

Evaluation of Groundwater Resources in Part of Southern Anambra Basin: Its Implications for Irrigation Purpose

[1]Daniel Chukwuemeka Ozoko, and [1, 2*]Kenneth Obinna Iheme,
[1]Department of Geology and Mining, Enugu State University of Science and Technology, Enugu, Nigeria
[2]Department of Geology and Mineral Sciences, University of Ilorin, Ilorin, Kwara State, Nigeria.
*Corresponding Author: Kenneth Iheme,

Abstract
Irrigation is vital for food security, but climate change and pollution threaten it. Thus, regular evaluations of groundwater quality for irrigation are needed. This study collected and analyzed thirty-five (35) groundwater samples from boreholes in the Southern Anambra Basin, covering the Ameki and Ogwashi-Asaba Formations. Six irrigation quality indices, including Kelly's Ratio (KR), Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Magnesium Adsorption Ratio (MAR), and Permeability Index (PI), were calculated to evaluate the area's irrigation suitability. Doneen PI, USSL, and Wilcox diagrams were also employed in evaluating irrigation suitability. The pH, EC, and TDS of the groundwater samples ranged from 6.6 to 8.4, 13 to 889 µS/cm, and 15.6 to 557.9 mg/L, respectively. The concentrations of HCO_3^-*,* SO_4^{2-}*,* Cl^-*,* Ca^{2+}*,* Mg^{2+}*,* Na^+*, and* K^+ *ranged from 24 to 580, 1 to 20, 0.4 to 92.5, 10 to 74, 0.09 to 49.50, 2.26 to 30, and 0.67 to 10.0 mg/L, respectively. In general, the physicochemical parameters meet the WHO guidelines for drinking. The range values of KR, SAR, SSP, RSC, MAR, and PI were 0.019-1.712 mmol/L, 0.067-2.113, 1.86-63.13%, -5.36-7.80 mmol/L, 0.00-3.79, and 15.82-547.10%, respectively. All samples had suitable SAR and MAR values for irrigation, while 97.14%, 94.29%, 80%, and 77.14% had suitable SSP, KR, RSC, and PI, respectively. This study has demonstrated that groundwater within the study area is suitable for drinking and irrigation, however, it is essential for periodic assessment as anthropogenic activities continue to increase in the area.*
Keywords: Kelly's Ratio, Sodium Adsorption Ratio, Soluble Sodium Percentage, Permeability Index, Potential Salinity

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1.0 Introduction

Urban centers are expanding and populations are teeming, creating an increased need for food production. However, this need is becoming increasingly affected by climatic change, which makes seasonal rainfall and surface water unreliable, thus impacting food production and threatening food security. Many previously productive agricultural regions are expected to face increasing water stress due to the impact of climate change. As a result, groundwater is increasingly being depended upon for irrigation needs. It's worth noting that irrigation accounts for 70% of freshwater use worldwide. However, the suitability of groundwater and surface water can be impaired by anthropogenic contamination (Bah, Rashid, Javed, Pasha, and Shahid, 2021; OECD,2013). The quality of the aquifer system in Nigeria is often degraded by the widespread practice of dumping cesspool and sewage directly into the groundwater source. This practice is widespread and can result in a high level of deterioration of the aquifer (Udom, Ushie, Esu, Oofojekwu, Ezenwaka, and Alegbeleye, 2023). Deteriorated groundwater with high sodium salt content, when used for irrigation, will gradually reduce soil permeability and cause the hardening of the soil which will lower water availability for crops thus affecting its yield and can even damage it. It is thus necessary to evaluate the suitability of any groundwater source for irrigation purposes. This will be beneficial to farmers, as there is currently an expanding groundwater irrigation practice in Nigeria. Several indices are used to evaluate the irrigation quality of groundwater including Magnesium hazard (MH), Potential Salinity (PS), Kelly's Ratio (KR), Residual Sodium Carbonate (RSC), Sodium Percentage (%Na), Soluble Sodium Percentage (SSP), and Permeability Index (PI) (Tiwari, Ghione, De Maio, and Lavy, 2017; El Osta, Masoud, Alqarawy, Elsayed, and Gad, 2022; Gaagai et al, 2023; Samtio et al., 2022; Nagaraju, Sreedhar, and Thejaswi, 2016; Akakuru, Akudinobi, Nwankwoala, Akakuru, and Onyekuru, 2021). Graphical methods commonly employed to evaluate irrigation suitability of groundwater include US salinity diagram, Doneen Permeability Index Chart, and Wilcox diagram (Doneen, 1964; Richards, 1954; Wilcox, 1955). MH and RSC were used to study irrigation suitability of groundwater from Aosta valley (Italy) (Tiwari et'al, 2017). PS, SAR, and RSC were used to investigate the irrigation suitability of groundwater from Makkah Al-Mukarramah Province (Saudi Arabia) (El Osta, et'al, 2022). SAR, KR, %Na, and PI were used to investigate irrigation suitability of Sahara Aquifer at Doucen Plain (Algeria) (Gaagai et al., 2023). SAR, KR, and %Na were used to investigate the irrigation potential of groundwater from Chachro sub-district in Thar Desert (Pakistan) (Samtio et al, 2023). SAR, %Na, RSC, PI, KR, and Wilcox diagram have been used to examine irrigation suitability of groundwater within Udayagiri (Andhra Pradesh, South India) (Nagaraju, 2016). Several studies have evaluated the irrigation suitability of water sources within the Anambra Basin in Nigeria using different indices and diagram (Akpah, Onwuka, and Oha, 2017; Eyankware, Okoeguale, and Ulakpa, 2017; Ugbor, Nwali, and Ugwuoke, 2022). For example, using four indices including SAR, %Na, MH, and PI, one study investigated the irrigation potential of shallow groundwater aquifer at Ankpa Town (Akpah, et'al, 2017). Similarly, another study used Wilcox diagram, Doneen Diagram, and USSL diagram to assess the irrigation suitability of surface water around Oji Town (Eyankware, et'al, 2017). In contrast, a third study used only three indices, SAR, MH, and KR, to evaluate the irrigation potentials of groundwater samples from parts of Southern Anambra basin at Okigwe and environs (Ugbor, et'al, 2022). The objective of this research paper is to evaluate groundwater quality for irrigation purposes at Orlu and environs within the Southern Anambra Basin and will contribute to a better understanding of the irrigational suitability of groundwater aquifers within the southern Anambra Basin.

