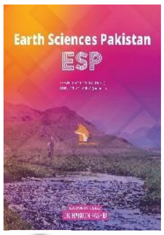
ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 2521-2893 (Print)
ISSN: 2521-2907 (Online)
CODEN: ESPADC

Earth Sciences Pakistan (ESP)

DOI: http://doi.org/10.26480/esp.02.2020.47.52



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RESEARCH ARTICLE

GROUNDWATER QUALITY MODELING FOR SUITABILITY FOR IRRIGATION PURPOSES IN OIL PRODUCING AREAS OF KHANA AND GOKANA LOCAL GOVERNMENT AREAS OF RIVERS STATE, NIGERIA

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ARTICLE DETAILS

Article History:

Received 01 April 2020
Accepted 04 May 2020
Available online 14 May 2020

ABSTRACT

This study is aimed at modeling groundwater quality for irrigation purposes in oil producing areas of Khana and Gokana Local Government areas of Rivers State, Nigeria. A random sampling approach was adopted in groundwater sampling in Khana and Gokana local government areas of Rivers State. Groundwater samples were collected from a total of twenty-two (22) boreholes in the area. Ten (10) residential boreholes were sampled in Khana while 12 boreholes were sampled in Gokana local government area. Various indices were used to determine the quality of groundwater for irrigation in the study area such as Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Permeability Index (PI), Percent Sodium (%Na), Magnesium Adsorption Ratio (MAR), Kelly's Ratio (KR) and Potential Soil Salinity (PS). In Khana area, all the water samples have PI values which render the groundwater unsuitable for irrigational purposes. Meanwhile, in Gokana, the groundwater samples show good to excellent quality for irrigation purposes. A high permeability index enhances crops yield, because the soils becomes more aerated and allows flow to occur easily, carrying plant nutrients from one part of the soil to the other. All groundwater samples in the area plotted in the C1-S1 (low sodium hazard and low salinity), C2-S1 (low sodium hazard and moderate salinity) and C3-S1 (low sodium hazard and high salinity) category which represents low sodium hazard and low salinity hazards and are therefore suitable for irrigation.

KEYWORDS

Modeling, irrigation, groundwater, borehole, soil productivity, oil producing areas.

1. INTRODUCTION

Water plays an important role in promoting agricultural production and standard of human health (Raju et al., 2013). The development and management of groundwater plays a vital role in agricultural production, for poverty reduction, environmental sustenance and sustainable economic development. Rapid industrialization, urbanization and population growth as well as fragile ecology has put tremendous pressure on the water regime. This has resulted in the degradation of both surface and groundwater quality. Both geogenic and anthropogenic reasons are responsible for groundwater quality degradation (Nwankwoala et al., 2016).

The quality of groundwater is very crucial for the sustainability of life. Groundwater is considered as the major source of water for human activities especially in the rural area. Groundwater is one of the important sources of water supply in Gokana and Khana Local Government Areas of Rivers State, Nigeria. This is because most of the available surface water in the area is generally polluted with solid and other wastes generated from oil exploitation activities. Most of the groundwater quality in Khana and Gokana Local Government Areas of Rivers State, Nigeria is of poor quality (Nwankwoala & Udom, 2011; Giadom et al., 2016). Knowledge of the effect of irrigation water on soil properties is therefore very important in the area in order to maintain good soil productivity.

There has been extensive oil contamination of swamp, rivers, creeks and groundwater in Ogoniland (Olof and Jonas, 2013; UNEP 2011; Ofoma et al., 2008). The contamination levels were high enough to cause significantly severe effects on human health and the ecosystem (Nwankwoala et al., 2013}. The UNEP assessment report 2011 stated that the effects of the contamination have destroyed mangrove areas. Favourable climatic conditions for natural degradation of petroleum hydrocarbon contaminants however continuous re-pollution has prevented quick environmental regeneration.

It has been envisaged that groundwater has the potential of being phased in sufficient quantities to meet irrigation needs to raise the living standards of the communities whose main stay over the years has been rain-fed peasant farming (Yidana and Yidana, 2009).

