Journal of Basics and Applied Sciences Research (JOBASR)
ISSN (print): 3026-9091, ISSN (online): 1597-9962
Volume 3(3) May 2025
DOI: https://dx.doi.org/10.4314/jobasr.v3i3.26

Investigation of Groundwater Salinity Levels using Physicochemical Analysis around Gada-Mashegu Area, North Central Nigeria: Implications of Drinking Water and Irrigated Farms

Shehu, I. D.[1*], Musa, A. U.[1], Daniel, J.[1], Ummi, U.[1] and Sanni, M. O.[2]
[1]Department of Physical Sciences, Niger state Polytechnic, Zungeru, Nigeria.
[2]Centre for Preliminary and Extra Moral Studies, Federal University of Technology, Minna, Nigeria.
*Corresponding Author Email: shehuisahdanlami@gmail.com

ABSTRACT
Water salinity is a growing global environmental health concern. However, little is known about the relationship between water salinity and chronic health outcomes in humans, fauna and flora in developing countries across the globe including the study area and the country at large This study was conducted in Gada–Mashegu, Niger North-Central Nigeria, to assess the salinity level in water samples that are used for consumption and irrigation practices. Three samples were obtained from the site (river, hand dug well and borehole) water sources. Laboratory analysis was conducted to determine different physicochemical properties of the water samples. Results of the water samples analyzed from river, hand dug well and borehole revealed that pH levels were (6.17, 6.60 and 7.53), SAR (0.07, 0.08, 7.35) ds/m EC (528, 12.51 and 4.19)$\mu S/$cm Hardness (4554.1, 2831. 25), respectively. The drinking water of Hand dug well and that of bore hole water of the study area were consistent with World Health Organization standard for drinking water (WHO). On the other hand, the electrical conductivity level (EC) of the river water is above that of WHO standard. This could be the effect of agricultural runoffs. Drinking this water source could result in health problems and diseases. On irrigation practices the entire water source may be used for irrigation but no guarantee of achieving100% crop yield.

Keywords:
Salinity,
Groundwater,
Irrigation,
Water physical and chemical properties.

INTRODUCTION

Groundwater, which makes up approximately 34 percent of the world's freshwater resources, is one of the most vital natural assets on Earth. It encompasses all water located beneath the Earth's surface, commonly known as subterranean water (Ibrahim & Ahmed, 2016). Beyond its critical role in supporting human life, groundwater also plays a key role in various practical applications such as agriculture, industry, and household use. It is naturally replenished when rain or melting snow seeps through the soil and into the pores of nearby rocks. As a vital part of the water resources system, groundwater remains one of the most essential sources for human communities. (Haghighi *et al*, 2020). Groundwater accounts for 26 percent of the world's renewable freshwater resources. It supplies water for residential, commercial, industrial, agricultural, and various other development activities (Arulbalaji *et al*, 2019). Poor management of groundwater has led to several adverse effects, such as declining water quality, dropping water tables, reduced crop yields, and other related issues (Konkul *et al*, 2014, Sarkar *et al*, 2022). Human activities can introduce pollutants into groundwater, negatively impacting its quality and Potentially making it unsafe for consumption (Karunanidhi *et al*, 2021). The sources of water contaminants include human activities such as sewage effluents, pharmaceuticals, dyes, perfumes, detergents, industrial discharges, mining waste, and agricultural runoff. Consuming contaminated water can lead to health issues, diseases, and in severe cases, death. Landrgan *et al.* (2017) highlighted that water pollution causes fatalities three times higher than those from diseases like TB, HIV, and malaria combined.

Agricultural activities that utilize fertilizers, herbicides, and pesticides generate toxic substances that can be carried as effluents into water sources, leading to pollution of water bodies (Obi *et al.*, 2007). When surface and groundwater become contaminated, the presence of harmful ions is typically detectable. Additionally, some ions introduced into water may react with other compounds to form insoluble substances, which, upon ingestion, can cause significant health risks (Olowe *et al.*, 2005).