2.0 Methodology

2.1 Location, Climate, and hydrogeology

The research area (Figure 1) spans 229 km² within the Southern Anambra Basin, Southeastern Nigeria. It extends from latitude 5° 41' to 5° 49' N and longitude 6°57' to 7° 11' E. The study area is characterized by a gently undulating topography and is dissected by several rivers, of which the most prominent is the Njaba River. The area is situated within Nigerian Rain Forest characterized by two distinct seasons: the wet (rainy) season and the dry season. The dry season spans from November to March, while the rainy season typically begins in April and ends in October. The regional geology of the study (Figure 2) is the Cretaceous Anambra Basin which roughly covers an area of about 40,000 sq.km (Babatunde, 2010). Within the study area, two geological formations are present: the Eocene Ameki Formation and the Miocene Ogwashi-Asaba Formation, which constitute the Western Uplands (Onu and Ibezim, 2004). The Ogwashi-Asaba and Ameki Formations are known to have high groundwater potential, with hydraulic conductivities (K) and transmissivity (T) values of 1.50-291.21m/hr and 0.429-10.34m2/hr, respectively (Onu and Ibezim, 2004).

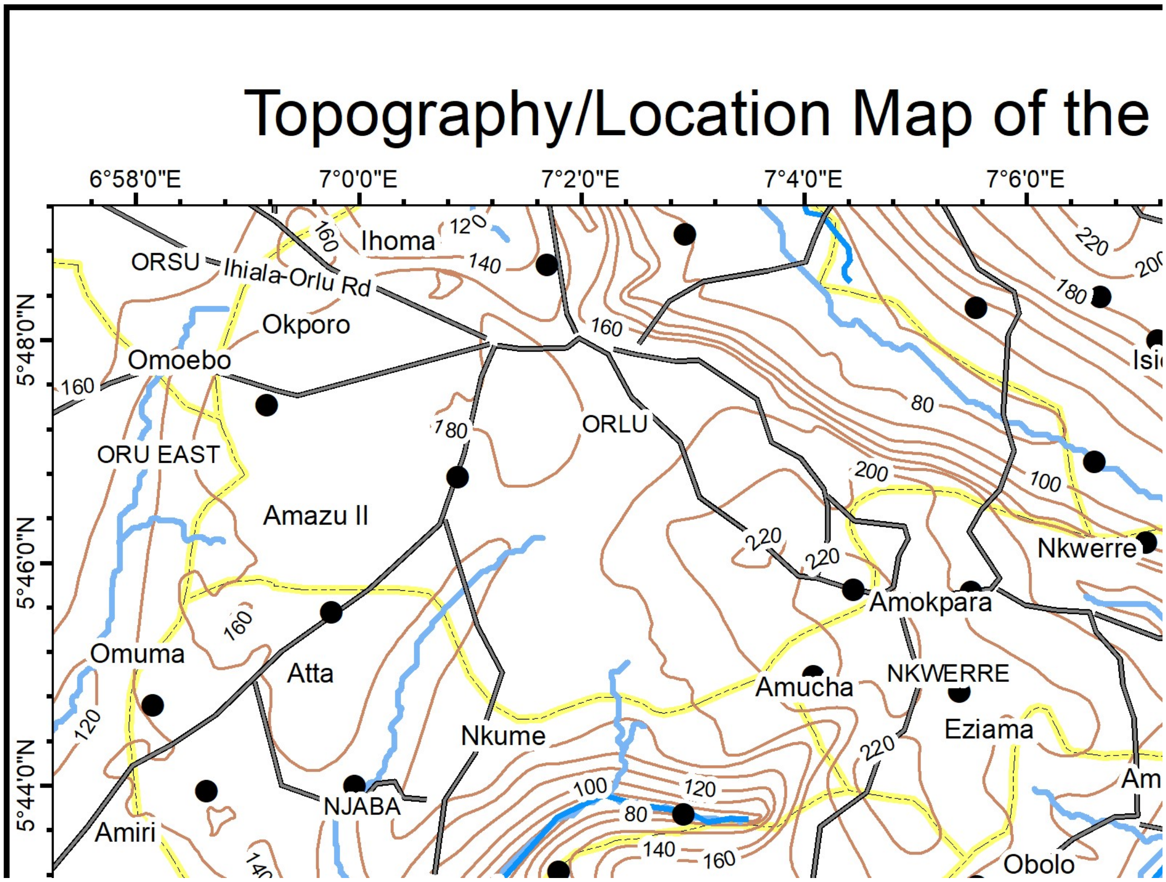

Fig. 1: Map showing location of study area and features of interest

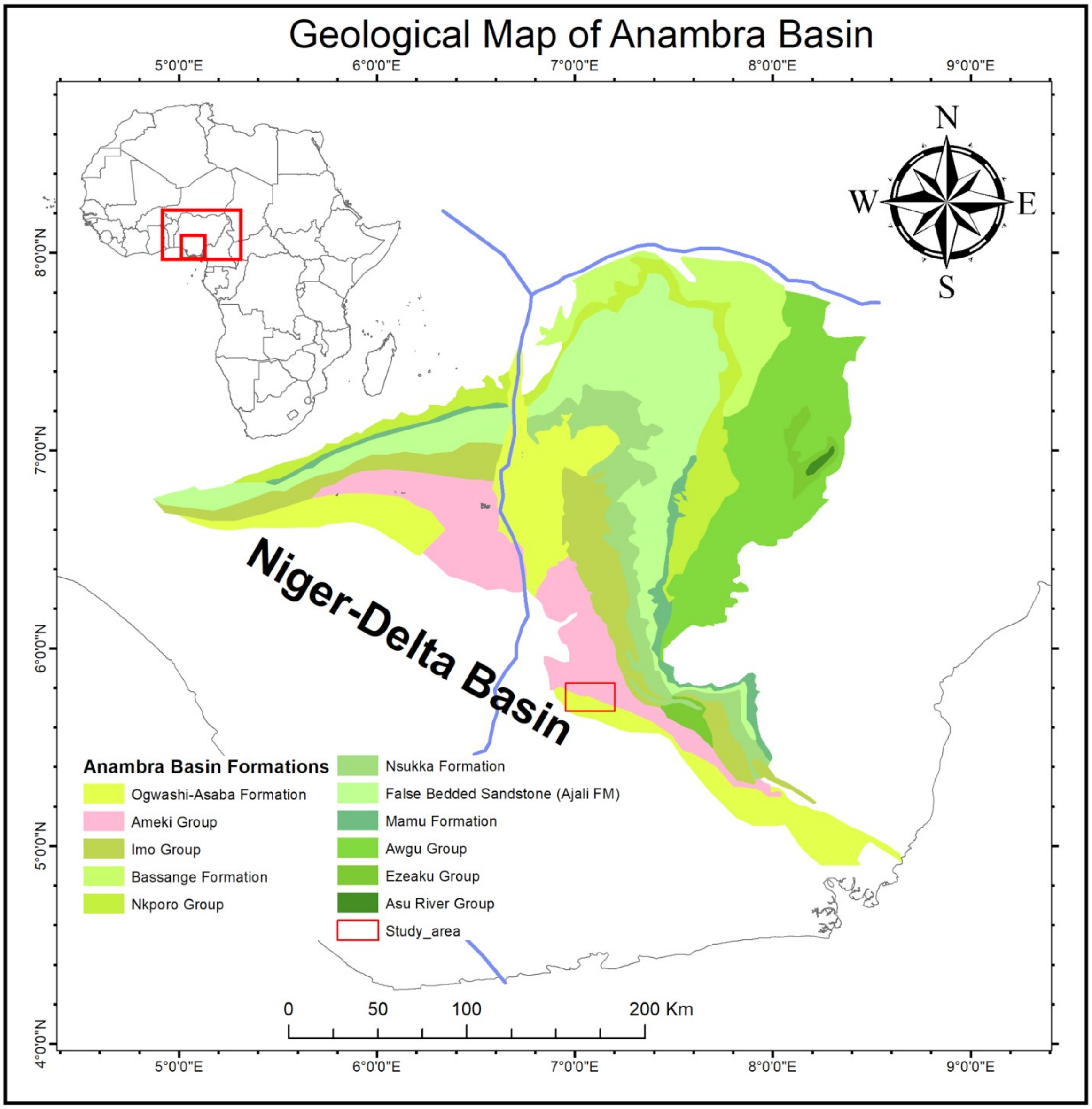

Fig. 2: Geological map of Anambra Basin showing the study area (red line) (Adapted from Nigerian Geological Survey Agency)

2.2 Sampling Procedures

Thirty-five groundwater samples were collected from various locations across the study area (Figure 1). All sampling tools were thoroughly cleaned and rinsed with deionized water before and after use to avoid cross-contamination of samples. The field equipment used for water sampling included a global positioning system (GPS), handheld water quality