Groundwater is generally assumed to be safe for consumption because it is located beneath the land surface and not typically in contact with the atmosphere (Quist et al., 1988). Although groundwater is generally buffered from most surface polluting activities (Yidana and Yidana 2009), its quality can further deteriorate with time as a result of increasing pollution of surface water. Groundwater quality may also be compromised as a result of anthropogenic activities close to boreholes and shallow hand

Quick Response Code	Access this article online	
	Website: www.earthsciencespakistan.com	**DOI:** 10.26480/esp.02.2020.47.52

Cite the Article: Nwankwoala, H.O, Amachree, T (2020). Groundwater Quality Modeling For Suitability For Irrigation Purposes In Oil Producing Areas Of Khana And Gokana Local Government Areas Of Rivers State, Nigeria. *Earth Sciences Pakistan, 4(2): 47-52*.

dug wells. Poor sanitation, improper waste disposal, seepage of agrochemicals and mining has been observed to affect the quality of groundwater (Salifu et al., 2013; Fianko et al., 2010; Jain et al., 2000; Carpenter et al., 1998). Sustaining current agricultural production and agri-food processing depends on quality water supplies. Irrigation requires good quality water in order to prevent damage to sensitive crops from pesticides, salts, and trace metals (Kurdi et al., 2013). In addition, low sodicity in irrigation waters is necessary to maintain soil structural stability (Little et al., 2010).

The quality of any water for irrigation use is determined by the concentration and composition of dissolved constituents in the water. A lot of chemical constituents affect the suitability of water for irrigation based on the total concentration of soluble salts and the relative proportion of major cations. The suitability of water for irrigation depends on the effect of mineral constituents of water for both plants and soil (Wilcox, 1955). It therefore becomes imperative to study and model the groundwater quality condition of the area in order to obtain information on the groundwater quality status, especially its use for irrigation purposes.

1.1 Geology and Hydrogeology of the Study Area

The hydrogeology of the area at different times has described the Benin Formation as a highest yielding water bearing zone of the area (Etu-Efeotor, 1981). Overlying the 40m-150m thick Quaternary deposits, the Benin Formation consists of sequences of sands and silty clay alternating which later become increasingly prominent seawards (Etu-Efeotor and Akpokodje, 1990). Based on strata logs in the area, described the aquifer in the area as a stack of alternating aquifers lying upon each other in a multiple fashion such that the uppermost ones are mostly unconfined and underlain by the confined aquifers. The Niger Delta consists of three diachronous units, namely Akata (oldest), Agbada and Benin (youngest) formations. The Benin Formation (Oligocene to Recent) is about 2100m thick at the basin centre and consists of medium to coarse grained sandstones, thin shales and gravels (Weber and Dakouru, 1975).

The Niger Delta has spread across a number of ecological zones comprising sandy coastal barriers, brackish or saline mangrove, freshwater and seasonal swamp forests. The Niger Delta has two most important aquifers, Deltaic and Benin Formations. With a typically dendritic drainage network, this highly permeable sands of the Benin Formation allows easy infiltration of water to recharge the shallow aquifers. Nwankwoala *et al*., 2013 described the aquifers in this area as a set of multiple aquifer systems stacked on each other with the unconfined upper aquifers occurring at the top. Recharge to aquifers is direct from infiltration of rainfall, the annual total of which varies between 5000mm at the coast to about 2540mm landwards. Groundwater in the area occurs in shallow aquifers of predominantly continental deposits encountered at depths of between 45m and 60m. The lithology comprises a mixture of sand in a fining up sequence, gravel and clay. Well yield is excellent, with production rates of 20,000 litres /hour common and borehole success rate is usually high (Efeotor and Odigi 1983). Across the area, measures transmissivity varies from 59 to 6050m^2/d, Hydraulic conductivity from 0.04 to 60m/d and storage coefficient from 10^{-6} to 0.15 (Amadi *et al*., 2012). Surface water occurrence includes numerous networks of streams, creeks and rivers.