High salt content in drinking water can negatively impact human health, potentially raising blood pressure and increasing the risk of hypertension (Rosinger &

How to cite this article: Shehu, I. D., Musa, A. U., Daniel, J., Ummi, U. and Sanni, M. O. (2025). Investigation of groundwater salinity levels using physicochemical analysis around Gada-Mashegu area, north central Nigeria: Implications of drinking water and irrigated farms. *Journal of Basics and Applied Sciences Research*, *3*(3), 244-250. https://dx.doi.org/10.4314/jobasr.v3i3.26

Young, 2020; Shammi *et al.*, 2019; Khan *et al*., 2014; Naser *et al.*, 2019). In women, increased intake of saline water has been linked to a higher risk of preeclampsia, gestational hypertension, and pregnancy-related mortality (Khan *et al*., 2014). Furthermore, water salinity may affect cognitive development, as research suggests a negative correlation between water salinity levels and children's educational achievement (Akter, 2019).

The recommended dose for chloride is 0.18g/day for infants 0-6 months, 0.57g/day for infants 7-12 months, children 1-3 years 1.5 g /day, and 4-8 yeas 2.3 g/day. For adolescents and adults 14-50 years 203g/day pregnant and lactating female 2-3g/day, for bicarbonates people with age greater than 12-18 years 325-2000 mg 1-4 times a day, Magnesium is recommended 280-350/day, Calcium is recommended 300 mg for infants 0-6 months, 500 mg for children 1-3 years, adolescents and pregnant/breast feeding women 1000 mg, adults 19-50years 800mg, 51 and above 1000 mg. Sodium is recommended less than 2 g per day for adults. Potassium is recommending 3.5 g per day for adults, 2.6g for women and 3.4 per day for men Ayers and Westcott (1994). The escalating salinity level of groundwater in Gada Town, pose significant concerns for public health and agricultural production. This call for investigating groundwater salinity due to its dependency for drinking and irrigation practices. Magaji *et al*, (2020) conducted assessment of salinity levels of soils and water in irrigated vegetable farms around Maiduguri Lake-Alau Dam, Maiduguri North-East Nigeria. The authors only dwell on irrigation and did not consider the implications of salinity levels in drinking water.

This article assesses the salinity of water samples collected from river water, hand dug water and borehole water that are used for consumption and irrigation in Gada area of Mashegu north central Nigeria. Rice and vegetables are frequently cultivated in the area using irrigation. The study focuses on implication of salinity levels in drinking water and irrigation practices. The adopted approach was to study the salinity levels of the water samples with the aim of investigating ground water salinity levels, their spatial distribution, implications to health, quality for domestic consumption and agricultural practices and also compare with WHO guidelines to evaluate sustainability for drinking and irrigation use.

Quality of Drinking and irrigation Water

The concentration and composition of soluble salts in water are critical factors that determine its suitability for various uses, including human and livestock drinking, as well as crop irrigation. Water quality is therefore a key consideration for the sustainable management of water resources, particularly in areas where salinity development poses a significant challenge to irrigated agriculture (Mohammed *et al*., 2018). To evaluate water quality for consumption and irrigation, specific criteria are used. Some of these criteria include:

Salinity hazards (EC)

Electrical conductivity (EC) measures the ability of water to conduct electric current, which is primarily influenced by the presence of dissolved salts such as sodium chloride that produce ions and generate electrical current. EC is commonly used as an indicator of water salinity (Lind, 1959).

Water with an electrical conductivity below approximately 200 µS/cm can lead to soil degradation, promote soil crusting, and reduce water penetration, negatively affecting soil health and plant growth (Mohammed *et al.*, 2018). For drinking water, the World Health Organization (WHO) recommends a maximum electrical conductivity of 400 µS/cm to ensure safety and taste quality.

Sodium Adsorption Ratio (SAR)

The potential of a salt solution to generate excessive exchangeable sodium in soils is an important factor to consider when evaluating water quality for irrigation (Mohammad *et al.*, 2018). The Sodium Adsorption Ratio (SAR) measures the relative proportion of sodium to calcium and magnesium in water, which influences soil sodicity.

An SAR value less than 8 (measured in millimoles per liter to the power 0.5) is classified as low sodium water, indicating that using such water for irrigation is generally safe and unlikely to cause sodicity issues. However, continuous use of water with SAR below 8, especially when water drainage and leaching are limited, can lead to soil sodification over time.

Furthermore, the detrimental effects of SAR are influenced by the water's electrical conductivity (EC). High EC values coupled with high SAR can exacerbate soil salinity and sodicity problems, emphasizing the need to consider both parameters together (Kinje, 1993).

