International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Assessment of Groundwater for Agricultural Uses in Ekeki, Yenagoa Local Government Area, Bayelsa State, Nigeria.

Ovuru. C, Okujagu D. C. and Joseph A. P

[1 &3]Department of Geology Niger Delta University
[2]University of Port Harcourt
cebimtaku@gmail.com, diepiriye.okujagu@uniport.edu.ng

ABSTRACT

This study is to access groundwater quality for agricultural purpose. Groundwater is important to the wellbeing of crops. Groundwater samples were obtained from seven different boreholes in Ekeki, Yenagoa, Bayelsa state and these samples were analyzed using Standard Laboratory Practice. The aim is to access groundwater quality for agricultural purpose using Ekeki, Yenagoa as a case study. The data obtained for this research work is the primary data as it was collected directly by the researcher on the field. Physiochemical parameters were also deciphered: pH, Conductivity, salinity, Turbidity calcium, Sodium, Sulphate, Nitrate, Chloride, Potassium, Magnesium, Iron, and Biological Oxygen Demand (BOD) etc. The results obtained from the work showed that the concentration of most parameters in the groundwater samples falls within the IWQS and WHO (2011), standards. All SAR values also fall within IWQS permissible limit for irrigation.

Keywords: *Irrigation, SAR, Groundwater and IWQS*

INRODUCTION

The availability of water is critical to the security of the food supply and the development of agricultural products. Due to climate change, population growth, and an increase in city dwellers, the battle for water supplies is anticipated to become increasingly challenging. The agricultural industry is going to give this matter their full attention. Water scarcity and low quality are major issues in many nations, particularly in arid and semi-arid regions where quality monitoring has not received adequate funding. For a variety of causes, over-and inadequate usage of groundwater constitutes a major issue in dry or semi-arid regions. A decline in water table levels and groundwater quality has undoubtedly resulted from these issues. Improper land use and unregulated extraction could degrade the quality of groundwater in aquifers. Because it is used for both agricultural and drinking, the water on these resources is of exceedingly high quality, which is highly significant. Groundwater is a common place to find compounds that could be dangerous to humans. World Health Organization (WHO), National Standards Institute (NSI), British Standards Organization (BS), and International Water Quality Standards are some of the organizations that have established regulations on the use of water (IWQS). The majority of the water for the residents of the Ekeki Yenagoa Local Government Area comes from neighboring streams and boreholes. This implies that industrial activity and heavy metals pose a threat to the town's groundwater.

Study Area Description

Ekeki, in the Yenagoa Local Government Area of the Nigerian state of Bayelsa, is where the research takes place. Located in southern Nigeria, it is in the heart of the Niger Delta sedimentary basin (Fig. 1). This region is defined by latitude 4º, 92'96ºN and Longitude 6º29'80ºE. Nearly all of the ground is level, with the highest point being around 40 meters above sea level and the lowest point being on the southwest side of the mountain. The lowest point is on the southwest side. It is conveniently located on a route that vehicles may use, making it easy to reach. The region is drained by streams that flow into the Nun River and Taylor Creek.

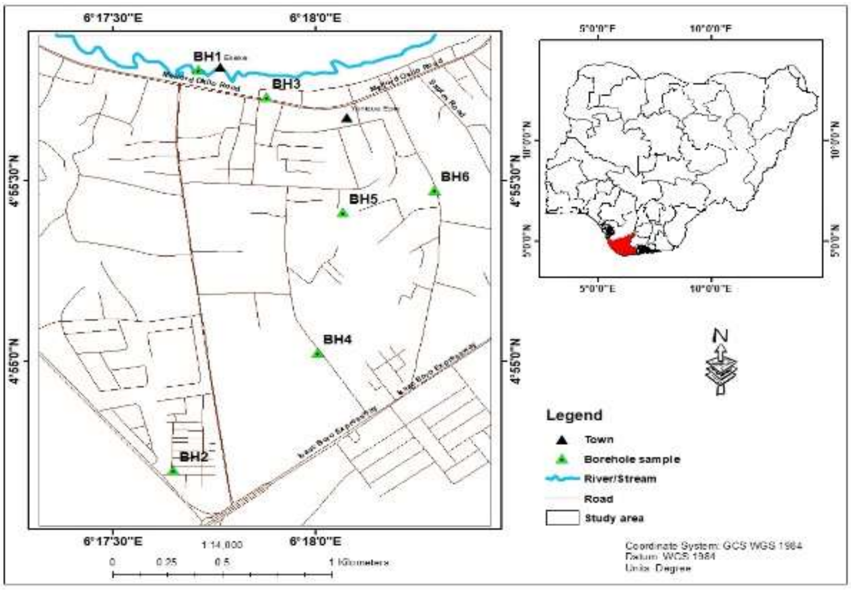


Fig.1.1: Map of study area

Climate and Vegetation

There is a distinct eight-month rainy season and a four-month dry season that characterize the local climate. Groundwater replenishment is greatly aided by the four thousand millimeters of rain that falls annually. But from November until the beginning of March, you'll experience the dry season. In late March, the rainy season begins and continues all the way into October. In the middle of August, the rainy season comes to a close. On a monthly average, the temperature is between 25 and 32 degrees Celsius.

