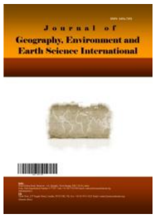

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Evaluation of Irrigation Quality of Groundwater in Wamba Sheet 210, North Central Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An evaluation of irrigation quality of groundwater from shallow aquifers within Wamba Sheet 210 in Nasarawa State, North Central Nigeria was carried out. The area is located between Latitudes 8°30'N and 9°00'N, and Longitudes 8°30'E and 9°00'E, covering about 3,025 Km^2. It is underlain by rocks belonging to the Basement Complex, the Younger Granites, and Cretaceous sedimentary rocks. The results of field tests and laboratory analysis were used in assessing the suitability of groundwater found in the area for irrigation. Values obtained for Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Magnesium Adsorption Ratio (MAR) and Kellys Ratio (KR) were 0.97 - 3.43, 8.18 - 81.76%, 8.03 - 80.22 and 0.04 - 3.43 respectively. These indices are largely within the safe limits for irrigation with very little likelihood that salinity hazards will develop.

Keywords: Wamba sheet 210; irrigation; Sodium Adsorption Ratio (SAR); Soluble Sodium Percentage (SSP); Magnesium Adsorption Ratio (MAR); Kellys Ratio (KR).

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1. INTRODUCTION

Population increase and increase in food demand, as well as a prolonged period of the dry season being experienced in northern parts of Nigeria, have led farmers in many communities to embark on dry season farming through irrigation, utilizing groundwater from shallow aquifers. Irrigation is the application of water to a crop to replace the climatic moisture deficit, especially during the dry season. Until recently, most streams and rivers within Wamba Sheet 210 were perennial, but are now mostly dry from November to April, necessitating the use of groundwater for irrigation as land use in the area is mainly for agriculture.

For water to be suitable for irrigation, indices such as Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Magnesium Adsorption Ratio (MAR) and Kellys Ratio (KR) must be within acceptable limits for crops to thrive because accumulation of ions especially sodium causes deterioration in the soil physical properties leading to a decrease in crop yield [1,2,3]. Assessment of water quality indices for irrigation is essential if the good agricultural output is to be achieved. This study intends to investigate the physical and chemical characteristics of groundwater from shallow aquifers within Wamba Sheet 210, to determine their suitability for irrigation.

2. MATERIALS AND METHODS

2.1 The Study Area

The study area (Wamba Sheet 210) is located in North Central Nigeria. The area falls within the Guinea Savannah characterized by short grasses and scattered trees. It is bordered by Latitudes 8°30'N and 9°00'N, and Longitudes 8°30'E and 9°00'E, covering an area of about 3,025 Km^2. According to Adefolalu [4], rainfall in the area is about 1500 mm and the average temperature is 26°C. Major settlements within Wamba Sheet 210 include Wamba, Nassarawa Eggon, Garko, Adogi, Assakio, Tugan, Panda and Nakere, and the occupation of the people is mainly farming.

The northern part of Wamba Sheet 210 is underlain by rocks of the Basement Complex and the Younger Granites, while the southern part is composed of Cretaceous sedimentary rocks of the Middle Benue Trough Macleod et al. [5]. Recent geological mapping of Wamba Sheet 210 [6] revealed that the Basement rocks in the area consist essentially of migmatites, gneisses and quartzites (Fig. 1). These rocks are associated with pegmatites in some places and structural trends within these pegmatites are generally N-S, NNE-SSW, NE-SW and NNW-SSE [7]. The Younger Granites are made up of microgranites and biotite granites while the sedimentary rocks which constitute the southern part consist of Awgu Shale and Lafia Formation. Awgu Shale is mainly of bluish-grey to black shales, while the Lafia Formation is made up of sandstones and claystones [8].

2.2 Methodology

Seventy-five (75) groundwater samples were collected from shallow wells during the dry season in different locations in the area, and the good coordinates determined using a Garmin Global Positioning System (Table 1). The depths to the static water level in the wells vary from 5-25 metres. The distributions of the wells are shown in Fig. 2. The physical parameters determined in the field included temperature, pH and electrical conductivity. The water samples were later filtered and preserved with 2 ml of nitric acid to avoid adsorption and precipitation of metals. They were then analyzed using Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES) at the ACME Laboratory Vancouver, Canada. Details of ICP-OES operation is presented by Xiandeng and Bradley [9].

To assess the quality of groundwater in the area irrigation, the Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Magnesium Adsorption Ratio (MAR) and Kellys Ratio (KR) were determined based on ionic concentrations (Meq/l) calculated from the results of chemical analysis.