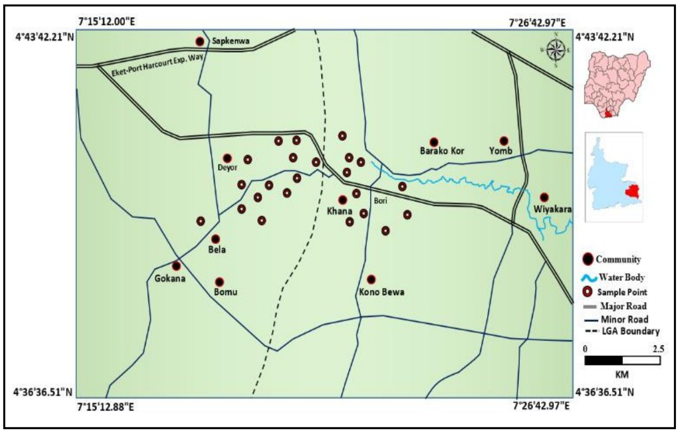

Figure 1: Map of Khana and Gokana Areas showing study locations

Groundwater recharge system in the study area is sourced from direct precipitation with an annual intensity of as high as 2000 – 2400mm. Water permeates the Benin formation sands to recharge the aquifers. The multi-layer aquifer system has shallow unconfined aquifers at the upper limit of the geologic units providing most of the domestic water needs of the communities' inhabitants (Nwankwoala *et al*., 2013). The water table in the area is between 0.7m to 3.5m depth and fluctuates with the prevailing land profile and season (UNEP, 2011). These aquifers are therefore vulnerable to pollution from a range of contaminants ranging from, hydrocarbon contaminant plumes, solid wastes and leachates.

2. MATERIALS AND METHODS

2.1 Groundwater Sampling

A random sampling approach was adopted in groundwater sampling in Khana and Gokana local government areas of Rivers State. Groundwater samples were collected from a total of twenty-two (22) boreholes in the area (Table 1). Ten (10) residential boreholes were sampled in Khana while 12 boreholes were sampled in Gokana local government area. At each borehole where water samples were to be collected, the sterilized sample bottles were thoroughly rinsed with the water to be sampled before actual samples were collected. The water was allowed to flow freely for about 5 minutes in order to clear all dissolved solids that may be stuck to the walls of the pipes and tap. The sample bottles were allowed to fill to the brim and corked immediately to minimize escape of dissolved oxygen.

Samples were collected in duplicates for analysis of physicochemical parameters, heavy metals and petroleum hydrocarbon compounds. Samples for physicochemical and heavy metal analysis were collected in plastic bottles, while samples for hydrocarbon compounds determination were collected in glass bottles. Water samples for the determination of physicochemical parameters and heavy metals were stabilized by adding few drops of diluted hydrochloric acid to them after collection. Unstable groundwater parameters such as pH, total dissolved solids and electrical conductivity were analyzed in-situ in order to preserve the integrity of the water samples. All sampling bottles were neatly labelled after sample collection and stored in an ice tight chest for onward transport to the laboratory for analysis. All sampling locations were noted with the aid of a global positioning system.

Table 1: Sampling location and geographic references for the sampled boreholes

Location	Borehole ID	Easting	Northing
Khana L.G.A.	BH1	318428.88	515856.14
	BH2	317976.04	516741.85
	BH3	320007.51	517190.53
	BH4	318200.19	517703.40
	BH5	319181.86	515201.95
	BH6	320215.87	516128.46
	BH7	317566.83	517306.79
	BH8	317724.13	518146.85
	BH9	317774.02	515758.14
	BH10	317370.54	518766.95
Gokana L.G.A	BH11	311415.80	515607.34
	BH12	314641.10	518751.29
	BH13	316157.97	517409.62
	BH14	315540.04	518848.68
	BH15	315304.79	517898.21
	BH16	315401.34	516504.62
	BH17	313590.93	515734.83
	BH18	313148.27	516222.46
	BH19	313803.46	516453.13
	BH20	313094.83	517074.10
	BH21	314237.74	517104.54
	BH22	313385.94	518168.20

2.2 Sample Analysis

Groundwater samples were transported to the laboratory for analysis of physicochemical parameters, heavy metals and hydrocarbon compounds. The physicochemical parameters analyzed includes; pH, Total Dissolved Solids, Electrical Conductivity, Sodium, Calcium, Magnesium, Potassium, Sulphate, Nitrate, Chloride and Bicarbonate. Heavy metals analyzed includes; Iron, Zinc, Manganese, Chromium, Lead, Nickel, Cadmium and Copper. The hydrocarbon compounds analyzed includes Polycyclic Aromatic Hydrocarbons and Total Petroleum Hydrocarbons. The analytical methods utilized for the analysis of these parameters are presented in Table 2.