MATERIALS AND METHODS

Study Area

The study was conducted in Gada town, located within Mashegu Local Government Area (LGA) of Niger State, Nigeria. Niger State comprises 25 LGAs, with Mashegu situated in the southwestern part of the state. The LGA is bounded by the Niger River to the west and the Kaduna River to the northeast, providing significant water bodies in the region.Geographically, Mashegu LGA lies approximately between latitude 9° 57′ N and longitude 5° 13′ E. The administrative center is Mashegu town, which serves as the headquarters of the LGA, and the area is divided into ten wards. The total land area of Mashegu LGA is about 9,182 square kilometers (Ayodeji et al., 2014). Climatically, the region experiences distinct dry and wet seasons, characteristic of the broader Niger State climate. The annual rainfall ranges from 1,100 mm to 1,600 mm, supporting agriculture and other livelihoods. Temperatures fluctuate between 21°C and 37°C. The rainy season lasts approximately 150 days, providing ample growing periods for crops (Ibrahim *et al.*, 2019). Agriculture is the primary occupation of residents in the study area. The main crops cultivated include yam, rice, cowpea, sorghum, maize, groundnut, tomato, and sweet potatoes, among others (Ayodeji *et al.*, 2014). Figure 1 below illustrates the geological map of Niger State, highlighting the Mashegu area and its geological features, which influence land use, soil properties, and water resources in the region.

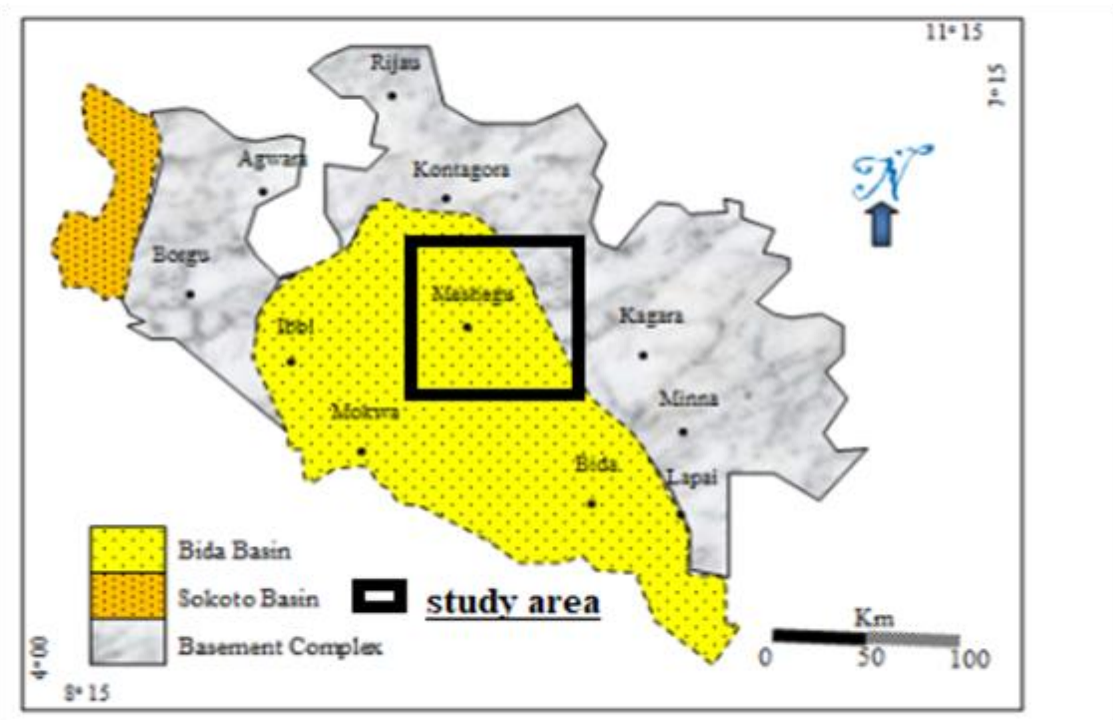

Figure 1. Geological map of Niger State showing Mashegu area (Adopted from Obaje, 2009)

Sampling Techniques and Data Analysis

Three water samples were collected from river, hand dug well and borehole (one sample per water source) in December 2024, which are frequently used for irrigation and consumption. Laboratory analysis (experimental) such as Physicochemical analysis were carried out on the three water samples collected to determine the salinity levels and the levels of cations and anions in the Gada-area of Mashegu local government using pH meter, electrical conductivity meter and Atomic absorption Spectroscopy. The water samples were collected in collaboration with the village head, former ward councilor and security personnel (policemen) due to insecurity in the area.