measuring equipment for measuring pH, electric conductivity, temperature, and TDS, as well as preserving containers. Before sampling, all field containers and equipment were cleaned and calibrated. The containers were pre-cleaned with acid and rinsed with the groundwater before sample collection. Water samples were collected at a point in the distribution system before the water entered any treatment facility. Prior to sampling, the boreholes were purged to remove stagnant water, ensuring that water originated directly from the aquifer. Water samples were collected shortly after purging. The sampling container was completely filled, and the collected water sample was acidified with HNO_3 to a pH of 2 to stabilize the cations and prevent adsorption on the walls of the containing vessels. The samples were then transported to the laboratory on ice and stored in a refrigerator at 4°C before analysis. In total, 35 water samples were collected from the study area. The groundwater samples were analyzed with the assistance of a chemist in the laboratory. The methods and reagents used were based on the description of water analysis procedures (Fishman and Erdmann, 1973). CO_3^-, Cl^-, HCO_3^-, Ca^{2+}, and Mg^{2+} were determined by titration. SO_4^{2-} was analyzed using gravimetric methods. Na^+ and K^+ were analyzed by flame photometry. Chloride (Cl^-) was determined by titrating the sample with $AgNO_3$ to a potentiometric endpoint, where a white precipitate of AgCl was formed. Bicarbonate (HCO_3^-) was determined by titrating with sulfuric acid to a phenolphthalein endpoint. The amount of HCO_3^- was proportional to the amount of H_2SO_4 consumed. EDTA was used to titrate the sample for the determination of Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) to a murexide endpoint and an eriochrome black T endpoint, respectively.