Table 2: Analytical methods used for groundwater samples analysis

Class	Parameter	Symbol	Unit	Type of Test	Laboratory Standard
Physicochemical parameters	pH	pH		In-situ	APHA 4500-H+B
	Total Dissolved Solids	TDS	mg/L	In-situ	APHA 2540C
	Electrical Conductivity	EC	uS/cm	In-situ	APHA 2510B
	Sodium	Na	mg/L	Laboratory	APHA 3111B
	Calcium	Ca	mg/L	Laboratory	APHA 3111D
	Magnesium	Mg	mg/L	Laboratory	APHA 3111B
	Potassium	K	mg/L	Laboratory	APHA 3111B
	Sulphate	SO4	mg/L	Laboratory	APHA 4500/SO_4-E
	Nitrate	NO_3	mg/L	Laboratory	APHA 4500/NO_3-E
	Chloride	Cl	mg/L	Laboratory	APHA 3111B
	Bicarbonate	HCO_3	mg/L	Laboratory	APHA 3111B

2.3 Irrigation Water Indices

Various indices were used to determine the quality of groundwater for irrigation in the study area. All parameters utilized for irrigation water analysis were in milliequivalents per litter (Meq/L). The various indices are discussed under the following sub-headings.

2.4 Sodium Adsorption Ratio (SAR)

This index is useful in classifying groundwater suitability for irrigation. The SAR was calculated as defined by Richards (1954):

$$SAR = \frac{Sodium}{\sqrt{\frac{(Calcium+Magnesium)}{2}}} \quad (1)$$

2.5 Magnesium Adsorption Ratio (MAR)

The presence of magnesium (Mg) in groundwater in high proportions will reduce the overbearing effect of sodium (Na) in groundwater. The MAR was calculated as defined by Raghunath (1987):

$$MAR = \frac{Magnesium}{Calcium+Magnesium} \times 100 \quad (2)$$

2.6 Kelly's Ratio (KR)

Kelly's Ratio is used for classifying water for irrigation purposes. A KR >1 shows an excess of Na and KR <1 shows its deficit in water (Kelly, 1940). Water having KR <1 are suitable for irrigation while those with greater ratios are unsuitable (Sundaray *et al.*, 2009). The KR was calculated as defined by Kelly (1940) as follows:

$$KR = \frac{Sodium}{Calcium+Magnesium} \quad (3)$$

2.7 Percent Sodium (% Na)

This is very useful for evaluating the suitability of groundwater quality for irrigation purposes (Wilcox, 1955). Very high percentage of sodium in water produces undesirable effects because sodium reacts with soil to reduce its permeability and supports little or no plant growth. The %Na was calculated as defined by Wilcox (1955) as:

$$Na\% = \frac{Na}{Calcium+Magnesium+Sodium+Potassium} \times 100 \quad (4)$$

2.8 Potential Salinity (PS)

Doneen (1954) pointed out that the concentrations of soluble salts in water has no control on its suitability for irrigation. Rather, his opinion is that the low soluble salts get precipitated in the soil and accumulates with each successive irrigation, and on the other hand, the concentrations of highly soluble salts enhance the salinity of the soil. The PS was calculated as defined by Doneen (1954) as:

$$PS = Cl^- + \sqrt{SO_4^{2-}} \quad (5)$$

2.9 Results of Groundwater Irrigation Indices

The results of groundwater irrigation indices are presented in Table 4.4. The results presented includes; Sodium adsorption ratio (SAR), Percent Sodium (%Na), Permeability Index (PI), Magnesium adsorption ratio (MAR), Kelly's ratio (KR) and Potential soil salinity (PS). The interpreted results are presented in Tables 4.5 and 4.6 for Khana and Gokana local government areas. The results for groundwater classification with respect to SAR and salinity hazards are presented in Figure 2. The Wilcox (1955) classification plot for groundwater samples from the study area is presented in Figure 3.

