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APPLICATION OF WATER QUALITY INDEX (WQI) FOR AGRICULTURAL AND IRRIGATIONAL USE AROUND OKPOKO, SOUTHEASTERN NIGERIA

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ABSTRACT

This study aims at using the water quality index (WQI) in the assessment of groundwater for agriculture and irrigation purposes. This was possible with the aid of several water quality indices including Sodium Adsorption Ratio (SAR), Magnesium Adsorption Ratio (MAR), Sodium Percentage (Na %), Permeability Index (PI), Residual Sodium Carbonate (RSC), Kelly's Ratio (KR) and Potential Salinity (PS). All the quality indicators show that the groundwater sources in the area are excellent for irrigation purposes. In this study, electrical conductivity (EC) ranges from 3.20 to 139.32 mg/L with mean and SD values of 47.32±45.20 mg/L. Based on Richard's classification scheme, the groundwater sources are of low salinity hazard (< 250 mg/L), hence, excellent for irrigation purposes. The values of SAR in groundwater from the study area range from 0.1 to 0.89, with mean and Standard Deviation (SD) of 0.41±0.28. SAR values less than 3.0 will not threaten vegetation while values above 12.0 is considered sodic and will threaten plant survival by increasing soil swell potential and reducing the permeability of soil. The results of SAR in this study indicates low sodium hazard for all the groundwater sources. Evaluation of water quality for agricultural purposes using SAR, Na %, RSC, PI, SP, and Kelly's ratio suggests that they are suitable for agricultural purposes. Water Quality Index implies that most of the areas around the area were dominated by the good to excellent quality water for different purposes. In addition, the results of this study will be useful in estimating the major sources of contamination in different areas within the framework of activities intending to improve the quality of water. Water Quality Index (WQI) ultimately helps us to understand the water quality in surrounding areas. Moreover, it will be helpful in monitoring activities and for further water quality management to prevent the pollution.

KEYWORDS

Groundwater, water quality index, agriculture, irrigation, salinity hazard.

1. INTRODUCTION

Groundwater is the water located beneath the earth's surface in the vadose zone. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable amount of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Gr0undwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells [1].

Groundwater moves through pore spaces within rocks and reacts with minerals that make up the rocks in the course of migration [2,3]. Groundwater quality in any locality takes after the chemical composition of the aquifer through which it migrates in accordance with the hydrological cycle and flow direction [3-6]. The aim of this study is to evaluate the hydrochemical characteristics, water quality, contamination as well as sources of contamination of ground and surface water around

Water quality, otherwise known as potability can be defined as the chemical, physical and biological properties of water as it concerns safe intake. It also involves the process of evaluating their physical, chemical and biological properties in relation to the natural quality and health effects. In a research, a couple researchers reported that water quality is enormously dependent on the indigenous geology, ecosystem, as well as human activities [7]. The potability of water is dependent on the intended use of the water. For instance, much concern given to water required for direct human use compared to water used for industrial and other environmental purpose [8].

Increased industrialization, urbanization and agricultural activities during the last few decades have impaired the groundwater quality [2]. The nature and the properties of the rock, aquifer specific yield and retention, the chemistry of water are governed by the geology of the environment [9]. According to a study, the quality of groundwater is a function of natural processes as well as man-made activities, and that the type, extent and duration of anthropogenic activities on groundwater quality are governed by the geochemical and physical processes and the hydrological conditions present [10,11].

2. DESCRIPTION OF THE STUDY AREA

The area of study is located in Onitsha North Local Government Area of Anambra State and bounded geographically by longitudes 06° 06′ 00″ N to 06° 09′ 00″ N and latitudes 06° 45′ 00″ E to 06° 49′ 30″ E (Figure 1). Communities situated within the study area include Woliwo and Awada layout on the eastern part of the area. The town within which the site is located is thickly populated. Several fuel filling and service stations are cited at very close proximities. The major station in the area is located along Onitsha - Owerri Expressway at about 20m from the main road, about 30m from Power Holding Company of Nigeria (PHCN) High Tension cable, about 50m from residential buildings, about 200m from New motor parts dealers market, about 540m from St. Lwangas Hospital and Maternity, School of Health and Technology, about 300m from Sako Oil and Gas LTD fuel filling station at the left hand side of the road, and about 400m from Lake side Petroleum filling station on the right hand side of the road.Generally, the study area has very good road network and link roads. Two major rivers are responsible for draining the area which includes the Niger River and its major tributary, Ulasi River. However, there are local creeks and ponds all over the vicinity of the area.