Sodium adsorption ratio (SAR) is a parameter used in the management of sodium in soils. It is an indicator of the suitability of water for use in irrigation, and it is determined from the concentrations of Na^+, Ca^{2+} and Mg^{2+} present in the water. Irrigation using water with high sodium adsorption ratio may cause long-term damage to the soil [10]. Sodium Adsorption Ratio (SAR) was calculated using Equation 1 according to Richards [11].

$$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{++}+Mg^{++})}} \quad (1)$$

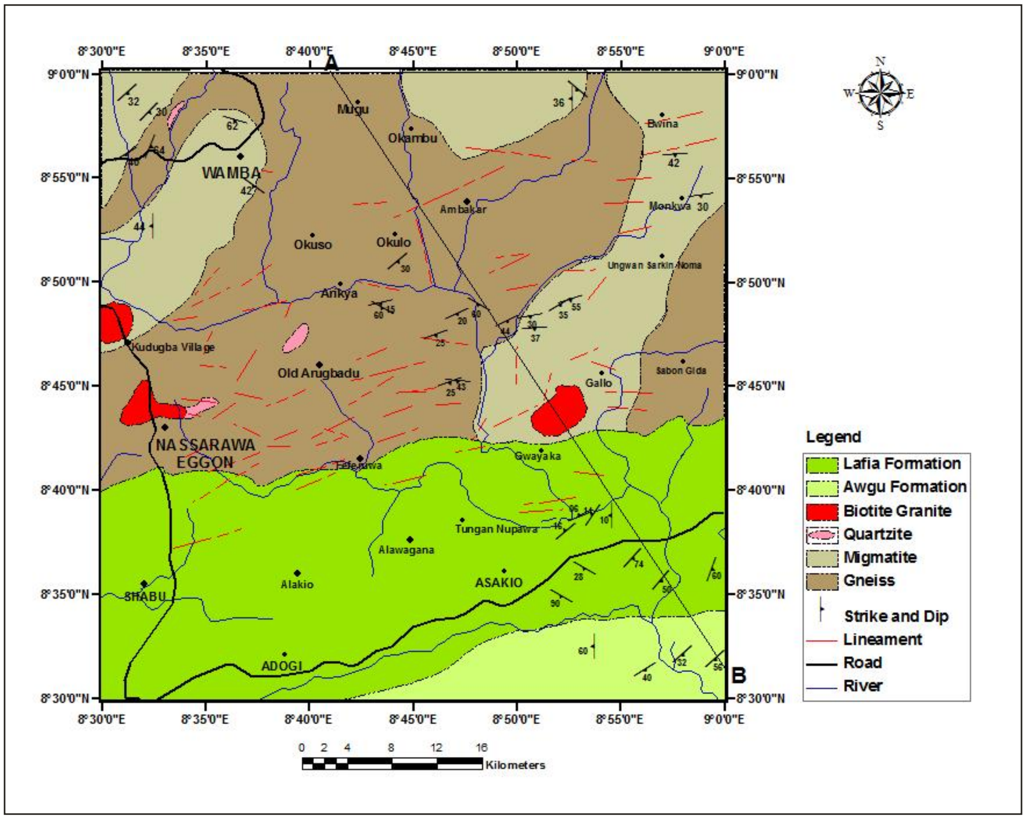

Fig. 1. Geological map of Wamba Sheet 210 (After Geology Department, University of Jos [6])