Table 3: Statistical summary of groundwater quality analysis in the area

Parameter	Symbol	Unit	Khana L.G.A.				Gokana L.G.A.				WHO (2012)	NSDWQ (2007)
			Min	Max	Mean	S.D.	Min	Max	Mean	S.D.		
pH	pH		5.43	6.61	6.10	0.39	5.43	6.67	6.12	0.37	6.5-8.5	6.5-8.5
Total Dissolved Solids	TDS	mg/L	29.00	439.00	135.30	118.20	34.54	652.00	276.05	188.02	500.00	500.00
Electrical Conductivity	EC	uS/cm	58.00	878.00	270.60	236.40	69.08	1304.00	552.10	376.04	1000.00	1000.00
Sodium	Na	mg/L	2.65	10.86	6.55	3.22	2.54	8.76	5.98	2.10	200.00	200.00
Calcium	Ca	mg/L	5.98	9.80	7.68	1.33	4.66	11.50	8.29	1.96	75.00	75.00
Magnesium	Mg	mg/L	3.98	8.39	5.87	1.30	2.65	9.45	6.74	2.10	50.00	30.00
Potassium	K	mg/L	0.38	2.88	1.21	0.94	0.41	2.67	1.23	0.75	55.00	200.00
Sulphate	SO_4	mg/L	3.32	86.55	18.64	24.19	8.98	29.80	16.26	6.92	500.00	500.00
Nitrate	NO_3	mg/L	3.59	12.22	8.47	2.81	0.54	14.27	8.18	5.13	5.00	5.00
Chloride	Cl	mg/L	22.34	121.45	50.91	35.36	23.64	105.43	58.44	32.15	250.00	250.00
Bicarbonate	HCO_3	mg/L	1.34	32.54	16.44	9.25	8.54	29.88	16.63	7.46	600.00	600.00
Iron	Fe	mg/L	0.01	0.7	0.37	0.19	0.18	0.63	0.32	0.13	0.30	0.30
Zinc	Zn	mg/L	0.40	3.76	1.23	1.27	0.23	0.95	0.59	0.20	5.00	3.00

Manganese	Mn	mg/L	0.02	0.39	0.12	0.12	0.01	0.43	0.10	0.11	0.20	0.20
Chromium	Cr	mg/L	0.02	0.08	0.04	0.03	<0.01	0.07	0.04	0.02	0.05	0.05
Lead	Pb	mg/L	0.001	0.02	0.009	0.0075	0.01	0.04	0.025	0.01	0.01	0.01
Nickel	Ni	mg/L	<0.01	<0.01	-	-	<0.01	0.00	-	-	0.02	0.02
Cadmium	Cd	mg/L	0.001	0.006	0.003	0.0015	0.002	0.005	0.003	0.001	0.003	0.003
Copper	Cu	mg/L	0.06	0.66	0.34	0.20	0.09	0.62	0.38	0.17	1.00	1.00
Polycyclic Aromatic Hydrocarbons	PAH	ug/L	<0.01	0.09	0.05	0.03	<0.01	0.09	0.06	0.02	0.15**	
Total Petroleum Hydrocarbons	TPH	ug/L	8.96	165.00	58.79	49.21	2.93	104.53	38.63	36.77	50.00**	

2.10 Suitability for Irrigation

Assessment of groundwater suitability for irrigation purposes was achieved using EC, Sodium Adsorption Ratio (SAR), Permeability Index (PI), Percent Sodium (Na%), and Magnesium Adsorption Ratio (Table 4).

2.10.1 Sodium Adsorption Ratio (SAR)

Excess Na^+ in water produces undesirable effects of changing soil properties and reducing soil permeability (Kelly, 1940). Hence, assessment of Na is essential when considering the suitability of water for irrigation. The degree to which irrigation water enters into cation exchange reactions in soil can be indicated by the SAR. Na replacing absorbed Ca^{2+} and Mg^{2+} causes damage to soil structure. The values of SAR in groundwater from the study area range from 0.06 to 0.24 in Khana and from 16 to 0.57 in Gokana area. The mean values are 0.14 and 0.38 respectively. SAR values less than 3.0 will not threaten vegetation while values above 12.0 are considered sodic and will threaten plant survival by increasing soil swell potential and reducing permeability of soil (Kuipers *et al*., 2004). The results of SAR in this study indicates low sodium hazard for all water samples. Jain *et al.,* (2000) warns that groundwater having high salinity and sodic hazard should not be utilized on soils which have restricted drainage.