Water parameter analysis

All collected water samples were tested for ionic balance and pH levels. The analysis focused on key cations—Calcium, Magnesium, Sodium, and Potassium—and major anions—including Chlorides, Sulfates, and Bicarbonates. In evaluating water quality chemically, two crucial parameters are considered: water hardness and the Sodium Adsorption Ratio (SAR). The hardness of water, expressed in milligrams per liter as $CaCO_3$ for samples from rivers, hand-dug wells, and boreholes, was determined using the formula developed by Todd and Mays (2005), based on the following relationship (1)

$$H_T = 2.5\ \text{Ca} + 4.1\ \text{Mg} \qquad (1)$$

where Ca^{2+} and Mg^{2+} are expressed in mg/l

The SAR is calculated according to equation proposed by Richards (1954) and represented as follows

$$\text{SAR} = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \qquad (2)$$

$Na,^{+}$ Ca^{2+} and Mg^{2+} are expressed in Meq/l.

$$\text{TDS} = \text{EC} \times 0.64 \qquad (3)$$

Table 1 WHO (2009) and USEPA (2009) Guidelines for drinking water

parameter	WHO (Mg/l)	USEPA (Mg/l)
Chloride	≤ 250	250
TDS		
Magnesium	500	
Sodium		200
Calcium	≤ 200	
pH	200	
Hardness	6.5 – 8.5	

Table 2 Sodium hazard of water based on SAR values Dry season (adapted from Ayers and Westcott, 1978)

Values (Meq/l)	Sodium hazard of water	Comment
1—9	Low	Use on sodium sensitive crops most be cautioned.
10 – 17	Medium	Amendment (such gypsum) leaching needed.
18 – 25	High	Unsuitable for continuous use.
25	Very high	Unsuitable for use.

Table 3 Irrigation water salinity tolerance levels for different crops (adapted from Ayers and Westcott, 1978)

Crop	100%	90%	75%	50%
Cabbage	1.2	1.9	2.9	4.6
Carrot	0.7	1.1	1.9	3.1
Cucumber	1.7	2.2	2.9	4.2
Lettuce	0.9	1.4	2.1	3.4
Onions	0.8	1.2	1.8	2.9
Pepper	1.0	1.5	2.2	3.4
Spinach	1.3	2.2	3.5	5.7
Sweet potato	1.0	1.6	2.5	4.0
Tomato	1.7	2.3	3.4	5.0

Yield potential EC_{iw} Based on EC_{iw} measured in mmhos/cm EC_{iw}= irrigation water electrical conductivity

RESULTS AND DISCUSSION

Total dissolved solids (TDS)

Total Dissolved Solids (TDS) denote the fraction of total solids that can pass through a filter, and their levels are measured in milligrams per liter (mg/l). Water with elevated TDS levels typically has poor taste and may cause negative physiological effects in temporary consumers (ASTM, 2004). Additionally, high TDS concentrations contribute to various water quality issues such as hardness, turbidity, odor, flavor, color, and alkalinity (ASTM, 2004). The World Health Organization (WHO) recommends a maximum TDS concentration of 500 mg/l for safe drinking water.The present investigation shows that TDS values for the water sample collected from Gada- Mashegu area range from 2.68 for borehole, 8.01 for hand dug well and 337.92 mg/l for river water respectively. The mean value is 116.20. The TDS concentration of the study area is within the permissible range of WHO standard.

Electrical conductivity (EC)

Pure water is a poor conductor of electricity and functions more as an insulator. An increase in ion concentration boosts the water's electrical conductivity. Generally, the level of dissolved solids in water influences its conductivity, as electrical conductivity (EC) measures the solution's ability to transmit current through ionic processes. According to WHO standards, the EC should not exceed 400 µS/cm. In the current study, the EC values for river water, hand-dug well water, and borehole water were found to be 528, 12.51, and 4.19 µS/cm, respectively, with an average of 181.57 µS/cm. These findings clearly suggest that the water samples in the study area have low ionization levels and minimal ionic activity, likely due to the small amount of dissolved solids present (Table 1).

PH of water

pH is a crucial parameter for assessing the acid-base balance in water and serves as an indicator of whether the water is acidic or alkaline. The World Health Organization (WHO) recommends a maximum permissible pH range of 6.5 to 8.5. In this study, the pH values recorded were 6.60 for river water, 6.17 for hand-dug well water, and 7.53 for borehole water, all falling within the WHO acceptable limits. Overall, the results suggest that the Gada-Mashegu water source is within the desirable and safe pH range. Essentially, pH levels are influenced by the concentration of dissolved carbon dioxide (CO_2), which forms carbonic acid in water.