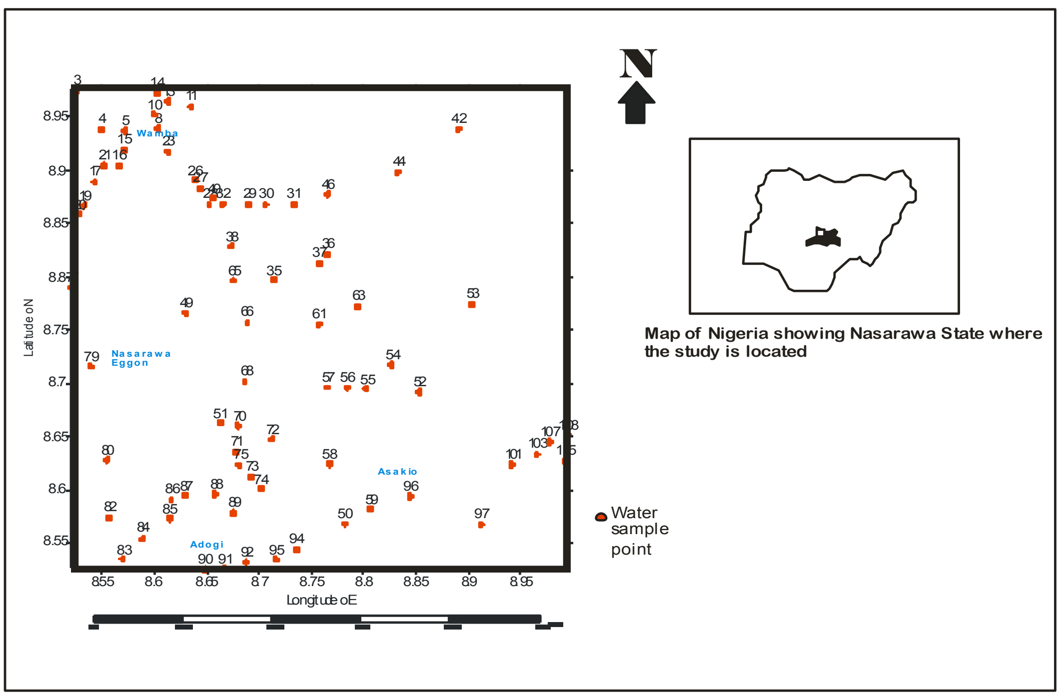

Fig. 2. Groundwater sample points within Wamba Sheet 210

Table 1. Locations of groundwater sample points

S/No	Sample Id	Town	Latitude °N	Longitude °E	S/No	Sample Id	Town	Latitude °N	Longitude °E
1	AR3	Nakere	8.974983	8.526497	39	AR57	Gid.Buba	8.696389	8.765
2	AR4	Gudi	8.938283	8.549533	40	AR58	Alawagana	8.623889	8.768056
3	AR5	Kurmi	8.937356	8.572111	41	AR59	Asige	8.582222	8.807222
4	AR8	Wamba Town	8.939431	8.603794	42	AR61	FadamaBauna	8.755083	8.756694
5	AR10	Wamba Rd	8.952367	8.599867	43	AR63	AdamuAgio	8.772333	8.794694
6	AR11	Gbombu	8.960161	8.635453	44	AR65	Lange	8.796975	8.675667
7	AR13	Angwan Mango	8.965447	8.613281	45	AR66	Arugwadu	8.757328	8.688803
8	AR14	Gwagi	8.972906	8.602508	46	AR68	Feferuwa	8.702317	8.687208
9	AR15	Wude	8.918303	8.571292	47	AR70	Ajuhulu	8.659878	8.680144
10	AR16	Oge	8.904489	8.566256	48	AR71	Akura 1	8.636444	8.678044
11	AR17	Dechu	8.888889	8.543056	49	AR72	Chiba	8.648103	8.712672
12	AR19	Kurize 2	8.867578	8.533028	50	AR73	Dungu1	8.612731	8.693231
13	AR20	Wadji	8.858667	8.528944	51	AR74	Dungu2	8.601381	8.702367
14	AR21	Odrah	8.905289	8.552386	52	AR75	Akura2	8.623119	8.681167
15	AR23	Ukya	8.9175	8.613056	53	AR77	Gako	8.789728	8.521431
16	AR26	Gwagi	8.890556	8.639167	54	AR79	Nass.Eggon	8.716161	8.538842
17	AR27	Otogu	8.882778	8.643611	55	AR80	Azuba	8.628122	8.555489
18	AR28	Okuso	8.868889	8.6525	56	AR82	Shabu	8.574769	8.557314
19	AR29	Ojule	8.868611	8.690278	57	AR83	Akuba	8.535342	8.569928
20	AR30	Gbanju	8.868333	8.706111	58	AR84	Asanya	8.554094	8.589508
21	AR31	Ukulo	8.868056	8.733611	59	AR85	Agabija	8.573469	8.614342
22	AR32	Konya	8.868889	8.665556	60	AR86	Doka	8.591089	8.615964
23	AR35	Wugi	8.797833	8.713917	61	AR87	Arugba	8.594486	8.630444
24	AR36	Kompany	8.821389	8.76575	62	AR88	Alakio	8.595833	8.658561
25	AR37	Wayo	8.812389	8.7575	63	AR89	Tu.Makeri	8.579153	8.675444
26	AR38	Arikiya	8.828944	8.67375	64	AR90	Adogi	8.525514	8.64855
27	AR40	Kwabe	8.873889	8.657222	65	AR91	Koro	8.526169	8.667886
28	AR42	Ambaka	8.939167	8.890556	66	AR92	Sabon-GidanKirayi	8.531872	8.688331
29	AR44	Pashabiyar	8.808889	8.833056	67	AR94	Mai-Akuya	8.544831	8.736111
30	AR46	Zalli	8.877778	8.766111	68	AR95	Abu	8.534928	8.716303

S/No	Sample Id	Town	Latitude °N	Longitude °E	S/No	Sample Id	Town	Latitude °N	Longitude °E
31	AR49	Bakyano	8.766611	8.630575	69	AR96	Assakio	8.593664	8.095486
32	AR50	Ashangwa	8.568222	8.781625	70	AR97	Tsorom	8.567639	8.912639
33	AR51	Tunga	8.663611	8.663611	71	AR101	BakinKogi	8.623736	8.942456
34	AR52	Gwayaka	8.691944	8.853333	72	AR103	Anungo	8.634094	8.96505
35	AR53	Gallo	8.774722	8.903611	73	AR105	Kumme	8.627556	8.993031
36	AR54	Alingani	8.717778	8.826667	74	AR107	Pandam	8.645233	8.977861
37	AR55	Uga	8.695	8.803056	75	AR108	DogonKurmi	8.651503	8.994981
38	AR56	Gid.Agu	8.696111	8.784167					

Soluble Sodium Percentages (SSP) expresses the solubility of Na^+ in relation to other cations such as Ca^{++}, Mg^{++} and K^+. Soluble Sodium Percentage (SSP) was calculated using Equation 2 (After [12]).