2.3 Method of Result Evaluation

Six irrigation quality indices were computed in this study, which include Kelly's Ratio (KR), Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Magnesium Adsorption Ratio (MAR), and Permeability Index (PI). Table 1 presents the equations used to compute these indices, with the concentrations of ions used in the equations in meq/L. SAR values classify irrigation water into four categories: excellent (S1) for SAR < 10, good (S2) for 10 < SAR < 18, doubtful (S3) for 18 < SAR < 26, and unsuitable (S4) for SAR > 26. SSP levels below 60 are considered good for irrigation, while those above 60 are considered poor. RSC divides groundwater into three categories: safe, marginally suitable, and unsuitable, depending on whether its value is less than 1.25, between 1.25 and 2.5, or greater than 2.5. A MAR value greater than 50 is harmful to soil, while a value less than 50 is beneficial. KR classifies groundwater as suitable, marginal, and unsuitable for values <1, 1-2, and >2 respectively, while PI classifies it as good, moderate, and poor for values >75, 75-25, and <25 respectively. Doneen PI, USSL and Wilcox diagrams were also used to evaluate the irrigation potentials of groundwater samples in the study area. The USSL diagram was first introduced by the United States Salinity Laboratory (USSL) in 1954 (USSL, 1954). The Wilcox diagram was first proposed by Wilcox in 1955. Doneen Permeability Diagrams have been widely used in groundwater studies for evaluating water quality for irrigation purposes (Kumar and Balamurugan, 2018; Rhoades, Kandiah, and Mashali, 1992; Todd and Mays, 1992). The USSL diagram categorizes water salinity and sodium hazard for irrigation into 16 fields determined by the EC of water (C1-C4) and SAR (S1-S4). C1-S1 represents the best water quality for irrigation, C2-S1 represents waters with medium to high salinity and low sodium hazard, C3-S1 represents waters with low to medium salinity and high sodium hazard, and C4-S3 represents the worst water quality for irrigation with high salinity and high sodium hazard. The Wilcox diagram is a graphical representation of water quality that evaluates the suitability of water for irrigation purposes. It plots SAR against EC of water and categorizes the results into six categories: excellent, good, permissible, doubtful, unsuitable, and unusable. These categories are based on the SAR and EC values and compared to established limits for different crops. The Doneen PI diagram classifies groundwater into three classes: Class I represents 100% permeability, Class II represents a maximum of 75% soil permeability, and Class III represents a maximum of 25% soil permeability. Both Classes I and II are good for irrigation (Singh, Rishi, and Arora, 1985).

Table 1 Equation for selected irrigation water quality parameters

S/N	Equation	Unit	Source
1	$SAR = \frac{N}{\sqrt{Ca^{2+}}}$	-	[24]
2	$SSP = \left(\frac{Na}{Ca + Mg + Na + K}\right) * 100$	%	[11], [25]
3	$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$	mmole/L	[11], [25]
4	$Magnessium\ adsorp.ratio\ (MAR)$	%	[26]
5	$KR = \frac{Na}{Ca + Mg}$	mmole/L	[27]
6	$PI = \left(\frac{Na + \sqrt{HCO3}}{Ca + Mg + Na}\right) * 100$	%	[10]

3.0 Results and Discussion

Table 2 shows the results of the chemical analysis of the water samples. The range and average values of the groundwater parameters, along with a comparison with the World Health Organization standards WHO, (2011) are presented in Table 3. Table 3 reveals that pH, EC, Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, CO_3^-, Cl^-, and SO_4^{2-} are within the WHO guideline for potable water in all the samples. However, two samples have TDS values outside the WHO standard for drinking water. The pH values in groundwater samples range between 6.6 and 8.4, which indicate neutral groundwater. The groundwater samples have EC and TDS ranges from 13 to 889 µS/cm and 15.6 to 557.9 mg/L respectively. The HCO_3^- concentration ranges from 24 to 580 mg/L, with a mean concentration of 132.91 mg/L. SO_4^{2-} concentrations vary from 1 to 20 mg/L (average: 7.66 mg/L). The Cl^- concentration ranges from 0.4 to 92.5 mg/L (average: 27.04 mg/L). The average anion inequality of the groundwater samples follows the order: HCO_3^-+CO_3^-> Cl^- > SO_4^{2-}. The Ca^{2+} concentration in the groundwater samples ranges from 10 to 74 mg/L, with an average of 43.89 mg/L. For Mg^{2+}, concentrations range from 0.09 to 49.50 mg/L, with an average value of 13.59 mg/L. As for Na^+, concentrations range from 2.26 to 30 mg/L, with an average of 14.67 mg/L. Concerning K+, values vary from 0.67 to 10.0 mg/L, with a mean value of 2.13 mg/L. The average cation inequality of the groundwater samples follows the order: $Ca^{2+} > Mg^{2+} > Na^+ > K^+$.

Table 4 presents the results of computed irrigation quality indices. KR, SAR, SSP, RSC, MAR, and PI have range values of 0.019-1.712mmol/L, 0.067-2.113, 1.86-63.13%, -5.36-7.80 mmol/L, 0.00-3.79, and 15.82-547.10%, respectively. The average values are 0.2820 mmol/L for KR, 0.574 for SAR, 17.92% for SSP, -1.07 mmol/L for RSC, 0.72 for MAR, and 84.80% for PI. Additionally, Table.5 provides the classification and proportions for these irrigation indices. The SAR classification reveals that all samples are classified as "Excellent," indicating a favorable alkalinity hazard. The RSC classification indicates that 80% of samples are "Safe," 17.14% are "Unsuitable," and 2.86% are "Marginally Suitable". The MH classification demonstrates that all the groundwater samples are 'beneficial' for irrigation. KR reveals that 94.29% of groundwater samples are considered "Suitable," while 5.71% are classified as having "marginal suitability". PI reveals that 34.28%, 42.86%, and 22.86% of the groundwater samples fall within Class I, Class II, and Class III respectively. Based on SSP, 97.14% of the groundwater is suitable and 2.86% is unsuitable for irrigation. In general, the majority of the irrigation water quality indices computed for this study reveals that the groundwater in the study area is good for irrigation purposes. The general suitability of the groundwater samples for irrigation purposes was further demonstrated by graphical tools used to assess irrigation suitability. The USSL salinity diagram (Fig. 3) indicates that all the groundwater samples have low alkalinity or sodium hazard (S1), while salinity hazard mostly varies between low (C1) and medium (C2). This implies that it is suitable for irrigating most crops. The Doneen diagram (Figure 4) indicates that over 85% of the samples are within Class II and I permeability index and are good for irrigation use. The Wilcox diagram (Fig.5) indicates that the groundwater within the study area is excellent for irrigation.