Chloride (Cl)

Chloride primarily originates from the dissolution of salts such as sodium chloride (NaCl), sodium bicarbonate ($NaHCO_3$), and can also enter water through industrial waste, sewage, and seawater. Surface water typically contains lower chloride levels compared to groundwater. Chloride plays a vital role in human metabolism and other essential physiological functions. However, high chloride concentrations can corrode metal pipes and structures and can negatively affect plant growth. According to WHO standards, the maximum safe concentration of chloride in drinking water is 250 mg/l. In the study area, chloride levels ranged from 13.6 mg/l in borehole water, 75.2 mg/l in hand-dug well water, and 106.21 mg/l in river water, with an average value of 65.0 mg/l across all samples.

Sulfate

Sulfate primarily originates from the dissolution of salts of sulfuric acid and is commonly found in nearly all water bodies. Elevated sulfate levels can result from processes such as the oxidation of pyrite and mine drainage. In natural waters, sulfate concentrations typically range from a few milligrams per liter to several hundred milligrams per liter, but there are no significant reports of adverse health effects associated with sulfate intake. The World Health Organization (WHO, 1984; WHO, 2011) recommends a maximum desirable limit of 250 mg/l for sulfate in drinking water. In the study area, sulfate levels ranged from 17.57 mg/l to 35.51 mg/l in Gada-Mashegu, with an average of 24.85 mg/l. These findings indicate that sulfate concentrations in the area are within the acceptable limits and are unlikely to pose health risks to humans.

Magnesium (Mg)
Magnesium is the eighth most common element in the Earth's crust and naturally occurs in water. It is vital for the proper functioning of living organisms and is found in minerals such as dolomite and magnetite. The human body contains approximately 25 grams of magnesium, with about 60% stored in bones and 40% in muscles and tissues. According to WHO, (2011) guidelines, the safe limit for magnesium in drinking water is 50 mg/l. In the study area, magnesium levels ranged from 2.48 mg/l to 310 mg/l in Gada-Mashegu, with an average of 271.16 mg/l. The findings indicate that magnesium concentrations in Gada-Mashegu exceed the WHO standard.

Calcium (Ca)
Calcium is the fifth most abundant element in the Earth's crust and plays a crucial role in human cell function and bone health. Approximately 95% of calcium in the human body is stored in bones and teeth. A deficiency in calcium can lead to conditions such as rickets, impaired blood clotting, and increased risk of fractures, while excessive calcium intake may contribute to cardiovascular diseases. According to WHO standards (1984), the permissible limit of calcium in drinking water is 75 mg/l. In the study area, calcium concentrations ranged from 9.55 mg/l in borehole water to 624.1 mg/l in hand-dug well water, and up to 1000 mg/l in river water, with an average value of 544.52 mg/l.

Sodium (Na)
Sodium is a metallic element with a silvery-white appearance found in trace amounts in water. Maintaining a proper level of sodium in the human body is essential for preventing serious health problems like kidney damage, high blood pressure, and headaches.In the majority of countries, the sodium concentration in water generally remains below 20 mg/l, though in certain areas, it can surpass 250 mg/l (WHO, 1984). The World Health Organization (WHO, 2009) sets the maximum allowable sodium level in drinking water at 200 mg/l. In the area studied, sodium levels varied from 1.8 mg/l in hand-dug wells, 1.9 mg/l in river water, up to 18.59 mg/l, with an average value of 7.43 mg/l.These findings demonstrate that the sodium levels in Gada-Mashegu water are significantly below the WHO threshold, implying that drinking this water is unlikely to present health hazards to the local population.

Potassium (k)
Potassium is a silvery-white alkali metal known for its high reactivity with water. It plays a crucial role in the functioning of living organisms and is present in all human and animal tissues, particularly within plant cells. The total potassium content in the human body typically varies between 110 and 140 grams.Potassium is essential for maintaining heart health, regulating blood pressure, aiding in protein breakdown, supporting muscle contractions, and facilitating nerve signal transmission. Although potassium deficiency is uncommon, it can cause problems such as depression, muscle weakness, and irregular heartbeats. According to WHO, (2011) guidelines, the maximum permissible concentration of potassium in drinking water is 12 mg/l. In the study area, potassium levels ranged from 6.4 mg/l in borehole water, to 34.9 mg/l in hand-dug well water, and 35.6 mg/l in river water, with an average of 25.63 mg/l. These levels surpass the WHO standard and may pose health risks if high potassium concentrations persist.