Geology of Study Area

Rumor has it that the research site lies just south of the boundary separating the Niger Delta Region of Nigeria from the remainder of the nation (1965). Bayelsa is a country in the Niger Delta region. Subsidence and sediment deposition interacted to create the Niger Delta Basin in the Tertiary period. Quite a few invasions and regressions in the Atlantic Ocean brought this about (Short & Stauble, 1967). In the vicinity of these periodic occurrences, three litho-stratigraphic units were deposited. The Agbada, Benin, and Akata Formations are displayed in chronological order of their formation. The Benin Formation is the most significant stratigraphic unit concerning aquifers in the region under investigation (Amajor, 1991). A significant portion of it consists of silt that is thick and features clay bands and lenses. Because the sands contain medium to large grains, separating them is not an ideal method. The region's intricate aquifer system was created through the mixing of sand and clay in various locations (Murat, 1970). Every single hole is dug into this Formation. Etu-Efeotor (1991) is the first aquifer, and it contains more water and is older (Holocene). It descends around sixty to ninety meters (unconfirmed). In contrast, a second, less rich aquifer can be traced to the Oligocene period. The initial system containing multiple aquifers is the primary emphasis. Udom et al. (1992), Offodile (1992) (1999).

Literature Review

Akinluyi et al. (2022) did a research on the purity of groundwater in the Ogbia local government area of Bayelsa State for the purposes of irrigation and domestic usage. The bulk of the physicochemical parameters were judged to be within the requirements given by the World Health Organisation (WHO), with the exception of fluoride and iron. Kudamnya et al. (2022) undertook study in Keffi, Nigeria, with the purpose of evaluating the seasonal oscillations in groundwater quality and determining whether or not it is adequate for agricultural exploitation. The findings demonstrated the excellent to exceptional quality of the groundwater in the study area. In different sites of the Southern Ijaw Local Government Area in Bayelsa State, Nigeria, Peterside et al. (2022) did studies to discover the classification of hydrochemical faces and the quality of groundwater that may be utilised for irrigation. The results imply that the groundwater in the area is highly suitable for use in agriculture. Following treatment, 92.5% of the groundwater samples that were analysed were suitable for drinking and irrigation, according to the findings of Fallatah and Khattab (2023), who conducted an evaluation of the quality of groundwater in Saudi Arabia and determined whether or not it was suitable for irrigation and human consumption. Diédhiou et al., (2023) In West Central Senegal did a hydrogeochemical study of groundwater quality and its acceptability for irrigation and drinking reasons. The statistics reveal that whilst the irrigation quality varies from outstanding to good depending on SAR, %N, RSC, KR, and MR values, while the groundwater is appropriate for drinking based on TDS and WQI index. Sadik et al., (2023) studied groundwater quality of Hooghly District West Bengal India for irrigation. The results indicated that only 4.08 % of the groundwater samples were of a quality that was unfit for use as irrigation while 26.53 % of the groundwater samples were of good quality and 61.22% were of low quality and 8.16% were of exceedingly bad quality. Ousmane et al., (2022) studied Senegals Diass Horst Systems Groundwater Quality for Irrigation Needs. The statistics reveal that 89.7% of the water in the Maastrichtian aquifer is appropriate for irrigation and 86.9% of the water in the Paleocene aquifer is okay for irrigation. Vasant et al., (2016) performed research on the subject of Artificial neural network model-based groundwater suitability prediction for irrigation: a case study of Nanded tehsil Maharashtra India. The results indicated that Nandeds groundwater suitability for irrigation is accurately predicted by the ANN model. Moutaz et al., (2017) studied the Dujaila region in the Wasit governorate of central Iraq for groundwater suitable for agriculture. Based on EC, the results revealed that drainage water and groundwater were not optimum for irrigation. Milad et al., (2017) did a research on the hydro-geochemical categorization and geographical distribution of groundwater in the northern Iranian province of Golestan to determine if it was appropriate for agriculture. The research regions groundwater quality diminishes from the southeast to the northwest and only the Kalou Kafshgari and Kia stations are adequate for irrigation according to the findings. Nolakana et al., (2017) evaluated the groundwater suitability in Newcastle Kwazulu-natal South Africa for irrigation and residential applications. The results indicated that groundwater is generally alkaline soft to hard, fresh to brackish and that the principal ions abundance is Na+Ca2+Mg2+K+ HCO3-SO42-Cl-NO3-. Mohamed et al. (2017) evaluated the suitability of groundwater for irrigation in the Perambalurs Veppanthattai Block of Tamil Nadu. The results indicated that although the Permeability Index values suggest that the groundwater is acceptable for irrigation, the categorization of groundwater is seasonal and may be categorised as fresh, fresh-brackish or brackish. Panaskar et al., (2016) analysed the groundwaters suitability for industrial household and irrigation applications in Nanded Tehsil Maharashtra India employing statistics and GIS. Two aquifers required purification before they could be accessed for favourable purposes but the remainder of the groundwater samples were assessed to be acceptable for drinking, irrigation and industrial uses. The results indicated that groundwater is excellent for use in farming. Hussein et al., (2020) examined how irrigation in the Iraqi province of Najaf affects the environment. Only four wells had water that could be utilized for irrigation according to the results whereas other wells had at least one characteristic that shouldn't be employed for irrigation. Bhupender et al., (2016) assessed if groundwater in the Kheda area of Matar Tehsil Gujarat was suitable for irrigation. Even though the groundwater assessments showed extreme salinity and sodicity the majority of the samples were categorized as having excessive SAR and alkali water. Examining the Ekeki Yenagoa Bayelsa State groundwater quality for agricultural purposes is the main objective of this study. Nutrient levels, conductivity, salinity, turbidity, and pH are some of the physicochemical parameters utilized in this study. The inquiry also aims to determine the groundwater samples' SAR values to determine their suitability for irrigation. In addition to the vast amount of data now available regarding groundwater quality, the study's findings will contribute significantly to that data. Additionally, they will demonstrate the significance of ongoing monitoring and evaluation in ensuring the longevity of agricultural activities.