Table 2: Results of chemical analysis of Groundwater Samples (TDS and major ions are in mg/L, and EC is in µS/cm)

ID	pH	EC	TDS	Ca	Mg	Cl	Na	K	SO4	CO3	HCO3
BH1	6.70	276.00	179.40	40.00	5.00	22.10	16.18	4.58	10.00	5	68
BH2	6.80	86.00	55.90	65.00	6.00	41.30	20.00	1.83	5.00	4	36
BH3	6.80	24.00	15.60	45.00	10.00	10.60	2.78	0.02	10.00	4	48
BH4	6.70	88.00	57.20	65.00	12.00	38.10	10.59	0.30	10.00	3	24
BH5	6.60	63.00	41.00	35.00	14.50	21.20	7.39	0.50	20.00	3	36
BH6	7.40	62.00	40.30	40.00	17.00	58.40	26.32	0.31	2.00	4	48
BH7	7.20	61.00	39.70	45.00	19.50	24.00	5.88	0.01	5.00	4	42
BH8	8.40	889.00	557.90	50.00	22.00	33.80	2.26	0.50	15.00	5	52
BH9	7.30	43.00	28.00	55.00	24.50	19.60	7.40	0.13	7.00	3	34
BH10	8.30	55.00	35.80	60.00	27.00	9.20	7.57	0.11	4.00	3	32
BH11	8.40	24.00	15.60	45.00	29.50	10.60	2.78	0.02	10.00	4	48
BH12	8.30	88.00	57.20	30.00	32.00	38.10	10.59	0.30	10.00	3	24
BH13	7.20	61.00	39.70	15.00	34.50	24.00	5.88	0.01	8.00	4	42
BH14	6.70	276.00	179.40	43.00	37.00	22.10	16.18	4.58	10.00	5	58
BH15	7.00	63.00	41.00	41.00	39.50	21.20	7.39	0.50	20.00	3	36
BH16	7.20	24.00	15.60	47.00	42.00	10.60	2.78	0.02	10.00	4	48
BH18	7.20	55.00	35.80	42.00	24.50	24.00	5.88	0.01	5.00	3	42
BH19	8.00	24.00	15.60	43.00	47.00	9.20	7.57	0.11	2.00	4	32
BH20	8.00	289.00	187.85	46.00	49.50	10.60	2.78	0.02	10.00	10	48
BH21	8.00	87.00	56.55	40.00	0.09	92.50	30.00	2.96	6.00	18	100
BH23	7.50	25.00	16.25	15.00	0.16	36.00	30.00	9.02	2.00	11	500
BH25	7.70	320.00	208.00	72.00	0.14	32.80	14.40	0.50	5.00	28	260
BH26	8.00	341.00	221.25	63.00	0.11	14.40	15.00	0.50	4.00	9	580
BH27	7.00	309.00	200.85	22.00	0.40	57.60	30.00	10.00	8.00	6	360
BH28	7.80	33.00	21.45	74.00	0.76	22.50	30.00	2.20	9.00	22	220
BH29	7.40	29.00	18.85	68.00	0.57	86.10	30.00	10.00	4.00	66	280
BH30	7.40	24.00	15.60	65.00	10.00	0.40	30.00	0.50	1.00	4	80
BH31	8.30	61.00	39.70	34.20	1.19	1.50	26.69	4.58	6.00	4	152
BH32	8.20	55.00	35.80	45.00	21.00	10.60	2.78	0.02	10.00	3	48
BH33	7.10	24.00	15.60	10.00	5.00	24.00	5.88	0.01	7.00	4	42
BH34	7.40	289.00	187.85	10.00	7.00	9.20	7.57	0.11	8.00	10	32
BH35	7.60	87.00	56.55	45.00	14.00	10.60	2.78	0.02	10.00	18	48
BH36	7.00	322.00	209.30	37.00	0.16	36.00	30.00	9.02	1.00	6	500
BH44	7.30	24.00	15.60	50.00	16.00	28.00	30.00	2.41	5.00	4	152
BH50	6.70	276.00	179.40	37.00	0.16	36.00	30.00	9.02	9.00	5	500

Table 3: Summary Statistics of Groundwater Parameters for the Water Samples

Parameters (unit)	Range	Average	WHO Std	Number of samples above WHO Std
pH	6.6 - 8.4	7.45	6.5 - 8.5	-
EC (µS/cm)	24 - 889	138.77	1400	-
TDS (mg/L)	15.6 - 557.9	89.63	500	2
Ca^{2+} (mg/L)	10 - 74	43.98	75	-
Mg^{2+}(mg/L)	0.09 - 49.5	16.28	50	-
Na^{+} (mg/L)	2.26 - 30	14.67	200	-
K^{+} (mg/L)	0.01 - 10	2.13	50	-
HCO_3^- (mg/L)	24 - 580	132.91	1000	-
CO_3^{2-} (mg/L)	3 - 66	8.46	500	-
Cl (mg/L)	0.4 - 92.5	27.04	250	-
SO_4^{2-}(mg/L)	1 - 20	7.66	400	-