Table 4. Results of physico-chemical analysis of water samples

Sample	pH	EC	Ca^{++}	Mg^{++}	Na^{++}	K^{+}	Cl^{-}	SO_4^3	HCO_3^-	SAR	TDS
River	6.60	528	1000	501	1.9	3.56	106.21	35.51	106.5	0.07	337.92
HDG	6.17	12.51	624.1	310	1.8	3.49	75.2	21.51	92.5	0.08	8.01
Bore hole water	7.53	4.19	9.55	2.48	18.59	0.64	13.6	17.57	3.11	7.35	2.68
Mean	6.77	181.57	544.55	271.16	7.43	2.56	65.0	24.86	67.37	2.95	116.20

EC in uS/cm at 25 ^{0}C, ions in Mq/l and TDS in Mg/l of $CaCO_3$

Note: EC = Electrical Conductivity, TDS = Total Dissolved Salt, P = Phosphorus, K = Potassium, Ca = Calcium, Na = Sodium, SAR = Sodium Absorption ratio.

Statistical analysis of the water samples using pH, EC, SAR and TDS parameters.

River water

Mean = x = $\frac{\sum x}{n} = \frac{872.59}{4}$ = 218.1475

Variance $S^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n} = \frac{202664.2}{4}$ = 50666.04

Standard Deviation S.D = $\sqrt{S^2} = \sqrt{50666.04}$ = 225.09

Hand dug water

Mean = x = $\frac{\sum x}{n} = \frac{26.77}{4}$ = 6.69

Variance $S^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n} = \frac{79.5773}{4}$ =19.89

Standard Deviation S.D = $\sqrt{S^2} = \sqrt{19.89}$ = 4.46

Borehole water

Mean = x = $\frac{\sum x}{n} = \frac{21.75}{4} = 5.44$

Variance $S^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n} = \frac{17.27318}{4} = 4.32$

Standard Deviation S.D = $\sqrt{S^2} = \sqrt{4.32} = 2.08$

The results of the statistical analysis of pH, EC, SAR and TDS parameters of river water, hand dug well and borehole water revealed that river water has the highest value of standard deviation (225.09), followed by hand dug well water (4.46) and borehole water (2.08). The result of river water suggests high variability inconsistent water quality while the results of hand dug well and borehole water suggests low variability consistent water quality. Comparing the standard deviation across the water sources the river water has more variability. The high standard deviation in river water reflects seasonal changes such as pollution events or agricultural runoff influences. Low standard deviation in borehole might indicate more consistent quality.

CONCLUSION

The study revealed the salinity levels of the water samples collected from the river, hand-dug well, and the borehole water that are frequently used for consumption and irrigation purposes in the Gada-Mashegu area. Based on the comparison of the water's physico-chemical parameters with WHO guidelines for drinking water, the study concluded that the water from hand-dug wells and boreholes in the area meets the World Health Organization (WHO) standards for safe drinking water. On the other hand, the electrical conductivity level (EC) of the river water exceeds the WHO standard. This could be due to agricultural runoffs. Drinking this water source may result in health problems and diseases. Regarding irrigation practices all the water source may be used for irrigation but there is no guarantee of achieving100% crop yield. Base on the statistical results, the river water has highest variability (225.09), suggesting inconsistent water quality; the result of hand dug well and bore waters revealed low variability values (4.46) and (2.08). These suggest low variability consistent quality. Base on the study findings I recommend that more water and soil samples from the study area and its environs should be collected during both rainy and dry season.

REFERENCE

Arulbalaji, P., Padmalal, D. & Sreelash, K.(2019). GIS and AHP techniques based delineation of groundwater potential zones: a case study from southern Western Ghats. India. Sci. Rep. 9, 1–17

A.E Khan (2014). Salinity in drinking water and the risk of (pre) eclampsiaand gestational hypertension in coastal Bangladesh: a case control study.