Methodology

Water samples were collected using seven boreholes. Each 1.5-liter plastic container was first washed with water from the sample. Next, water samples were collected from running faucets and added to the containers. Once this was completed, only then could the collection procedure begin. To ensure that oxygen did not initiate any reactions and alter the data, all of the bottles were filled to capacity. The water samples were transferred to a chemistry facility for analysis no later than 48 hours after being stored in ice coolers. Since pH and temperature are inherently unstable, the experiments were conducted in a real-world setting. We used a mercury thermometer to get the temperature and a handheld pH meter to get the pH level. Utilizing a methodology developed by the World Health Organization, the laboratory ascertains the remaining physicochemical components (WHO, 2011). The bacteriological analysis for every sample was conducted using a membrane filter technique (Fawole and Oso, 1998).

Result and Discussion

All of the groundwater samples collected from Ekeki had pH levels ranging from 5.26 mg/l to 5.46 mg/l. Irrigation water pH levels should be between 6.5 to 8.5 millimg/l, according to the World Health Organization (WHO) (2011) and the International Water Quality Standards (IWQS) (2004). This indicates that the pH is within the acceptable range. This suggests that Ekeki's water is likely slightly acidic. Acid rain, which can be produced by a variety of sources including tree roots, oil drilling, industrial activities, bacteria in the soil, and animals grazing, could be to blame. These factors may contribute to acid pollution. Additionally, it may include poisonous heavy metals that are bad for plants. Copper, nickel, cadmium, chromium, lead, and zinc are among the heavy metals (Zn). It is difficult for plants to absorb nutrients via their roots in soil with a low pH. (acidic). Plants may experience stunted growth, a lack of fruit or flower production, or even leaf drop as a result of this. Between 186.20 and 186.70 mg/l is the conductivity range. There is a risk that plants won't get enough nutrients to grow properly because the levels are below what the WHO considers to be safe. Its high conductivity raises the possibility that plants are perishing. But there are situations where imbibing is perfectly acceptable. A range of 117–12 mg/L was determined for the Total Dissolved Solid (TDS). According to the World Health Organization, 1000 mg/l is considered sufficient (2011). Compared to the levels recommended by the World Health Organization, the TDS levels in the research area are lower. So, it's safe to presume that the water is suitable for agricultural and human consumption. Nitrate concentrations in the sample ranged from 0.20 mg/l to 0.22 mg/l. Since 10.0 mg/l is the upper limit permitted by both WHO 20011 and IWQS 2004, the contamination level in the groundwater is within safe limits. Nitrate ions, which are essential for the synthesis of amino acids—the building blocks of proteins—can be taken up by plants. Iron levels in the study region were greater than the 2.75–2.9 mg/l range considered safe by the World Health Organization. The correct concentration of iron is 0.30 mg/l, according to the World Health Organization in 2011. It is evident from this that the water is suitable for irrigation purposes only; it is not fit for human consumption. Because it aids in enzyme production, metabolism, and the synthesis of chlorophyll—all of which are essential for plants to survive—iron plays a pivotal role in plant development and growth. Chloride levels in the region fluctuated between 20.58 mg/L and 20.0 mg/L during the course of the experiment. These figures fall short of what the World Health Organization recommended in 2011. There is an upper limit of 250 mg/l for chloride. What this implies is that the water is suitable for agricultural and drinking purposes. Chloride pollution of water sources could occur in various locations, including wastewater treatment plants that handle waste water from oil wells, runoff from farms, unclean rocks, and industrial effluent. The presence of chloride allows plants to absorb more elements, such as magnesium, potassium, and calcium. The manganese concentration in samples collected from Ekeki boreholes ranged from 0.032 to 0.038 mg/L. The World Health Organization established a safe limit of 0.1 to 0.3 mg/l in 2011, and these levels fell below it. Because of this, you can safely use the water for drinking, industrial purposes, and plant irrigation. Manganese may wreak havoc on your neurological system in excessive doses. The biological oxygen demand (BOD) value ranged between 12.50 and 12.59 mg/l. The World Health Organization (WHO) 2011 limit is 30 mg/L for BOD. The water is useful for both plants and humans. The acronym for "biological oxygen demand" describes how much oxygen microorganisms require to decompose complicated substances. One technique to quantify the amount of organic matter in water is by looking at the Body Organic Matter (BOD). In contrast, a low BOD indicates that the water is suitable for farming and drinking, whereas a high BOD indicates that the water is severely polluted.