On the USSL (1954) water classification diagram which plots sodium hazard (SAR) against Electrical conductivity (EC), all groundwater samples in the area plotted in the C1-S1 (low sodium hazard and low salinity), C2-S1 (low sodium hazard and moderate salinity) and C3-S1 (low sodium hazard and high salinity) category (Fig. 5) which represents low sodium hazard and low salinity hazards and are therefore suitable for irrigation.

2.10.2 Percent Sodium (% Na)

Water for irrigation containing large amount of sodium is a special concern due to sodium hazard on soil. Excess sodium in water produces undesirable effects of reducing soil permeability (Subba-Rao, 2006). Sodium content is very important in the classification of groundwater for irrigation because it reacts with soil and reduces its permeability. The value of %Na ranges from 1.44 to 5.78 in Khana and 9.69 to 29.29 in Gokana area. These results show that the water samples are good to excellent for irrigation purposes. These results are confirmed by the plot of Na% against electrical conductivity on the Wilcox (1955) diagram which revealed that most of the samples plotted within the field of permissible to good, with only four samples within the field of good to permissible (Figures 5 and 6).

2.10.3 Permeability Index (PI)

The permeability index is a crucial parameter for assessing the suitability of irrigation water. The permeability index indicates whether water is suitable for irrigation. Doneen (1964) classified water as Class I with permeability index <75% (Excellent); Class 11 having PI of between <75 to >25% (Good) and Class III with PI <25% (Unsuitable). The groundwater PI ranged from 6.36 to 12.69 and from 44.98 to 115.48 in Khana and Gokana areas respectively. Based on Doneen (1964) classification of PI, in Khana area, all the water samples have PI values which renders the groundwater unsuitable for irrigational purposes. Meanwhile, in Gokana, the groundwater samples show good to excellent quality for irrigation purposes. A high permeability index enhances crops yield because the soils becomes more aerated and allows flow to occur easily, carrying plant nutrients from one part of the soil to the other.

2.10.4 Magnesium Adsorption Ratio (MAR)

The MAR in groundwater from the study area ranges from 4.39 to 7.66% and 47.62 to 68.11% in Khana and Gokana areas. Excess magnesium in water affects the soil by making it alkaline and results in decreased crop yield. All groundwater samples in Khana area have MAR values <50, indicating that the water sources are fit for irrigation. Meanwhile in Gokana area, 84% of the groundwater samples have unsuitable quality for irrigation (Table 6).

2.10.5 Kelly's Ratio (KR)

Kelly's ratio in groundwater from the study area ranges from 0.14 to 0.45 and from 0.08 to 0.45 in Khana and Gokana areas. Water quality is good for irrigation when KR < 1. The KR values for groundwater recorded in this study area indicate that there are all suitable for irrigation (Table 4).

2.10.6 Salinity Potential (PS)

Salinity Potential in groundwater from the study area ranges from 1.13 to 3.91 and from 1.20 to 3.48 in Khana and Gokana areas. Salinity potential <5 suggests that groundwater is good to excellent for irrigation purposes. Based on Salinity Potential index, these results are within the classification of good to excellent for irrigation purposes.

Table 4: Results of groundwater quality models for irrigation purposes

Community	Borehole	SAR	NA %	PI	MAR	KR	PS
Khana	BH1	0.19	4.91	6.93	7.43	0.35	2.42
	BH2	0.11	2.57	6.72	5.12	0.26	1.36
	BH3	0.06	1.44	6.36	4.39	0.17	1.13
	BH4	0.23	5.78	11.92	7.66	0.41	2.93
	BH5	0.10	2.60	10.40	5.41	0.25	1.29
	BH6	0.22	4.86	12.55	7.62	0.34	3.91
	BH7	0.14	2.97	7.29	5.24	0.29	1.23
	BH8	0.24	5.54	12.69	6.47	0.45	3.33
	BH9	0.07	1.88	11.17	5.21	0.18	1.14
	BH10	0.07	1.46	7.51	5.27	0.14	1.20
Minimum		0.06	1.44	6.36	4.39	0.14	1.13
Maximum		0.24	5.78	12.69	7.66	0.45	3.91
Mean		0.14	3.40	9.35	5.98	0.28	1.99
Gokana	BH11	0.51	25.95	58.14	62.52	0.28	2.90
	BH12	0.57	29.29	60.54	47.62	0.45	1.60
	BH13	0.42	22.87	53.52	56.27	0.27	1.59
	BH14	0.40	22.52	63.62	56.46	0.27	2.41
	BH15	0.16	9.69	65.58	68.11	0.08	1.20
	BH16	0.41	20.35	67.36	59.75	0.22	3.48