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

Magnesium Adsorption Ratio (MAR) is an index for calculating the magnesium hazard. Magnesium Adsorption Ratio for the water samples was calculated using Equation 3, according to Raghunath [13].

$$MAR = \frac{Mg^{++} \text{ x } 100}{Ca^{++} + Mg^{++}} \quad (3)$$

Kelly's Ratio (KR) was calculated using Equation 4 as given by Kelly, [14].

$$KR = \frac{Na^{2+}}{Ca^{2+} + Mg^{2+}} \quad (4)$$

3. RESULTS AND DISCUSSION

The results of the physicochemical parameters of the groundwater samples from Wamba Sheet 210 are presented in Table 2. It shows that groundwater temperatures here are from 23.2 - 28.4°C with an average of 27.4°C, the pH ranges from 5.4 - 7.0, and the electrical conductivity varies from 9.2 - 210 µS/cm with an average of 125.63 µS/cm. Electrical conductivity is a measure of the water's capability to pass electrical flow and this is directly dependent on the concentration of ions present in the water.

Generally, all groundwater contains a significant amount of dissolved salts depending on the geology of the area. Most of the salts are left in the soil after the water is lost by evaporation or through transpiration by the irrigated plants. Salts may, therefore, accumulate in sufficient quantities to prevent the effective growth of such crops. According to Ayers, [15], the higher the value of electrical conductivity (EC), the higher the hazards potential to crops. Ayers and Westcot [3] also concluded that for suitability for irrigation, water with electrical conductivity of <117.51 µS/cm is excellent, while 117.51-508.61 µS/cm is good (Table 3). On the basis of EC values of 9.2 to 210 µS/cm therefore, it can be concluded that groundwater found within the shallow aquifers of Wamba Sheet 210 are generally good for irrigation.

The concentrations of $Ca^{2+,}$ Mg^{2+}, Na^+ and K^+ in the water samples are shown in Table 4 and the corresponding milliequivalent values in Table 5. Calcium, magnesium, sodium and potassium concentrations range from 0.89 - 94.15 ppm, 0.13 - 40.47 ppm, 0.51 - 107.9 ppm, and 0.3 - 78.1 ppm respectively. Calcium is a very important mineral in agriculture. Calcium is an important plant nutrient, and calcium-rich soils are friable and easily cultivated, allowing for easy infiltration and good drainage [16,17]. Magnesium equally improves soil fertility and it is an essential constituent of plant chlorophyll [18]. Sodium occurs widely in many igneous and sedimentary rocks but the high concentration of sodium in the soil is generally unfavourable for plant growth as it renders the soils alkaline by replacing calcium and magnesium [19,20]. Potassium is generally found in small concentration in groundwater.

Values obtained for the various irrigation parameters are shown in Table 6. The Sodium Adsorption Ratio (SAR) ranges from 0.07 - 3.42, with a mean value of 0.93 and a standard deviation of 0.726. Only 2 out of the 75 groundwater samples had SAR value of more than 3 indicating therefore that groundwater from more than 97% of the area is good for irrigation in terms of SAR. According to Rollins [23], SAR of less than 3 is generally recommended for irrigation.

The Soluble Sodium Percentage (SSP) ranges from 8.80 - 81.76%. Although SSP values of more than 60% were found in some areas, over 85% of the water samples analyzed have SSP of <60% (Table 6). According to Ayers and Westcot [3], Eaton [21] and Wilcox [22], water with SSP of <60% is generally considered good for irrigation while those >60% are not.

Magnesium Adsorption Ratios (MAR) obtained varies from 8.03 - 80.22. It is generally known that Ca^{2+} and Mg^{2+} maintain a state of equilibrium in groundwater. According to Joshi et al. [2], more Mg^{2+} in groundwater could affect the soil quality by making it alkaline and this, in turn, could result in a decrease in crop yield. Water with MAR values of <50 are considered suitable for irrigation but those >50 are generally considered unsuitable. Although few of the water samples have MAR values greater than 50, the bulk of the samples (94%) have MAR values of less than 50 (Table 6). The water samples can, therefore, be classified as generally good for irrigation on the basis of MAR.

The Kelly Ratio (KR) obtained ranges from 0.04 - 3.42 out of which about 84% are less than 1, thus indicating that groundwater from shallow aquifers in many areas within Wamba Sheet 210 is good for irrigation. Generally, waters with KR value of less than 1 are considered suitable for irrigation, while those greater than 1 are unsuitable Kelly [14].