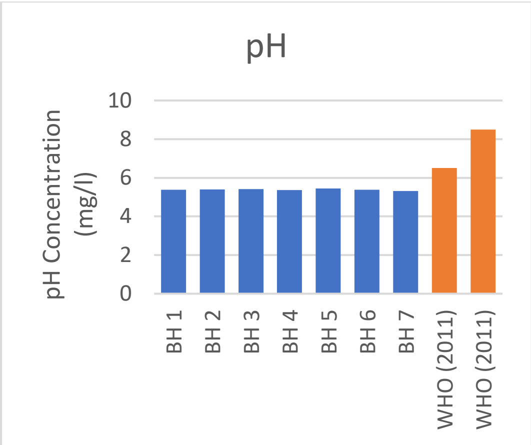


Fig.4.1: pH Graph

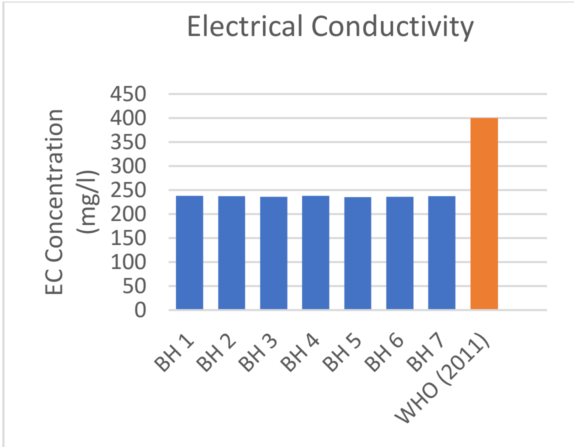
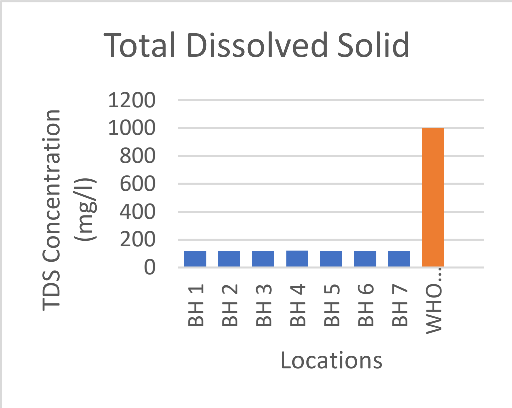


Fig.4.2: Conductivity Graph

TABLE 2: RESULT OF PHYSIOCHEMICAL ANALYSIS OF GROUNDWATER SAMPLE (mg/l)

S/N	Sample Code	GPS Coordinates	pH	SA1	CON D	TURB	TDS	TSS	N0$_3$	Cl	SO$_4$	Ca	Mg	Na	K	DO	BOD	COD	Mn	Fe
1	BH$_1$	4° 54’ 46” N 6° 17’ 41” E	5.38	0.11	238	25.72	119	2.52	0.217	20.0	4.54	13.45	3.18	7.24	1.56	4.87	12.46	185.58	0.034	2.84
2	BH$_2$	4° 54’ 30” N 6° 17’ 42” E	5.40	0.10	237	25.70	118	2.50	0.219	21.0	4.52	13.57	3.40	7.78	1.70	4.85	12.48	185.68	0.036	2.82
3	BH$_3$	4° 55’ 00” N 6° 17’ 41” E	5.42	0.09	236	25.68	118	2.48	0.215	19.0	4.56	13.68	3.20	7.36	1.60	4.83	12.44	185.62	0.038	2.86
4	BH$_4$	4° 55’ 03” N 6° 17’ 43” E	5.36	0.12	238	25.70	120	2.50	0.218	19.58	4.54	13.50	3.26	7.48	1.50	4.80	12.45	185.70	0.036	2.84
5	BH$_5$	4° 55’ 06” N 6° 17’ 41” E	5.44	0.10	235	25.72	119	2.52	0.20	20.25	4.27	13.55	3.42	7.55	1.64	4.89	12.39	185.60	0.034	2.86
6	BH$_6$	4° 55’09” N 6° 17’ 41” E	5.38	0.13	236	25.65	117	2.48	0.217	20.0	4.56	13.68	3.20	7.60	1.70	4.90	12.36	185.68	0.038	2.84
7	BH$_7$	4°55’12” N 6°17’42” E	5.32	0.11	237	25.71	118	2.54	0.219	21.0	4.50	13.65	3.36	7.40	1.60	4.56	12.50	186.20	0.032	2.88
Range			5.3-5.4	0.1-1.3	235-238	25.7-25.72	117-120	2.48-2.54	0.2-0.22	20-20.1	4.27-2.6	13.54-13.68	3.18-3.48	7.24-7.78	1.5-1.7	4.56-4.9	12.5-12.6	186.-186.7	0.032-0.038	2.82-2.88
IWQS 2004			6.0-8.5		0-3		0-2000				0-20	0-20	0-5	0-40						
WHO 2011			6.5-8.5	200-250	400	5 NTU	1000	500	10	250	250	100	50	200	20	6.5-9.5	3.0	250-400	0.1-0.5	0.3



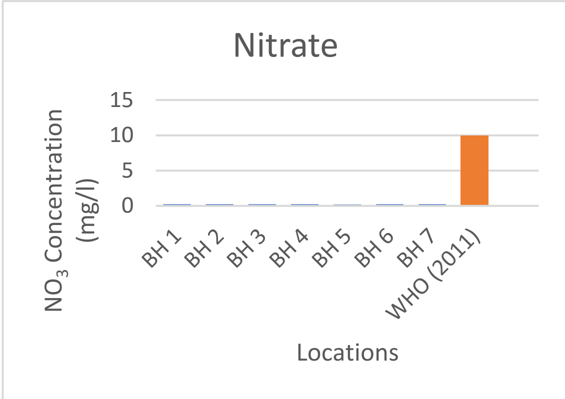
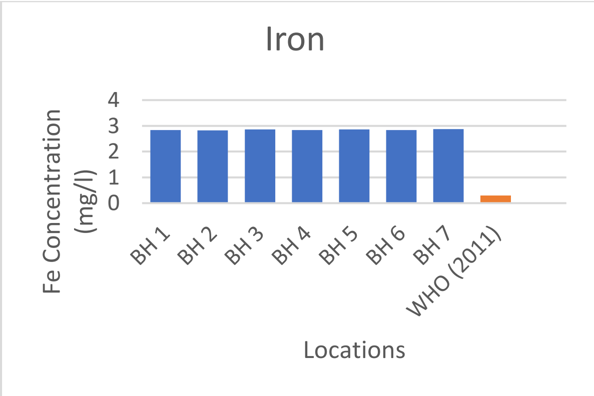