	BH17	0.47	22.02	51.59	57.92	0.25	3.14
	BH18	0.39	19.84	68.87	57.38	0.22	3.11
	BH19	0.36	26.73	115.48	48.40	0.39	1.43
	BH20	0.26	13.24	44.98	57.54	0.14	1.28
	BH21	0.27	18.22	84.35	54.50	0.21	3.17
	BH22	0.30	19.21	58.29	51.44	0.23	1.32
Minimum		0.16	9.69	44.98	47.62	0.08	1.20
Maximum		0.57	29.29	115.48	68.11	0.45	3.48
Mean		0.38	20.83	66.03	56.49	0.25	2.22

Table 5: Results interpretation for the various irrigation water quality models for Khana L.G.A.

Classification Scheme	Categories	Range (mg/L)	Percent of	Number of
Sodium Adsorption Ratio (SAR)	Excellent	<10	100	10
	Good	10-18	0	Nil
	Fair	>18-26	0	Nil
	Poor	>26	0	Nil
	Hard	>200-300	0	Nil
	Very hard	>300	0	Nil
Percent Sodium (%Na)	Excellent	<20	10	10
	Good	>20-40	0	Nil
	Permissible	>40-60	0	Nil
	Doubtful	>60-80	0	Nil
	Unsuitable	>80	0	Nil
Permeability Index (PI)	Excellent	> 75	0	Nil
	Good	25-75	0	Nil
	Unsuitable	< 25	100	10
Magnesium Adsorption Ratio (MAR)	Acceptable	<50	100	10
	Non-acceptable	>50	0	Nil
Kelly's Ratio (KR)	Suitable	<1	10	10
	Unsuitable	>1	0	Nil
Potential Soil Salinity (PS)	Excellent to good	<5	100	10
	Good to injurious	5-10	0	Nil
	Injurious to Unsatisfactory	>10	0	Nil

Table 6: Results interpretation for the various irrigation water quality models for Gokana L.G.A.

Classification Scheme	Categories	Range (mg/L)	Percent of Samples	Number of samples
Sodium Adsorption Ratio (SAR)	Excellent	<10	100	12
	Good	10-18	0	Nil
	Fair	>18-26	0	Nil
	Poor	>26	0	Nil
	Hard	>200-300	0	Nil
	Very hard	>300	0	Nil
Percent Sodium (%Na)	Excellent	<20	42	5
	Good	>20-40	58	7
	Permissible	>40-60	0	Nil
	Doubtful	>60-80	0	Nil
	Unsuitable	>80	0	Nil
Permeability Index (PI)	Excellent	> 75	16	2
	Good	25-75	84	10
	Unsuitable	< 25	0	Nil
Magnesium Adsorption Ratio (MAR)	Acceptable	<50	16	2
	Non-acceptable	>50	84	10
Kelly's Ratio (KR)	Suitable	<1	100	12
	Unsuitable	>1	0	Nil
Potential Soil Salinity (PS)	Excellent to good	<5	100	12
	Good to injurious	5-10	0	Nil
	Injurious to unsatisfactory	>10	0	Nil