The results obtained in this study are similar to those obtained from shallow aquifers in Awe and Kyekwura areas of same Nasarawa State where SAR, SSP, MAR, and KR values were found to vary from 0.02 - 1.63, 2.18 - 52.72%, 24.43 - 73.44 and 0.00 – 0.98 respectively [24]. They are also comparable to those obtained from shallow groundwater in Pindiga, Gombe, and Yola areas to the NE of the Benue Trough [25] where SAR of 0 - 0.035, SSP of 2.60 - 38.40, and KR of 0.0004 - 0.029 were reported.

Table 2. Result of physico-chemical parameters of groundwater samples

S/No	Sample ID	PH	Cond. (mS/cm)	Temp (°C)	S/No	Sample ID	PH	Cond. (mS/cm)	Temp (°C)
1	AR 3	6.6	181.7	27.4	39	AR57	6.3	69.8	23.3
2	AR4	6.4	78.7	28.4	40	AR58	6.1	206	23.23
3	AR5	6.3	198.6	27.5	41	AR59	6.2	26.4	27.9
4	AR8	6.3	160.9	27.7	42	AR61	6.5	194.9	27.7
5	AR10	6.6	9.2	27.3	43	AR63	6.2	183.4	27.7
6	AR11	6.5	96.7	27.6	44	AR65	7.0	198.6	27.4
7	AR13	6.9	77.6	27.8	45	AR66	6.3	160.9	27.8
8	AR14	6.8	11	27.3	46	AR68	6.6	9.2	27.3
9	AR15	6.7	210	27.3	47	AR70	5.4	96.7	27.7
10	AR16	6.5	100.8	27.4	48	AR71	6.4	77.6	27.8
11	AR17	6.2	158.1	27.7	49	AR72	6.8	11	28.4
12	AR19	6.1	69.8	27.3	50	AR73	6.6	187	27.8
13	AR20	6.1	205.2	23.3	51	AR74	6.7	210	27.5
14	AR21	6.3	106	23.2	52	AR75	6.1	100.8	27.7
15	AR23	6.8	55.9	27.9	53	AR77	6.7	158.1	27.7
16	AR26	6.9	82.7	27.7	54	AR79	6.2	181.7	27.3
17	AR27	6.6	206	27.7	55	AR80	6.0	78.7	27.6
18	AR28	6.3	26.4	27.4	56	AR82	6.5	198.6	27.8
19	AR29	6.3	194.9	27.8	57	AR83	6.4	160.9	27.3
20	AR30	6.4	183.4	27.3	58	AR84	6.3	9.2	27.3
21	AR31	6.6	11	27.7	59	AR85	6.9	96.7	27.4
22	AR32	6.6	210	27.8	60	AR86	6.2	77.6	27.7
23	AR35	6.9	100.8	28.4	61	AR87	6.1	11	27.3
24	AR36	7.0	158.1	27.5	62	AR88	6.3	210	27.8
25	AR37	6.8	181.7	27.7	63	AR89	6.2	160.4	27.5
26	AR38	6.8	78.7	27.3	64	AR90	6.5	100.8	27.3
27	AR40	6.5	198.6	27.6	65	AR91	6.7	194.9	27.7
28	AR42	6.5	160.9	27.8	66	AR92	6.2	183.4	27.3
29	AR44	6.3	9.2	27.3	67	AR94	6.1	198.6	27.6
30	AR46	6.5	111.2	27.2	68	AR95	6.3	160.9	27.4
31	AR49	6.2	198.6	27.7	69	AR96	6.4	9.2	28.4
32	AR50	6.4	160.9	27.3	70	AR97	6.6	198.6	27.5
33	AR51	6.4	200.6	27.6	71	AR101	6.4	160.9	27.7
34	AR52	6.2	100.8	27.4	72	AR103	6.1	9.2	27.4
35	AR53	6.0	181.7	28.4	73	AR105	6.3	96.7	27.8
36	AR54	5.7	210	27.5	74	AR107	6.7	77.6	27.3
37	AR55	5.7	100.8	27.7	75	AR108	6.2	11	27.7
38	AR56	6.0	158.1	27.3					

Table 3. Some parameter indices for rating the sustainability of groundwater quality for irrigation [3, 21,22]

Class	EC (µS/cm)	RSC	SAR	SSP	Suitability for irrigation
I	<117.51	<1.25	<10	<20	Excellent
II	117.51-508.61	1.25-2.5	10-18	20-40	Good
III	>508.61	>2.5	18-26	40-80	Fair
IV	-	-	>26	>80	Poor

Table 4. Results of chemical analysis of the groundwater samples (ppm)