Fig:4.3: Total Dissolved Solid (TDS) Graph

Fig.4.4: Nitrate ($NO_{3)}$ graph



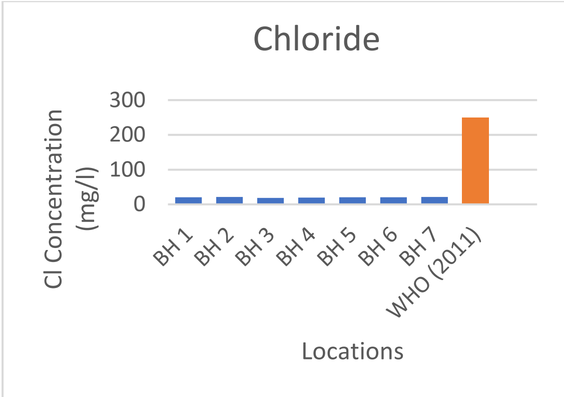
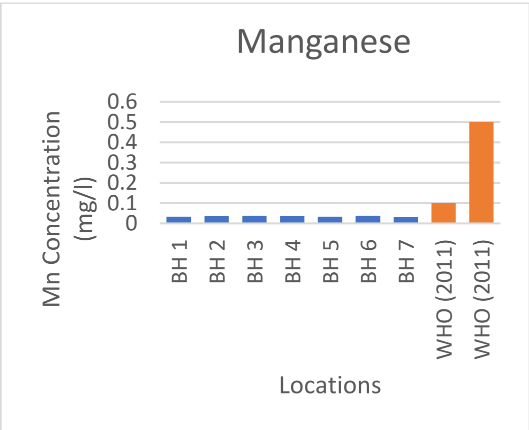


Fig.4.5: Iron Graph

Fig.4.6: Chloride Graph



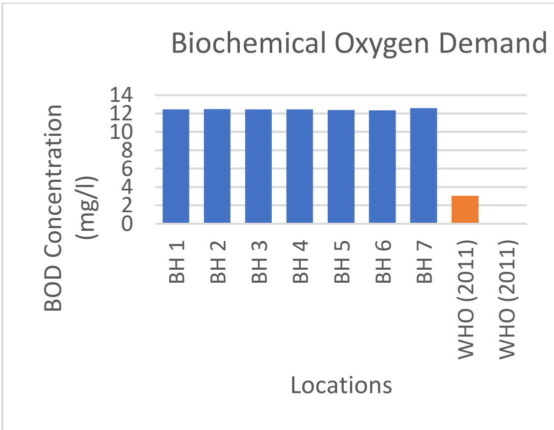


Fig.4.6: Manganese (Mn) Graph

Fig.4.7: BOD Graph

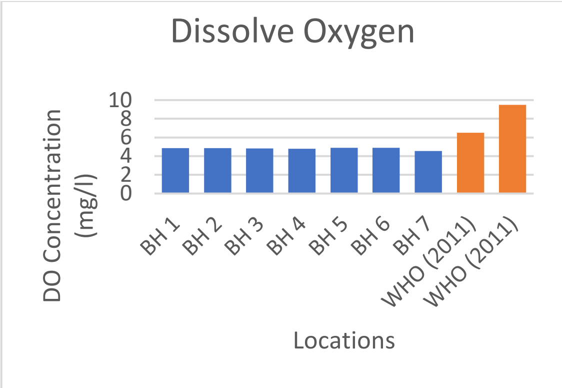


Fig.4.8: DO Graph

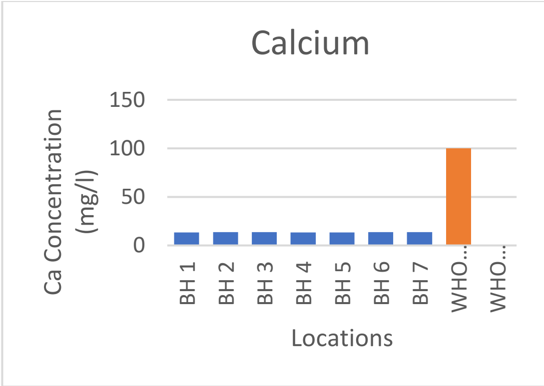


Fig.4.9: Calcium Graph

Levels of oxygen demand (DO) can range from 4.2 to 4.8 mg/l. As of 2011, the recommended range was 6.5 to 9.5 mg/L according to the World Health Organization (WHO). Irrigation might be an option for the water. The amount of oxygen in the water is reduced when aquatic animals breathe. Fish and other aquatic creatures may not do well in water with dissolved oxygen (DO) levels higher than 13–14 mg/l. Diffusion, aeration, and photosynthesis are the three main pathways for oxygen to reach the air and improve water quality. When dissolved oxygen (DO) is present, plant growth and reproduction can continue unabated.