Table 4 Computed irrigation quality indices

ID	KR	SAR	SSP	RSC	MAR	PI
BH1	0.29	0.64	22.62	-1.13	0.21	73.08
BH2	0.23	0.64	18.88	-3.01	0.15	43.82
BH3	0.04	0.1	3.79	-2.15	0.37	32.84
BH4	0.11	0.32	9.81	-3.74	0.3	25.71
BH5	0.11	0.27	9.85	-2.25	0.68	37.06
BH6	0.34	0.88	25.21	-2.48	0.7	59.83
BH7	0.07	0.18	6.23	-3.03	0.71	28.19
BH8	0.02	0.07	2.23	-3.29	0.73	23.73
BH9	0.07	0.21	6.33	-4.1	0.73	22.44
BH10	0.06	0.2	5.94	-4.59	0.74	20.2
BH11	0.03	0.08	2.52	-3.75	1.08	21.56
BH12	0.11	0.32	10.03	-3.64	1.76	26.33
BH13	0.07	0.19	6.65	-2.77	3.79	30.25
BH14	0.14	0.44	11.94	-4.07	1.42	32.34
BH15	0.06	0.2	5.72	-4.61	1.59	20.57
BH16	0.02	0.07	2.04	-4.88	1.47	17.37
BH18	0.06	0.18	5.86	-3.32	0.96	26.4
BH19	0.05	0.19	5.19	-5.36	1.8	17.52
BH20	0.02	0.07	1.86	-5.25	1.77	15.82
BH21	0.65	1.3	39.43	0.24	0	129.01
BH23	1.71	2.11	63.13	7.8	0.02	547.1
BH25	0.17	0.47	14.8	1.59	0	74.64
BH26	0.21	0.52	17.14	6.65	0	118.48
BH27	1.15	1.73	53.57	4.97	0.03	330.18
BH28	0.35	0.95	25.78	0.58	0.02	85.3
BH29	0.38	0.99	27.49	3.35	0.01	100.19
BH30	0.32	0.91	24.29	-2.62	0.25	60.23
BH31	0.64	1.22	39.13	0.82	0.06	151.76
BH32	0.03	0.09	2.95	-3.09	0.77	25.36
BH33	0.28	0.38	21.93	-0.09	0.82	119.21
BH34	0.31	0.45	23.45	-0.22	1.15	97.99
BH35	0.04	0.09	3.43	-2.01	0.51	29.66
BH36	0.7	1.35	41.23	6.54	0.01	224.1
BH44	0.34	0.94	25.49	-1.19	0.53	75.63
BH50	0.7	1.35	41.23	6.5	0.01	224.1

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Table 5: Proportion of Groundwater Samples Falling Within Each Computed Irrigation Index Classification Range

Irrigation Indices	Range	Classification	No. of Samples	Proportion
Sodium Adsorption Ratio (SAR)	<10	Excellent (S1)	35	100%
	10-18	Good (S2)	nil	nil
	18-26	Doubtful (S3)	nil	nil
	>26	Unsuitable (S4)	nil	nil
Soluble Sodium Percentage	<60	Good	34	97.14
	>60	Poor	1	2.86
Residual Sodium Carbonate (RSC)	< 1.25	Safe	28	80
	1.25-2.5	Marginally Suitable	1	2.86
	>2.5	Unsuitable	6	17.14
Magnesium Hazard (MH)	<50	Beneficial	35	100
	>50	Harmful	nil	nil
Kelly's Index (KI)	<1	Suitable	33	94.29%
	1-2	Marginal	2	5.71%
	>2	Unsuitable	nil	nil
Permeability Index (PI)	Class I	Max. permeability	12	34.28
	Class II	75% of Max. permeability	15	42.86
	Class III	25% of Max. permeability	8	22.86

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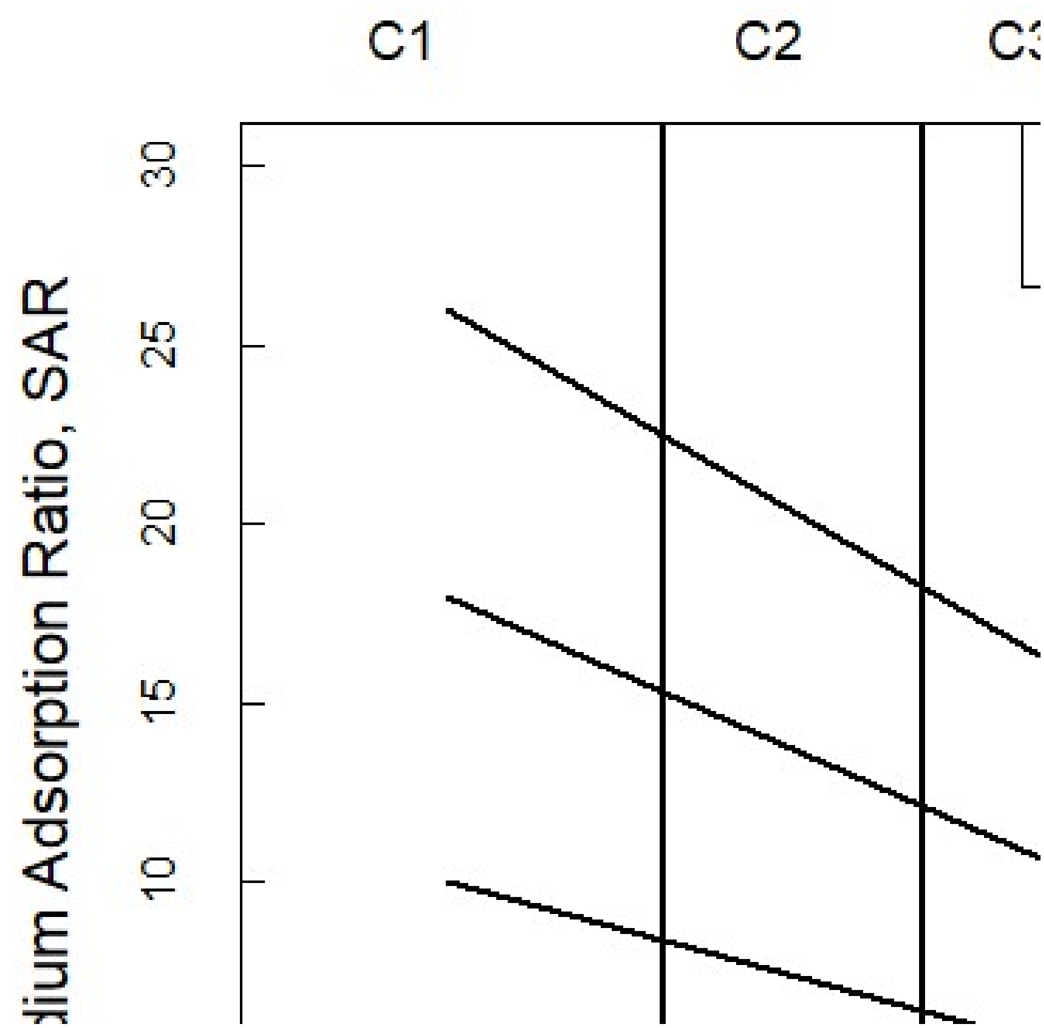