S/No	Sample ID	Ca^{2+} (ppm)	K^+ (ppm)	Mg^{2+} (ppm)	Na^+ (ppm)	S/No	Sample ID	Ca^{2+} (ppm)	K^+ (ppm)	Mg^{2+} (ppm)	Na^+ (ppm)
1	AR3	21.94	3.34	4.78	15.11	39	AR57	1.29	1.52	0.13	0.51
2	AR4	31.54	2.62	9.1	19.22	40	AR58	3.88	4.9	1.09	3.92
3	AR5	20.21	3.23	1.91	7.1	41	AR59	37.51	5.5	9.38	10.2
4	AR8	69.54	8.69	16.39	51.3	42	AR61	72.06	7.74	34.23	39.84
5	AR10	30.82	6.08	2.14	54.19	43	AR63	32.95	4.73	14.55	80.81
6	AR11	21.72	2	5.85	18.07	44	AR65	49.8	26.03	11.29	36.03
7	AR13	89.44	38.15	7.13	6.58	45	AR66	72.7	44.84	15.91	38.64
8	AR14	29.73	3.06	9.54	11.89	46	AR68	25.47	13.58	4.35	13.68
9	AR15	28.64	3.55	3.37	6.64	47	AR70	19.36	3.84	4.87	13.77
10	AR16	17.22	2.6	2.72	8.19	48	AR71	33.32	13.77	12.08	49.68
11	AR17	34.42	2.54	15.28	25.68	49	AR72	4.12	3.27	0.69	4.8
12	AR19	58.3	1.32	13.81	14.98	50	AR73	3.06	1.09	0.65	1.52
13	AR20	66.56	3.61	36.2	36.95	51	AR74	1.23	0.47	0.2	0.61
14	AR21	20.22	1.82	6.79	16.94	52	AR75	0.95	0.46	0.15	2.39
15	AR23	22.37	3.67	10.94	18.28	53	AR77	45.93	36.31	15.72	11.8
16	AR26	20.54	4.63	15.3	29.28	54	AR79	76.77	1.66	34.84	69.37
17	AR27	18.62	5.57	3.33	28.87	55	AR80	25.88	5.47	2.52	8.76
18	AR28	31.91	8.11	9.29	32.76	56	AR82	1.96	1.92	0.41	1.67
19	AR29	34.57	4.54	7.05	25.64	57	AR83	25.63	37.15	11.2	56.54
20	AR30	1.43	5.83	3.5	6.15	58	AR84	16.45	10.35	1.77	25.78
21	AR31	45.67	3.8	18.5	36.77	59	AR85	2.49	1.97	0.5	1.4
22	AR32	23.66	7.52	8.24	19.46	60	AR86	8.28	4.77	4.76	11.06
23	AR35	25.95	12.38	7.33	32.31	61	AR87	1.02	0.3	0.31	0.82
24	AR36	32.29	6.08	9.33	18.88	62	AR88	3.49	0.72	0.57	1.93

S/No	Sample ID	Ca^{2+} (ppm)	K^{+} (ppm)	Mg^{2+} (ppm)	Na^{+} (ppm)	S/No	Sample ID	Ca^{2+} (ppm)	K^{+} (ppm)	Mg^{2+} (ppm)	Na^{+} (ppm)
25	AR37	29.65	10.17	5.47	22.69	63	AR89	0.89	0.73	0.15	4.56
26	AR38	77.99	78.1	20.26	53.56	64	AR90	1.6	0.81	0.57	0.93
27	AR40	16.64	2.8	4.63	15.73	65	AR91	2.45	2.44	1.1	4.22
28	AR42	3.32	1.58	0.73	11.71	66	AR92	17.43	4.12	11.29	1.59
29	AR44	37.1	12.39	7.33	23.55	67	AR94	3.97	2.21	2.76	6.82
30	AR46	79.81	8.07	23.47	66.78	68	AR95	1.48	0.84	0.51	0.94
31	AR49	88.8	1.88	40.47	32.57	69	AR96	2.12	2.5	0.55	3.29
32	AR50	2.39	1.72	1.02	1.21	70	AR97	3.76	2.82	1.09	5.28
33	AR51	2.15	7.32	1.12	2.79	71	AR101	36.17	27.93	7.69	77.96
34	AR52	32.86	24.22	8.65	49.14	72	AR103	8.48	8	1.17	11.18
35	AR53	94.15	5.27	28.73	107.9	73	AR105	2.94	4.48	0.79	2.43
36	AR54	66	19.56	19.13	42.43	74	AR107	3.42	9.66	0.71	12.46
37	AR55	3.38	9.18	0.63	17.48	75	AR108	0.97	4.42	0.2	2.11
38	AR56	4.56	14.11	1.71	5.46						

Table 5. Results of chemical analysis of the groundwater samples (meq/l)

