.38 % indicating that they are below the acceptable limit of 50%[3]. The waters are therefore considered suitable. This is because high magnesium adsorption ratio causes a harmful effect to soil when it exceeds 50%.

Kelly's Ratio indicator

The Kelly's Ratio (KR) values of the study area ranged between 0.10 and 1.50 with a mean value of 0.59. These indicate that Most of the KR for the shallow groundwater samples however fall within the permissible limit of 1.0 and are considered suitable for irrigation purposes.

Total Dissolved Solids indicator

Salts of calcium, magnesium, sodium, potassium present in the irrigation water may prove to be injurious to plants. When present in excessive quantities, they reduce the osmotic activities of the plants and may prevent adequate aeration.

The TDS value of the study area ranges from 130 mg/l to 310 mg/l with a mean value of 118.65. They are generally less than 200 mg/l and can be classified as excellent irrigation water according to[24].

Permeability Index indicator

The soil permeability is affected by the long-term use of irrigated water and the influencing constituents are the total dissolved solids, sodium bicarbonate and the soil type. In the present study, the permeability index values range between 4.56 % to 73.52 % with a mean value of 54.70 %. The above result therefore suggests that water samples fall within Class I and Class II and can be categorized as good irrigation water[7].

Electrical Conductivity indicator

The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC). The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water is available to plants; even though the soil may appear wet. Thus because plants can only transpire water ("pure water"), usuable plant water in the soil solution decreases dramatically as EC increases[14].

On the basis of electrical conductivity, the irrigational classification is given in Tables 5 and 6. The electrical conductivity values of all the analyzed samples ranges from 25 µS/cm to 200 µS/cm with a mean value of 97.68 µS/cm are generally less than the[33] recommended limit of 140 µS/cm and fall below 250 µS/cm (Table 6).

Table 6: Quality of Irrigation Water In Relation To Electrical Conductivity (EC) After Richards 1954

S/No	Electrical conductivity (μS/cm)	Type of water	Suitability for irrigation	Remarks
1	Below 250	Low saline water	Entirely safe	All samples in the study area fall within this zone
2	250-750	Moderately saline (2)	Safe under practically all conditions	NIL
3	750-2250	Medium to high salinity (3)	Safe only with permeable soil and Moderate Leaching	NIL
4	Above 2250			
(i)	2250-4000	High salinity	Unfair for irrigation	NIL
(ii)	4000-6000	Very high salinity	Unfair for irrigation	NIL
(iii)	Above 6000	Excessive salinity class	Unfair for irrigation	NIL

Furthermore, the values of total dissolved solids (< 500 mg/l), electrical conductivity (< 160 μS/cm), soluble sodium percentage (< 80 %), permeability index (< 50 %), residual sodium bicarbonate (< 2.50), Kelly's ratio (<1.00) and sodium adsorption ratio (< 10) obtained for most of the water samples were found to be within the safe limits for irrigation purposes. Thus most of the shallow ground waters indicate low sodic waters that will neither cause salinity hazards nor have adverse effect on the soil properties. They are therefore largely suitable for irrigation purposes.

However, some wells such as BH3 Jidil, BH12 Moda, BH13 Sangere, BH14 Hausari, BH22 Kuda and HDW3 Tudunwada should be treated for salinity hazards before use. This study discovered that the chemical composition of the shallow groundwater is strongly influenced by anthropogenic activities but is largely suitable for domestic and irrigation purposes. This is beneficial for farmers because the shallow groundwater will neither cause salinity hazards nor have an adverse effect on the soil properties. This study will help the researchers to uncover the critical areas of shallow groundwater in irrigation in a remote semi-arid basement terrain of northeastern Nigeria that many researchers are not able to explore. Thus a new research findings, data and information and conclusions on the suitability of shallow groundwater of Michika Area of Northeastern Nigeria has been arrived at.

Conclusion

The groundwater quality of Michika Area of Northeastern Nigeria was assessed for its irrigational and domestic suitability. The result revealed that the values of total dissolved solids (< 500 mg/l), electrical conductivity (< 160 μS/cm), soluble sodium percentage (< 80 %), permeability index (<50 %), residual sodium bicarbonate (<1.0), Kelly's ratio (< 1.00) and sodium adsorption ratio (<10) obtained for most of the water samples occurred within the safe limits. These indicate low sodic waters that will neither cause salinity hazards nor have an adverse effect on the soil properties and are thus largely suitable for irrigation purposes.

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