American Society for Testing and Material, ASTM (2004). Annual Book of Standard, water and environmental technology, volume 11.01, Water (i) ASTM international, West Conshohocken, P.A, 352-371

Ayers R.S and Westcott D.W (1994). Water quality for agriculture: FOA. Irrg. Drain 29: 1-30

Aiyeloja A.A., Oladele A.T. and Ozoema C.S. (2014). Socio-economic analysis of wood furniture production in Rivers State, Nigeria. J. Trop. Forest Res., 30, 126-135

Haghighi, A. T. *et al*. (2020). Unsustainability syndrome—from meteorological to agricultural drought in arid and semi-arid regions. Water 12(3), 838

Ibrahim-Bathis, K. & Ahmed, S. A. (2016). Geospatial technology for delineating groundwater potential zones in Doddahalla watershed of Chitradurga district, India. Egypt. J. Remote Sens. Sp. Sci. 19, 223–234.

Ibrahim F.D., Oformata A.O., Jirgi A.J. and Adewumi A. (2019). Optimum production plan for maize-based crop farmers in Niger State, Nigeria. Agro-Science, 18 (3), 35-41. http://dx.doi.org/10.4314/as.v18i3.7

Karunanidhi, D., Aravinthasamy, P., Deepali, M., Subramani, T. & Shankar, K. (2021) Groundwater pollution and human health risks in an industrialized region of southern India: Impacts of the COVID-19 lockdown and the monsoon seasonal cycles. Arch. Environ. Contam. Toxicol. 80, 259–276 water Samples in Osogbo Metropolis. Afr. J. Clin. Exper. Microbiol. 6(3): 219-222

Konkul, J., Rojborwornwittaya, W. & Chotpantarat, S.(2014).Hydrogeologic characteristics and groundwater potentiality mapping using potential surface analysis in the Huay Sai area Phetchaburi Province, Tailand. Geosci. J. 18, 89–103

Kinje J.W (1993). Irrigation water –Quality issues, Limits, and way forward

Lind, J.E. (1959). Water pollution, Clarendon Press, oxford, P.9

Magaji M.J, Samndi A.M., Pantami S.A. Abdulrahman B.L Buji I.B. and Abubakar M. A.M (2020). An Assessment of Salinity levels of Soil and Water in irrigated Vegetable Farms around Lake-Alau Dam of Maiduguri, Borno State, *Nigeria. Journal of Agricultural Economics, Environment and Social*

Sciences 6(1):61-70. http://www.jaeess.com.ng. ISSN: 2476-8423

Mohammed Z., Shabbir A.S. and Lee H. (2018): Irrigation water Quality. *Int. Atomic Energy Agency. Guidelines for salinity assessment, mitigation and adaptation using Nuclear and related techniques,* *https://doi.org/10.1007/978-3-31996190-3_5*

Obi C.N, Okocha C.O (2007). Microbiological and physioco-chemical of selected Bore-hole waters in World Bank Housing Estate, Umuahia, Abia state, Nigeria. J. Eng. Applied Sci. 2(5); 920-929

Obaje, N.G. (2009). Geology and Mineral Resources of Nigeria. Dordretcht, Heidelberg, London New York. Springer

Olowe O.A, Ojurongbe O, Opaleye O.O, Adedosu O.T, Oluwe R.A, Eniola K.I.T (2005). Bacteriological Quality of water samples in Osogbo Metropolis. Afr. J. Clin. Exper. Microbial 6(3): 219-222

Rosinger A. Y, and Young S.L (2020). The Toll of household water insecurity on health and human biology: current understandings and future direction. WIRES water

Sarkar, S. K., Esraz-Ul-Zannat, M., Das, P. C. & Ekram, K. M (2022). Delineating the groundwater potential zones in Bangladesh. Water Supply 22(4), 4500–4516. https://doi.org/10.2166/ws.113

S. Akter (2019). Impact of drinking water salinity on children's education: empirical evidence from Coastal Bangladesh. *Journ. of total environment.*

Shammi M, Rahman M.M, Bonded S.E and Bodrud-Doza M. (2019). Impacts of Salinity intrusion in commentary Health: a Review of experiences on Drinking water of Bangladesh Heal care 7(1):50

Todd D.K. and Mays L.W (2005). Ground water Hydrology. 3rd edition

USEPA (2009). United State Environmental Protection Agency (USEPA), EPA 816—12-09-004

WHO (2009). Calcium and Magnesium in drinking water, public health significance, World Health Organization

WHO (2011). Guidelines for drinking-water quality, 4th edn. Geneva, Switzerland

WHO (1984). International standards for drinking water. 2nd edition Geneva, Switzerland