S/No	Sample ID	Ca^{2+} (meq/l)	K^{+} (meq/l)	Mg^{2+} (meq/l)	Na^{+} (meq/l)	S/No	Ca^{2+} (meq/l)	K^{+} (meq/l)	Mg^{2+} (meq/l)	Na^{+} (meq/l)	Ca^{2+} (meq/l)
1	AR3	1.097	0.086	0.398	0.657	39	AR57	0.065	0.039	0.011	0.022
2	AR4	1.577	0.067	0.758	0.836	40	AR58	0.194	0.126	0.091	0.17
3	AR5	1.011	0.083	0.159	0.309	41	AR59	1.876	0.141	0.782	0.443
4	AR8	3.477	0.223	1.336	2.23	42	AR61	3.603	0.198	2.853	1.732
5	AR10	1.541	0.156	0.178	2.356	43	AR63	1.648	0.121	1.213	3.513
6	AR11	1.086	0.051	0.488	0.786	44	AR65	2.49	0.667	0.941	1.567
7	AR13	4.472	0.978	0.594	0.286	45	AR66	3.635	1.15	1.326	1.68
8	AR14	1.487	0.078	0.795	0.517	46	AR68	1.274	0.348	0.363	0.595
9	AR15	1.432	0.091	0.281	0.289	47	AR70	0.968	0.098	0.406	0.599
10	AR16	0.861	0.067	0.227	0.356	48	AR71	1.666	0.353	1.007	2.16
11	AR17	1.721	0.065	1.273	1.117	49	AR72	0.206	0.084	0.058	0.207
12	AR19	2.915	0.034	1.151	0.651	50	AR73	0.153	0.028	0.054	0.067
13	AR20	3.328	0.093	3.017	1.607	51	AR74	0.062	0.012	0.017	0.027
14	AR21	1.011	0.047	0.566	0.737	52	AR75	0.048	0.012	0.016	0.104
15	AR23	1.119	0.094	0.912	0.795	53	AR77	2.297	0.931	1.31	0.513

S/No	Sample ID	Ca^{2+} (meq/l)	K^+ (meq/l)	Mg^{2+} (meq/l)	Na^+ (meq/l)	S/No	Ca^{2+} (meq/l)	K^+ (meq/l)	Mg^{2+} (meq/l)	Na^+ (meq/l)	Ca^{2+} (meq/l)
16	AR26	1.027	0.119	1.275	1.273	54	AR79	3.839	0.043	2.903	3.016
17	AR27	0.931	0.143	0.278	1.255	55	AR80	1.294	0.14	0.21	0.381
18	AR28	1.6	0.208	0.774	1.424	56	AR82	0.098	0.049	0.034	0.072
19	AR29	1.735	0.116	0.588	1.115	57	AR83	1.282	0.953	0.933	2.458
20	AR30	0.072	0.149	0.292	0.267	58	AR84	0.823	0.263	0.148	1.121
21	AR31	2.284	0.097	1.542	1.599	59	AR85	0.125	0.051	0.042	0.061
22	AR32	1.183	0.193	0.687	0.846	60	AR86	0.414	0.122	0.397	0.481
23	AR35	1.3	0.317	0.612	1.405	61	AR87	0.051	0.008	0.026	0.036
24	AR36	1.615	0.156	0.778	0.821	62	AR88	0.175	0.018	0.048	0.084
25	AR37	1.483	0.261	0.456	0.987	63	AR89	0.045	0.019	0.013	0.198
26	AR38	3.9	2.003	1.688	2.329	64	AR90	0.08	0.021	0.05	0.04
27	AR40	0.832	0.072	0.386	0.684	65	AR91	0.123	0.063	0.092	0.183
28	AR42	0.166	0.041	0.061	0.509	66	AR92	0.872	0.106	0.941	0.069
29	AR44	1.855	0.318	0.611	1.024	67	AR94	0.199	0.057	0.23	0.297
30	AR46	3.991	0.207	1.956	2.903	68	AR95	0.074	0.022	0.043	0.041
31	AR49	4.44	0.048	3.373	1.416	69	AR96	0.106	0.064	0.046	0.143
32	AR50	0.12	0.044	0.085	0.053	70	AR97	0.188	0.072	0.091	0.23
33	AR51	0.108	0.188	0.093	0.121	71	AR101	1.809	0.716	0.641	3.39
34	AR52	1.643	0.621	0.721	2.137	72	AR103	0.423	0.205	0.098	0.486
35	AR53	4.708	0.135	2.394	4.691	73	AR105	0.147	0.115	0.066	0.106
36	AR54	3.3	0.501	1.594	1.845	74	AR107	0.171	0.248	0.059	0.542
37	AR55	0.169	0.235	0.053	0.76	75	AR108	0.049	0.113	0.017	0.092
38	AR56	0.228	0.362	0.143	0.237						

Table 6. Calculated irrigation parameter indices for groundwater in Wamba Sheet 210