The Anambra Basin which includes the study area is located at the southwestern extreme of the Benue Trough formed after the Santonian tectonic depression, dating back to 84 MYA [12]. It is a Cretaceous sedimentary domain partly bounded between the southern Benue Trough below and the Niger Delta Basin above. 1t originated following the subsidence of a platform in the southern Benue Trough, concurrent with the lateral translocation of the depocentres during the Santonian thermotectonic event that folded and was also elevated the Abakaliki region [13].

The basin is believed to have been formed as a direct impact of the stresses generated by the movement along the fracture zones. It is bounded to the west by the Precambrian basement complex rocks of the Western Nigeria and on the east by the Abakaliki Anticlinorium. At the Southern part, the boundary is at Onitsha, which is the northern-most limit of the Niger delta basin. The northern boundary of the Anambra basin is not well defined. The basin is connected with the NW-SE trending Bida Basin. Before the Santonian period, the south-western area of its rift valley was the tectonically stable Anambra platform. The Santonian compressional event was followed by magmatism, folding and faulting, which led to the formation of the Abakaliki Anticlinoruim. To the west and southward areas of the Anticlinorium was the depocentre, creating the Anambra and the Afikpo basins respectively [14]. Subsidence in these basins continued after the Santonian compression [15]. The 1sostatic response to the Early Cretaceous Crustal thinning and post drift thermal relaxation of the lithosphere was believed to be due to the accelerated subsidence that continued till the Eocene.

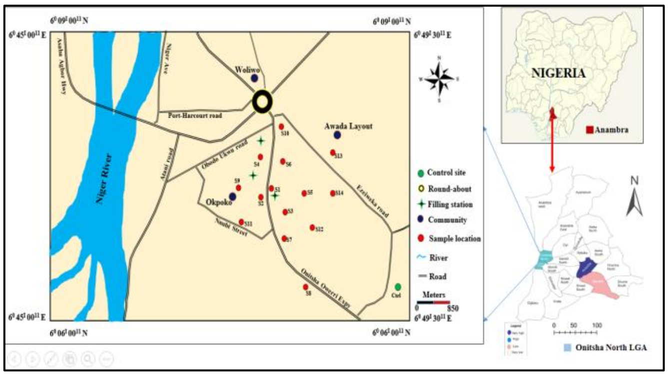

Figure 1: Map of the study area showing sampled locations

3. METHODOLOGY

Groundwater sampling in the study area was carried out during the raining season (March, 2017). Fifteen (15) groundwater samples were collected from boreholes distributed randomly in Okpoko and Environs. The water samples were collected as close as possible to the well head to prevent loss of ions or contamination of the water. The water samples were collected in washed and pre-cleaned plastic bottles. Before sampling, the water was allowed to flow for about three minutes to prevent sampling of ions that have settled in the pipes. The sampling containers were washed with the water to be sampled several times before sampling began, and immediately corked to prevent introduction of oxygen. All the groundwater samples were carefully labelled and stored in ice before transportation to the laboratory for analysis. Parameters that were analyzed in-situ in the field include: pH, temperature and electrical conductivity using potable -held meters.

3.1 Water Quality Indices

The Water Quality Index (WQI) analysis provides a comprehensive picture of the quality of surface and groundwater for most domestic uses. WQI is defined as a rating that reflects the composite influence of different water quality parameters [16]. It is an important parameter for assessing groundwater quality and its suitability for drinking purposes [3,17-21].

Water Quality Index (WQI) is a single value expression that numerically summarizes multiple water quality parameters. It is calculated from the point of view that a lower value of it signifies less deviation from the recommended values of parameters included and more good quality water for human consumption or vice versa.

Salinity hazard, Kelly's ratio (KR), residual sodium carbonate (RSC), sodium adsorption ratio (SAR), permeable index (PI), sodium percentage (Na%), and magnesium adsorption ratio (MAR) were calculated to determine the groundwater suitability for agriculture and irrigation purposes. All parameters were converted to Meq/L before calculations were made.

3.2 Sodium Adsorption Ratio (SAR)

This index is useful in classifying groundwater suitability for irrigation. The SAR was calculated as defined in a research [22]:

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

3.3 Magnesium Adsorption Ratio (MAR)

The presence of Mg in groundwater in high proportions will reduce the overbearing effect of Na in groundwater. The MAR was calculated as defined by some research:

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

3.4 Kelly's Ratio

Kelly's Ratio is used for classifying water for irrigation purposes. A KR >1shows excess of Na and KR <1 shows its deficit in water [23]. The water with KR <1 is suitable for irrigation while those with greater ratios are unsuitable. The KR was calculated as defined:

$$KR = \frac{Na}{Ca+Mg} \quad (3)$$

3.5 Sodium Percentage (Na %)

This is very useful for evaluating the suitability of groundwater quality for irrigation purposes [24]. Very high Na in water produces undesirable effects because Na reacts with soil to reduce its permeability and supports little or no plant growth. The Na% was calculated as defined:

$$Na\% = \frac{Na}{Na+Ca+Mg+K} \times 100 \quad (4)$$

3.6 Residual Sodium Carbonate (RSC)

The sum of CO_3 and HCO_3 over the sum of Na and Mg in groundwater influences the usability of water for irrigation purposes. An excess Na-HCO_3 and CO_3 influences physical properties of soil by dissolving soil organic matter and leaves black stain on its surface when dried [25]. The RSC was calculated as defined:

$$RSC = (CO_3^- + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad (5)$$

3.7 Permeability Index (PI)

The permeability of soil is influenced by Na, Ca, Mg and HCO_3 in soil which in turn influences the quality of irrigation water. The RSC was calculated as defined by:

$$PI = \left(\left\lfloor\left(Na^+ + \sqrt{HCO_3^-}\right)\right\rfloor \div \lfloor(Ca^{2+} + Mg^{2+} + Na^+)\rfloor\right) \times 100 \quad (6)$$

3.8 Potential Salinity (PS)

A researcher pointed out that the concentrations of soluble salts in water has no control on its suitability for irrigation [26]. Rather, his opinion is that the low soluble salts get precipitated in the soil and accumulate with 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:

$$PS = Cl^- + \sqrt{SO_4^{2-}} \quad (7)$$

4. RESULTS AND DISCUSSION

Table 1: Results for groundwater quality indicators in the study area

Parameters	SAR	Na %	RSC	PI	MAR	KR	PS
BH1	0.17	12.47	2.11	78.49	39.47	0.05	0.95
BH2	0.22	11.57	1.73	64.18	34.62	0.06	1.06
BH3	0.38	12.64	0.82	56.60	35.00	0.10	1.18
BH4	0.56	24.88	-1.31	33.15	6.06	0.15	0.78
BH5	1.00	33.86	-0.93	53.32	29.27	0.32	1.06
BH6	0.16	14.22	-1.70	30.73	12.90	0.04	0.84
BH7	0.14	18.62	-0.23	38.73	4.66	0.04	1.64
BH8	0.73	22.88	-2.55	35.17	7.65	0.19	1.69
BH9	0.94	36.05	-0.28	43.56	14.37	0.35	1.88
BH10	0.23	11.27	1.11	63.04	35.29	0.06	1.31
BH11	0.84	38.81	-0.26	51.40	10.34	0.34	1.31
BH12	0.83	35.85	-1.03	32.78	24.74	0.30	2.41
BH13	1.25	38.39	-0.76	52.42	12.15	0.50	1.11
BH14	1.05	23.96	0.04	58.42	39.56	0.27	1.08
BH15	0.16	9.62	0.04	50.29	36.54	0.04	1.10
Minimum	0.14	9.62	-2.55	30.73	4.66	0.04	0.78
Maximum	1.25	38.81	2.11	78.49	39.56	0.50	2.41
Mean	0.58	23.01	-0.21	49.49	22.84	0.19	1.29
Standard deviation	0.39	11.04	1.27	13.76	13.40	0.15	0.44

Table 2: Classification schemes for groundwater quality indicators in the area

Classification scheme	Categories	Range (mg/L)	Percentage	Number of samples
Sodium adsorption ratio (SAR)	Excellent	<10	1	15
	Good	10-18	0	Nil
	Fair	>18-26	0	Nil
	Poor	>26	0	Nil
	Hard	>200-300	0	Nil
	Very hard	>300	0	Nil
Sodium Percentage (Na%)	Excellent	up to 20	47	7
	Good	>20-40	53	8
	Permissible	>40-60	0	Nil
	Doubtful	>60-80	0	Nil
	Unsuitable	>80	0	Nil
Residual Sodium Carbonate (RSC)	Good	<1.25	87	13
	Medium	1.25-2.5	13	2
	Bad	>2.5	0	Nil
Magnesium Adsorption Ratio (MAR)	Acceptable	<50	100	15
	Non acceptable	>50	0	Nil
Kelly's ratio	Suitable	<1	100	15
	Unsuitable	>1	0	Nil
Salinity Potential (PS)	Excellent to good	<5	100	15
	Good to injurious	5-10	0	Nil
	Injurious to unsatisfactory	>10	0	Nil
Permeability Index (PI)	Excellent	>75	7	1
	Good	25-75	93	14
	Unsuitable	<25	0	Nil

4.1 Suitability for Agricultural Purposes

The suitability of groundwater for agricultural and irrigation purposes is contingent on the overall effects the chemical constituents in the groundwater has on both plants and soils. Assessment of groundwater suitability for irrigation purposes was achieved using Salinity Index, Sodium Adsorption Ratio (SAR), Permeability Index (PI), Percent sodium (Na%), Residual Sodium Carbonate (RSC) and Magnesium Adsorption Ratio (Table 1).