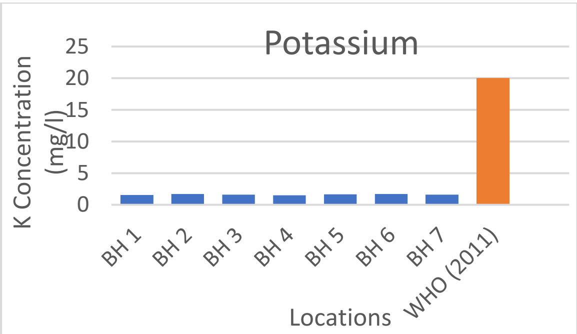


Fig.4.10: Potassium Graph

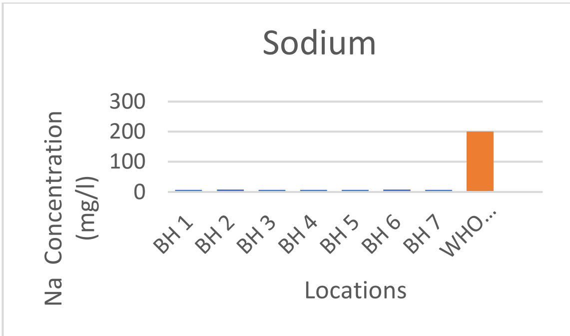


Fig.4.11: Sodium Graph

From 13.52 mg/l to 13.68 mg/l, calcium levels are found in boreholes that stretch deep into the Ekeki region. Because it falls below the 60-120 mg/l suggested by the World Health Organization in 2011, the water is deemed acceptable for consumption and agricultural use. Still, regardless of the level of stress they experience, plants can't grow and thrive without calcium. Plant cell walls and membranes rely on calcium for effective function. Groundwater draws calcium ions from the earth's surface and stores them underground. The Ekeki boreholes contained potassium concentrations ranging from 1.75 mg/l to 1.4 mg/l. The water is fit for human consumption and agricultural use if the concentration is less than 20 mg/l, the 2011 recommended level established by the World Health Organization. Fruits and vegetables benefit greatly from potassium because it increases their sugar content, promotes healthy growth, and increases their resistance to disease. In general, this improves agricultural output.

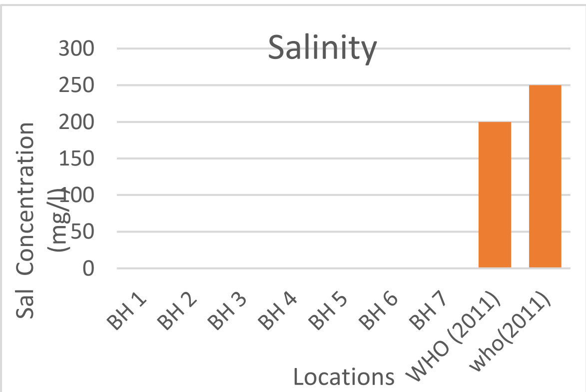


Fig.4.12 Graph Salinity

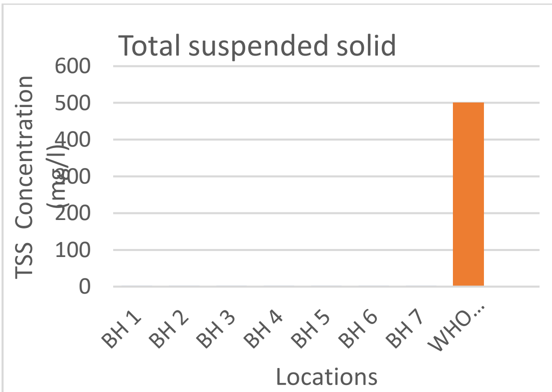
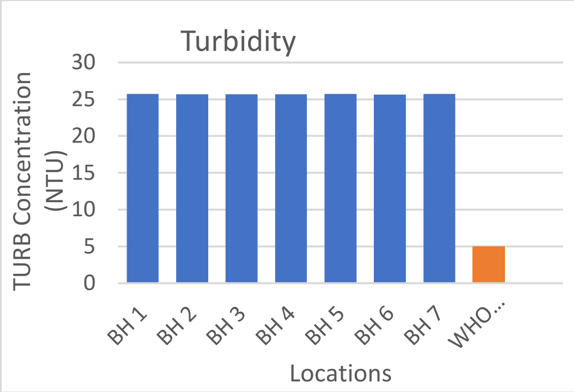
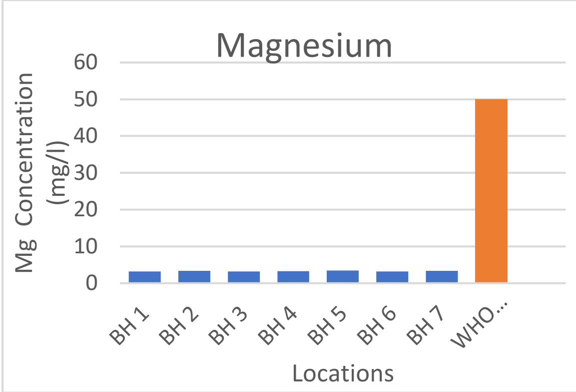


Fig.4:13 TSS Graph

On average, the salt content of Ekeki's groundwater ranges from 6 to 7 points8 mg/l. This means that the water is fit for drinking and for irrigation. The World Health Organization (WHO) suggested values ranging from 20 to 200 mg/l in 2011. Throughout the course of the study the regions salt concentration fluctuated between 0 and 1 point09 mg/l and 1 and 30 mg/l. Based on these results the World Health Organization has set an acceptable limit of 250 mg/l. This is encouraging for the waters suitability for human use and irrigation.





.

Fig.4.14: Turbidity Graph

Fig.4.15: Magnesium Graph

Concentration of total suspended solids (TSS) ranged from 12 mg/L to 117 mg/L. The World Health Organization (2011) states that a dosage of 1000 mg/l is ideal. This suggests that the water is suitable for both human use and irrigation. The study region have turbidity levels ranging from 25.6 to 25.74 NTU. In excess of what is considered safe by the World Health Organization, these figures indicate excessive alcohol use. The World Health Organization established a drinking water limit of five nanograms per liter in 2011. One common way to measure turbidity is using nephelometric turbidity units, or NTUs. The nephelometric approach is one tool for comparing the light scattering patterns of a reference solution and a water sample. To determine the degree of water cloudiness, many individuals use electronic portable meters. There may be dangerous microorganisms in the water if the turbidity level is high.