S. No	Sample ID	SAR	MAR (%)	SSP (%)	KR	SNo	Sample ID	SAR	MAR (%)	SSP (%)	KR
1	AR 3	0.76	27.45	33.2	0.44	39	AR57	0.11	14.47	45.53	0.1
2	AR4	0.77	32.46	27.89	0.36	40	AR58	0.6	31.93	50.95	0.6
3	AR5	0.4	13.59	25.1	0.26	41	AR59	0.38	29.42	18.01	0.17
4	AR8	1.44	28.38	33.76	0.46	42	AR61	0.96	44.19	23.01	0.27
5	AR10	2.54	10.35	59.37	1.46	43	AR63	2.94	42.4	55.95	1.23
6	AR11	0.89	31	34.72	0.5	44	AR65	1.2	27.43	39.44	0.46

S. No	Sample ID	SAR	MAR (%)	SSP (%)	KR	SNo	Sample ID	SAR	MAR (%)	SSP (%)	KR
7	AR13	0.18	11.73	19.97	0.06	45	AR66	1.07	26.73	36.32	0.34
8	AR14	0.48	34.83	20.68	0.23	46	AR68	0.66	22.17	36.43	0.36
9	AR15	0.31	18.12	18.78	0.17	47	AR70	0.72	29.55	33.66	0.44
10	AR16	0.3	8.03	13.02	0.13	48	AR71	1.87	36.67	48.46	0.81
11	AR17	0.91	42.52	28.3	0.37	49	AR72	0.57	21.97	52.43	0.78
12	AR19	0.46	28.31	14.42	0.16	50	AR73	0.21	26.09	31.46	0.32
13	AR20	0.9	47.55	21.13	0.25	51	AR74	0.14	21.52	33.05	0.34
14	AR21	0.83	35.9	33.21	0.47	52	AR75	0.58	25	64.44	1.6
15	AR23	0.78	44.9	30.44	0.39	53	AR77	0.38	36.32	28.59	0.14
16	AR26	1.19	55.39	37.68	0.55	54	AR79	1.64	43.06	31.21	0.45
17	AR27	1.62	23	53.62	1.04	55	AR80	0.44	13.96	25.73	0.25
18	AR28	1.31	32.6	40.74	0.6	56	AR82	0.28	25.76	47.83	0.55
19	AR29	1.03	25.31	34.64	0.48	57	AR83	2.34	42.12	60.63	1.11
20	AR30	0.63	80.22	53.33	0.73	58	AR84	1.61	15.24	58.77	1.15
21	AR31	1.16	40.3	30.71	0.42	59	AR85	0.21	25.15	40.14	0.37
22	AR32	0.87	36.74	35.72	0.45	60	AR86	0.76	48.95	42.64	0.59
23	AR35	1.44	32.01	47.39	0.73	61	AR87	0.18	33.75	31.43	0.47
24	AR36	0.75	32.51	29	0.34	62	AR88	0.24	21.33	31.19	0.37
25	AR37	1	23.52	39.16	0.51	63	AR89	1.16	22.41	78.91	3.41
26	AR38	1.39	30.21	77.52	0.42	64	AR90	0.16	38.46	31.94	0.31
27	AR40	0.88	31.69	38.3	0.56	65	AR91	0.56	42.79	53.31	0.85
28	AR42	0.51	26.87	70.79	2.24	66	AR92	0.07	51.9	8.8	0.04
29	AR44	0.92	24.78	35.24	0.42	67	AR94	0.64	53.61	47.01	0.69
30	AR46	1.68	32.89	34.34	0.49	68	AR95	0.17	36.75	35	0.35
31	AR49	0.72	43.17	15.78	0.18	69	AR96	0.52	30.26	57.66	0.94
32	AR50	0.17	41.46	32.12	0.26	70	AR97	0.62	32.62	51.98	0.82
33	AR51	0.38	46.27	60.59	0.6	71	AR101	3.06	26.16	62.63	1.38
34	AR52	1.97	30.5	53.85	0.9	72	AR103	0.95	18.81	57.01	0.93
35	AR53	2.49	33.71	40.46	0.66	73	AR105	0.33	30.99	50.92	0.5
36	AR54	1.18	35.57	32.4	0.38	74	AR107	1.6	25.65	77.45	2.36
37	AR55	3.42	23.87	81.76	3.42	75	AR108	0.51	25.76	75.64	1.39
38	AR56	0.55	38.54	61.75	0.64						

4. CONCLUSION

The qualities of groundwater from shallow aquifers in Wamba Sheet 210 in North Central Nigeria have been assessed for the purpose of irrigation. The study revealed that the electrical conductivities (EC) are within the recommended range suitable for irrigation. Other major indices such as Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP) Magnesium Adsorption Ratio (MAR) and Kellys Ratio (KR) are also largely within the safe limits. It can be concluded therefore that groundwater from virtually all parts of the study area is suitable for irrigation purposes.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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