4.2 Sodium Adsorption Ratio

In this study, based on classification scheme, the groundwater sources are of low salinity hazard (< 250 mg/L), and hence, excellent for irrigation purposes [22]. The values of SAR in groundwater from the study area range from 0.1 to 0.89, with mean and SD of 0.41±0.28. SAR values less than 3.0 will not threaten vegetation while values above 12.0 is considered sodic and will threaten plant survival by increasing soil swell potential and reducing permeability of soil [19]. The results of SAR in this study indicates low sodium hazard for all the groundwater sources.

Groundwater having high salinity and sodic hazard should not be utilized on soils which have restricted drainage.

On the US Salinity Laboratory diagram which plots sodium hazard against Electrical conductivity, all the groundwater samples plot in the C1-S1 category (Figure 2) which represents low sodium hazard and low salinity hazards and are therefore suitable for irrigation [27].

4.3 Sodium Percentage (Na %)

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 9.62 to 8.81, with mean and SD of 23.01±11.04%. This shows that the water sources are good to excellent for irrigation purposes and confirmed by the plot of Na% against electrical conductivity on the diagram (Figure 3) [24].

4.4 Residual Sodium Carbonate (RSC)

The relative abundance of sodium with respect to carbonate and bicarbonate over alkaline earth affects the suitability of water for irrigation purpose [28]. Residual Sodium Carbonate ranges from -2.55 to 2.11, with mean and SD of -0.21±1.27 (Table 1). Majority of the samples (13 samples) shows that the water is in perfect condition for irrigation whereas a few samples recorded manageable water conditions (Table 2).

4.5 Magnesium Adsorption Ratio (MAR)

The MAR in groundwater from the study area ranges from 4.66 to 39.66, with mean and SD of 22.84±13.40. Excess Mg in water affects the soil by making it alkaline and results in decrease of crop yield. All groundwater samples have MAR values <50, indicating that the water sources are fit for irrigation (Table 2).

4.6 Kelly's Ratio (KR)

Water quality is good for irrigation when KR< 1. The KR values for ground water in the study area indicate that there are all suitable for irrigation (Table 2).

4.7 Salinity Potential (SP) and Permeability Index (PI)

In this study, salinity potential (PS) and Permeability Index ranged from 0.78 to 2.41 and 30.73 to 78.49, with mean and SD values of 1.29±0.44 and 49.49±12.76 respectively (Table 1). Based on SP and PI indices, these results are within the classification of good to excellent for irrigation purposes [29].

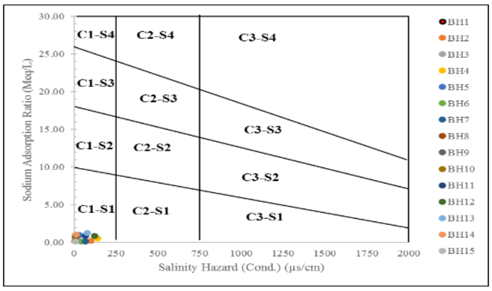

Figure 2: Rating of groundwater samples for irrigation purposes in relation to salinity hazard and sodium hazard [27]

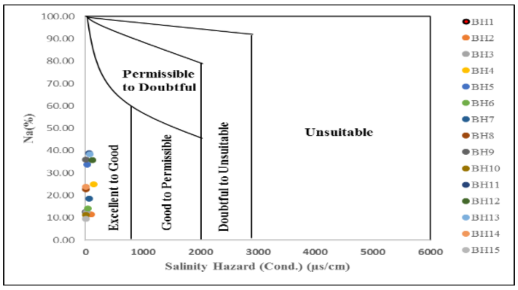

Figure 3: Groundwater classification for irrigation purposes based on Wilcox (1955) diagram [27]

5. CONCLUSION

Assessment of groundwater for irrigation purposes was possible with the aid of several water quality indices including MAR, SAR, Na%, PI, RSC and PS. All the quality indicators show that the groundwater sources in the area are excellent for irrigation purposes.

Water Quality Index implies that most of the areas around the area were dominated by the good to excellent quality water for different purposes. In addition, the results of this study will be helpful to estimate the major sources of contamination in different areas within the framework of activities intending to improve the quality of water. Water Quality Index (WQI) ultimately helps us to understand the water quality in surrounding area. Moreover, it will be helpful in monitoring activities and for further water quality management to prevent the pollution.

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