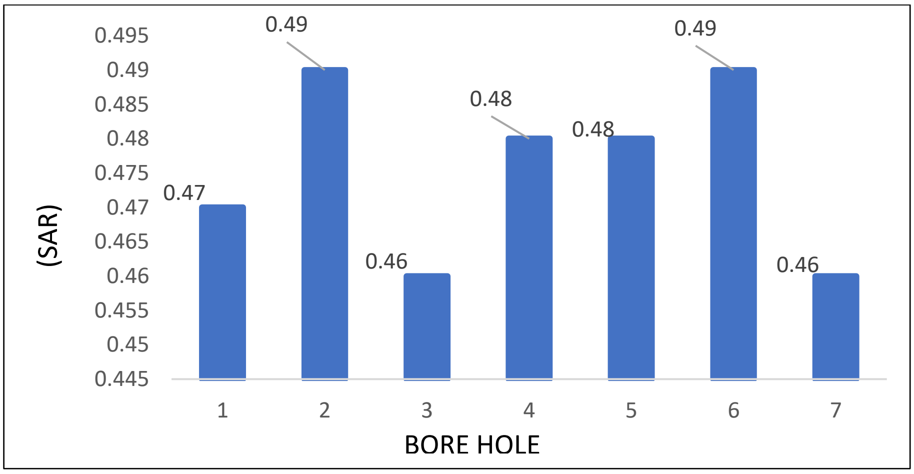


Fig 4.16: SAR Graph

The levels of magnesium in the research region were determined to be 3.0 mg/l to 3.5 mg/l. Since these values are lower than the 10 mg/l to 30 mg/l standard set by the WHO in 2011, the water can be utilized for irrigation. The amounts being discussed are below the threshold level of magnesium, which is the main component of chlorophyll. Plants can't develop without enzymes and proteins, and it facilitates their production as well. Water treated with magnesium hydroxide is not only made more alkaline, but it also removes heavy metals from the water. To get magnesium ions, groundwater travels through rocks and sediments.

SAR calculation

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

Ca=0.04990 x 13.45 = 0.67. Mg=0.08226 x 3.18 = 0.26.

Na=0.04350 x 7.24 = 0.32

$$SAR = \frac{0.32}{\sqrt{\frac{0.67+0.26}{2}}} = \mathbf{0.47}$$

The SAR values are within the range of 0 to 15 mg/l, and these values are lower than the IWQS permitted limit for irrigation. Therefore, the water in the area under study is water that can be used for irrigation.

CONCLUSION

Ekeki is located in the Yenagoa LGA, and the majority of the metrics used to assess the groundwater's suitability for agricultural use fall short of the standards established in 2004 and 2011 by the World Health Organization, respectively. This ensures that the water can be safely used for agriculture and drinking.

REFERENCES

Adimalla, N.; Dhakate, R.; Kasarla, A.; Taloor, A.K., (2020). Appraisal of groundwater quality for drinking and irrigation purposes in Central Telangana, India.Groundw. Sustain.10, 100334.

Akpofure, E., Kenneth, O., and Arobo, A. (2019). Hydrochemistry and Groundwater Quality in a Quaternary Phreatic Aquifer in Yenagoa, Southern Nigeria

Amajor, L.C. (1991). Aquifers in the Benin formation (Miocene-recent), eastern Niger Delta, Nigeria: lithostratigraphy, hydraulics, and water quality. Journal of Environmental Geology, 17 (2), 85-101.

Aragaw, T.T.; Gnanachandrasamy, G., (2021). Evaluation of groundwater quality for drinking and irrigation purposes using GIS-based water quality index in urban area of Abaya-Chemo sub-basin of Great Rift Valley, Ethiopia. Appl. Water Sci., 11, 148.

Arslan, H. (2012). Spatial and temporal mapping groundwater salinity using ordinary kriging and indicator kriging: The case of Bafra Plain, Turkey. *Agricultural Water Management*, 57-63.

Batarseh, M.; Imreizeeq, E.; Tilev, S.; Al Alaween, M.; Suleiman, W.; Al Remeithi, A.M.; Al Tamimi, M.K.; Al Alawneh, M., (2021). Assessment of groundwater quality for irrigation in the arid regions using irrigation water quality index (IWQI) and GIS-Zoning maps: Case study from Abu Dhabi Emirate, UAE. Groundw. Sustain. Dev. 14, 100611.

Etu-Efeotor, J.O.(1991). Preliminary hydro-geochemical investigation of subsurface water in parts of the Niger Delta.*Jour. Mining and Geosc*. Soc. 108-110

Offodile, M.E. (1992). Groundwater Study and Development in Nigeria. 2nd edition. Mecon Geology, Ltd, Jos 453p [14]. Oteze, G.E., and Akujieze, C.N. (2012). A Review of Groundwater Pollution in Nigeria. Journal of the Nigerian Association of Hydrogeologist. Special Publication Series 2 [15].

Reyment, R. A. (1965). Aspects of Geology of Nigeria. University of Ibadan Press, Nigeria. 133.

Short, K.C., & Stauble, A.J. (1967). Geology of Niger Delta. AAPG Bulletin, 5, 761779.

Umar, R. M. (2006). Groundwater hydrochemistry of a sugarcane cultivation belt in parts of Muzaffarnagar district, Uttar Pradesh, India. Environmental Geology, pp. 999–1008.