Fig. 3: Plot of the groundwater samples on USSL Diagram

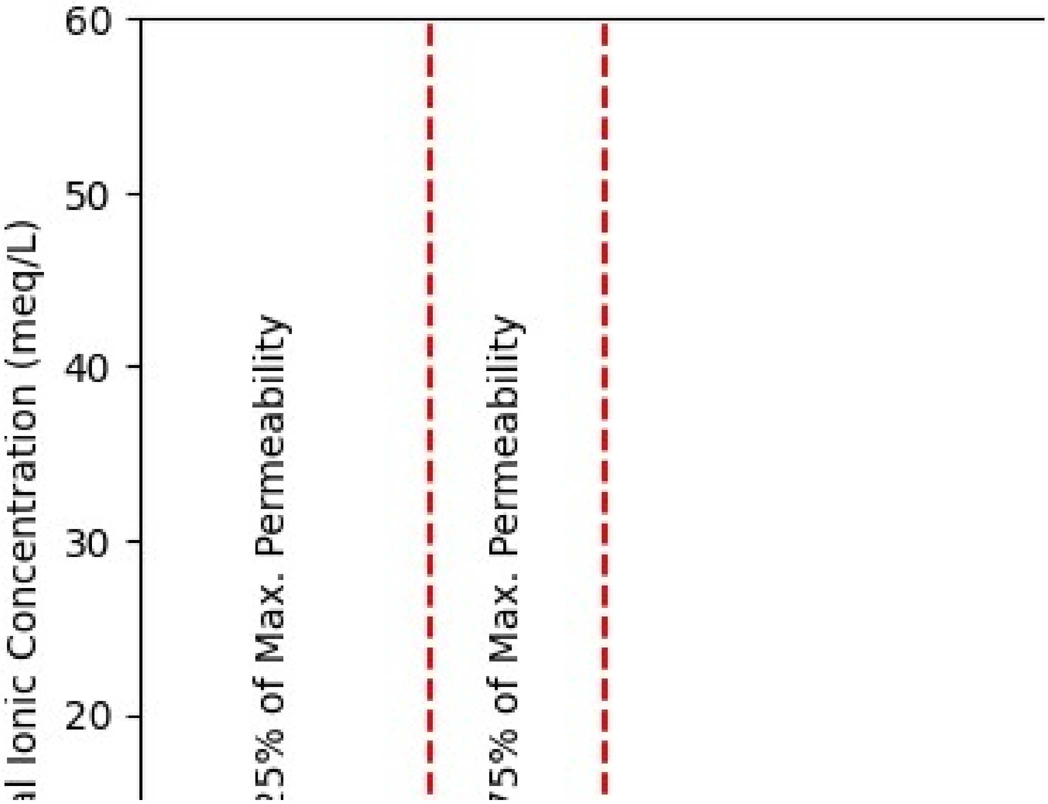

Fig. 4: Plot of the groundwater samples on Doneen PI Diagram

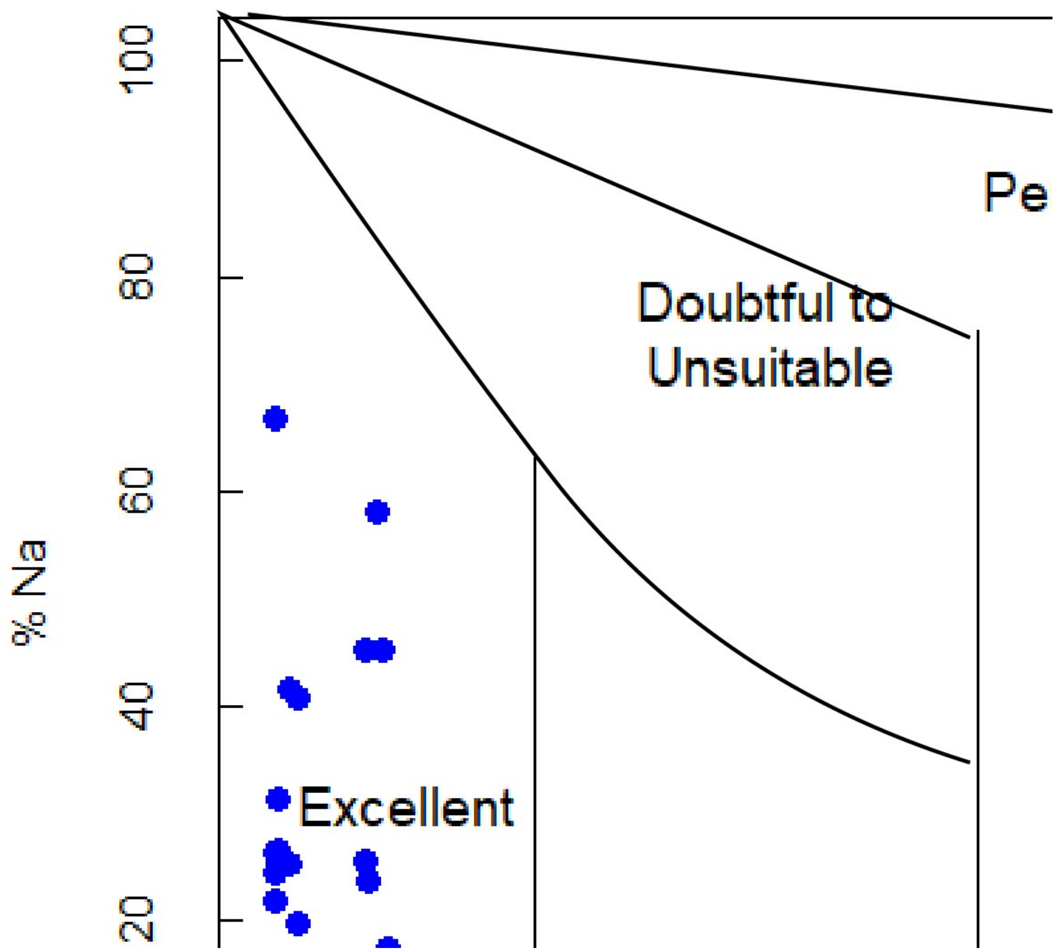

Fig. 5: Plot of the groundwater samples on Wilcox Diagram

4.0 Discussion

The pH, EC, and TDS of the groundwater samples in this study range from 6.6 to 8.4, 13 to 889 µS/cm, and 15.6 to 557.9 mg/L respectively. The concentrations of HCO_3^-, SO_4^{2-}, and Cl^- range from 24 to 580 mg/L, 1 to 20 mg/L, and 0.4 to 92.5 mg/L respectively. The concentrations of Ca^{2+}, Mg^{2+}, Na^+, and K^+ in the groundwater samples range from 10 to 74 mg/L, 0.09 to 49.50 mg/L, 2.26 to 30 mg/L, and 0.67 to 10.0 mg/L respectively. With the exception of TDS in 2 groundwater samples, all values of the groundwater parameters fall within the WHO recommended standard for portable water. One study reported that the pH of groundwater samples in the Nando area of the Anambra Basin is mostly slightly acidic or slightly alkaline, and the water is generally of good drinking quality (Egbunike, 2007). However, elevated levels of Na+ and K+ were attributed to natural activities such as weathering. Another study conducted in some parts of the Southern Anambra Basin showed acidic pH values but EC, TDS, and major ion concentrations within WHO standards (Egbueri, Ezugwu, Unigwe, Onwuka, Onyemesili, and Mgbenu, 2021). A third study reported that major ions in Umuahia South, a part of the Southern Anambra Basin, were within acceptable ranges for drinking purposes (Amos-Uhegbu, Igboekwe, and Chukwu, 2013). The groundwater samples reported for the Okigwe Area of the Southern Anambra Basin by a fourth study had an average pH value of 7.05, which is similar to the values reported in this study (Ugbor, ety'al, 2022). However, their EC range of 5.15 to 23.5 µS/cm is less than those reported in this study. This is because their study area had a smaller areal extent with a more uniform distribution of groundwater properties expected. The pH, TDS, EC, and Na value ranges of 6.01 to 6.87, 2001 to 2506 mg/L, 3.01 to 5.76 dS/m, and 73.45 respectively, were reported by a study around Ele River Nnewi within the Anambra Basin (Ubah, Orakwe, Ogbu, Awu, Ahaneku, and Chukwuma, 2021). This is similar to the pH and Na^+ values reported in this study.