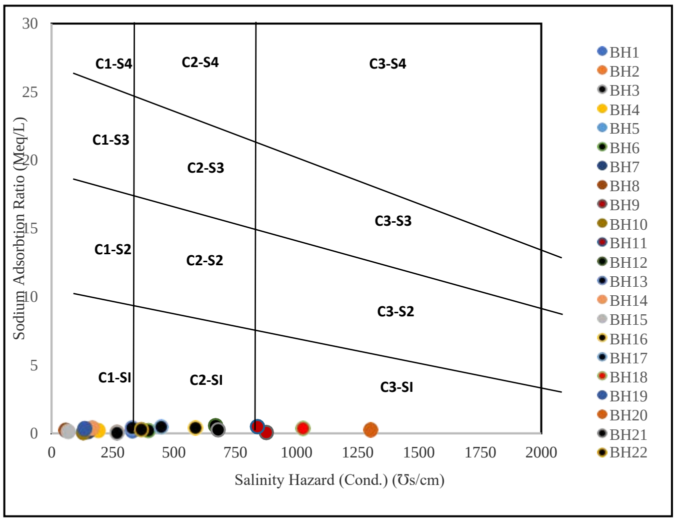

Figure 2: Classification of groundwater with respect to SAR and salinity hazard

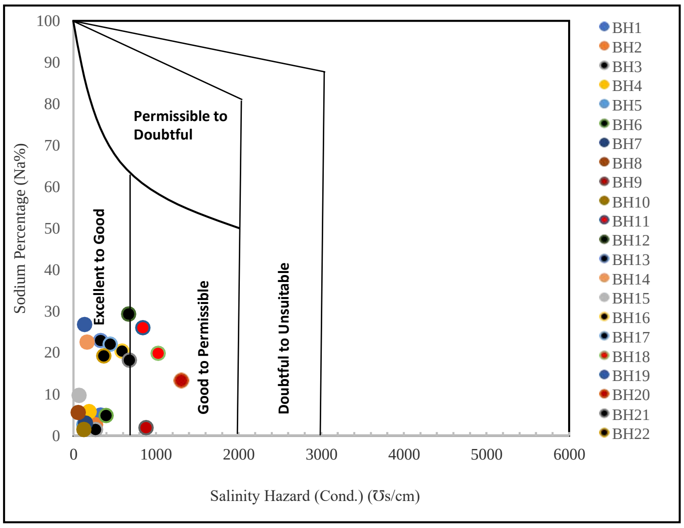

Figure 3: Groundwater classification for irrigation purposes based on Wilcox (1955) diagram

3. Conclusion

This study revealed that the value of Na% ranges from 1.44 to 5.78 in Khana and 9.69 to 29.29 in Gokana area. These results show that the water samples are good to excellent for irrigation purposes. These results are confirmed by the plot of %Na against electrical conductivity on the Wilcox (1955) diagram which revealed that most of the samples plotted within the field of permissible to good, with only four samples within the field of good to permissible.

All groundwater samples in Khana area have MAR values <50, indicating that the water sources are fit for irrigation. Meanwhile in Gokana area, 84% of the groundwater samples have unsuitable quality for irrigation.

This study revealed that in Khana area, all the water samples have PI values which render the groundwater unsuitable for irrigational purposes. Meanwhile, in Gokana, the groundwater samples show good to excellent quality for irrigation purposes. A high permeability index enhances crops yield because the soils becomes more aerated and allows flow to occur easily, carrying plant nutrients from one part of the soil to the other. All groundwater samples in the area plotted in the C1-S1 (low sodium hazard and low salinity), C2-S1 (low sodium hazard and moderate salinity) and C3-S1 (low sodium hazard and high salinity) category which represents low sodium hazard and low salinity hazards and are therefore suitable for irrigation.

Kelly's ratio in groundwater from the study area ranges from 0.14 to 0.45 and from 0.08 to 0.45 in Khana and Gokana areas. Water quality is good for irrigation when KR < 1. The KR values for groundwater recorded in this study area, indicates that there are all suitable for irrigation.

Salinity Potential in groundwater from the study area ranges from 1.13 to 3.91 and from 1.20 to 3.48 in Khana and Gokana areas. Salinity potential <5 suggests that groundwater is good to excellent for irrigation purposes. Based on Salinity Potential index, these results are within the classification of good to excellent for irrigation purposes.

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Cite the Article: Nwankwoala, H.O, Amachree, T (2020). Groundwater Quality Modeling For Suitability For Irrigation Purposes In Oil Producing Areas Of Khana And Gokana Local Government Areas Of Rivers State, Nigeria. *Earth Sciences Pakistan, 4(2): 47-52*.