Ovuru, C., Udom, G.J., and Oborie, E. (2010). Electrical resistivity survey for groundwater in parts of Yenagoa and Ogbia Local Government Area, Bayelsa state, Nigeria. International Journal of Physical Science, 5 (3), 2006-1064.

WHO (2011).GuilinesFor Drinking Water Quality. 4th Edition World Health Organization. Geneva,Switzerland.http://apps.who.int/bitstream/10665/44584/1/978924154815_eng.pdf

Kudamnya, E. A., Edet, A., & Ekwere, A. S. (2022). Assessment of seasonal variations in groundwater quality and its suitability for agricultural use in Keffi, Nigeria [Preprint]. doi: 10.21203/rs.3.rs-1612590/v1

Frances, O., Omowonuola, A., Akinluyi, J. A., Adeyeye, S., & Agbo, S. (2022). GIS-based groundwater quality assessment for domestic and irrigation purposes in Ogbia local government area of Bayelsa State, Nigeria. *International Journal of Health Sciences* (IJHS), doi: 10.53730/ijhs.v6ns8.9680

Adline, Nimi, Peterside., A., I., Hart., H., O., Nwankwoala. (2022). Groundwater Quality for Irrigation Purposes and Classification for Hydrochemical Facies in Parts of Southern Ijaw Local Government Area, Bayelsa State, Nigeria. Journal of Environmental Protection, doi: 10.4236/jep.2022.134020

Abdalla, Elamin., Mustafa, M., Bob., Saud, Taher., Norhan, Abd, Rahman. (2016). Assessment of groundwater suitability for irrigation in Madinah City, Saudi Arabia. Springer US,

SK, Saha., BM, Rabby, Hossain., Anwar, Jahid. (2016). Chemical suitability of groundwater for irrigation in Trimohoni and Sagardari union, Keshabpur Upazila, Jessore, Bangladesh. The Bangladesh journal of scientific research, doi: 10.3329/BJSR.V27I2.26230

Bhupender, Singh., Prafulla, Kumar, Sharma., A., B., Parmar., M., K., Choudhary. (2016). Groundwater quality and its suitability for irrigation in Matar Tehsil of Kheda district, Gujarat.. International Journal of Farm Sciences,

Hussein, S., Al-Bahrani., Zainab, D., Abbas., Insaf, J., AL-Yaseri. (2020). Environmental assessment of groundwater in najaf governorate (iraq) for irrigation purposes. Kufa journal of Engineering, doi: 10.30572/2018/KJE/110404

D., B., Panaskar., Vasant, Wagh., Aniket, Muley., Shrikant, Mukate., R., S., Pawar., Manesh, Laxman, Aamalawar. (2016). Evaluating groundwater suitability for the domestic, irrigation, and industrial purposes in Nanded Tehsil, Maharashtra, India, using GIS and statistics. Arabian Journal of Geosciences, doi: 10.1007/S12517-016-2641-1

A., Mohamed, Ibraheem., S., M., Mazhar, Nazeeb, Khan. (2017). Suitability Assessment of Groundwater for Irrigation Purpose in Veppanthattai Block, Perambalur District, Tamil Nadu.

Pamela, Nolakana., Abdi, Siad., Henok, Solomon. (2017). Evaluation of groundwater suitability for domestic and irrigational purposes in newcastle, kwazulu-natal, south africa. Visnyk of Taras Shevchenko National University of Kyiv. Geology, doi: 10.17721/1728-2713.76.11

Milad, Kurdi., Milad, Kurdi., Taymor, Eslamkish. (2017). Hydro-geochemical classification and spatial distribution of groundwater to examine the suitability for irrigation purposes (Golestan Province, north of Iran). Paddy and Water Environment, doi: 10.1007/S10333-017-0587-X

Moutaz, A., Al-Dabbas., Sattar, O., Maiws., Weam, H., Kadhim. (2017). Evaluate the groundwater suitability for irrigation in dujaila area – wasit governorate – middle of iraq.

Vasant, Wagh., D., B., Panaskar., Aniket, Muley., Shrikant, Mukate., Yogesh, Lolage., Manesh, Laxman, Aamalawar. (2016). Prediction of groundwater suitability for irrigation using artificial neural network model: a case study of Nanded tehsil, Maharashtra, India. Modeling Earth Systems and Environment, doi: 10.1007/S40808-016-0250-3

O., Fallatah., Mahmoud, R, Khattab. (2023). Evaluation of Groundwater Quality and Suitability for Irrigation Purposes and Human Consumption in Saudi Arabia. Water, doi: 10.3390/w15132352

Diédhiou, M.; Ndoye, S.; Celle, H.; Faye, S.; Wohnlich, S.; Le Coustumer, P. Hydrogeochemical Appraisal of Groundwater Quality and Its Suitability for Drinking and Irrigation Purposes in the West Central Senegal. Water 2023, 15, 1772.

Sadik Mahammad, Md. Mofizul Hoque, Aznarul Islam, & Arijit Majumder. (2023). Chapter 16 - Assessment of groundwater quality for irrigation purposes: A case study of Hooghly District, West Bengal, India. In Pravat Shit, Gouri Bhunia, & Partha Adhikary (Eds.) (2023). Case Studies in Geospatial Applications to Groundwater Resources (289-314). Elsevier. https://doi.org/10.1016/B978-0-323-99963-2.00003-1

Ousmane, Diouf., Hameth, Sarr., M.L., Diedhiou., Lutz, Weihermüller., Ndeye, Maguette, Dieng., Seynabou, Cissé, Faye., Harry, Vereecken., Serigne, Faye. (2022). Groundwater Quality for Irrigation Purposes in the Diass Horst System in Senegal. Water, doi: 10.3390/w14193002