Another study at Umunya (Anambra Basin) reported the range of concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, and HCO_3^{-} as 1.23 to 48.80, 0.00 to 9.32, 1.00 to 20.54, 0.00 to 9.00, 2.99 to 65.00, 0.00 to 14.00, and 0.44 to 144.0 respectively (Egbunike, 2018). All fall within the WHO guidelines for drinking water WHO, (2011) and are similar to those reported in this study.

The computed irrigation indices reveal the general suitability for irrigation of the groundwater within the study area, including SAR (100%), RSC (80%), Magnesium Hazard (100%), KR (94.29%), SSP (97.14%), and PI (77.14%). A previous study evaluated some irrigation properties of the Anambra Basin at Umunya and environs with the Ameki Formation as the aquiferous formation, reporting a low sodium adsorption ratio (SAR) value range of 0.18 to 3.35, which is suitable for irrigation use and aligns with the SAR value range of 0.067 to 2.113 reported in this study (Egbunike, 2018). A similar study reported SAR values of <3.5 mmol/L for groundwater samples collected in the Coastal Sand Aquifer of Anambra and the Eastern Niger/Delta Basin (Akakuru and Akudinobi, 2018). This finding also agrees with the results of this study.

5.0 Conclusion

The increasing significance of irrigation in sustaining our growing global population, alongside the looming threats of climate change and contamination, necessitates regular evaluations of groundwater viability for irrigation. Thirty-five groundwater samples from boreholes across the southern Anambra Basin were chemically analyzed. Various indices, including SAR, and diagrams such as the Wilcox diagram, were used to assess the irrigation suitability of the area's groundwater. The groundwater within the area is generally excellent for irrigation purposes. However, it is crucial to periodically evaluate groundwater quality, especially with expanding populations and industries impacting groundwater quality.

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