Assessment of the Quality of Some Sources of Irrigation Water in Bade Local Government Area, Yobe State

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Abstract-* Water quality plays a vital role in sustainable agriculture, particularly in arid regions like Bade Local Government Area, Yobe State, Nigeria. This study evaluated the suitability of surface and underground water sources for irrigation in the area. Water samples were collected and analyzed for physico-chemical parameters including pH, electrical conductivity (EC), total dissolved solids (TDS), major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), anions (NO_3^-, PO_4^{3-}, HCO_3^-, CO_3^{2-}, Cl^-), and indices such as Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (PI), Kelly's Ratio (KR), and Potential Salinity (PS). Results showed that both water sources were moderately acidic with non-saline EC and TDS values. All cation and most anion concentrations were within permissible limits, except for chloride, which exceeded the irrigation threshold. SAR and RSC values indicated good irrigation quality. However, the PI of surface water exceeded the safe threshold, suggesting long-term use may impair soil permeability. Overall, underground water showed better suitability for irrigation. This study provides essential baseline data for water management strategies to ensure agricultural sustainability in the region.

***Indexed Terms-* Bade, Irrigation, Surface, Underground, Water.**

I. INTRODUCTION

Water quality is a critical factor in agricultural productivity, especially in arid and semi-arid regions where irrigation is essential for crop production [1]. The suitability of water for irrigation depends on its physical, chemical, and biological characteristics, which can significantly impact soil health, crop yield, and overall agricultural sustainability [1]. In regions like Yobe State, Nigeria, where climate change and anthropogenic activities are increasing water scarcity and potentially impacting water quality, the assessment of irrigation water sources is of paramount importance [2]. Yobe State, located in northeastern Nigeria, faces significant challenges related to water resources due to its arid and semi-arid climate. The Bade Local Government Area (LGA) within Yobe State is particularly vulnerable, with communities heavily reliant on agriculture for their livelihoods [3]. Understanding the quality of irrigation water sources in this area is crucial for ensuring sustainable agricultural practices and preventing potential health and environmental issues and studies have shown that the quality of irrigation water can vary greatly depending on the source, including rivers, streams, groundwater, and harvested rainwater [4].

Despite the importance of irrigation water quality, there is a lack of comprehensive data and research on the specific water sources used for irrigation in Bade LGA, Yobe State. The absence of this information makes it difficult to assess the potential risks associated with using these water sources for agriculture. Potential problems arising from poor irrigation water quality include high salinity or sodicity in irrigation water can lead to soil salinization and reduced permeability, hindering crop growth; Poor water quality can directly affect plant health, leading to reduced crop yields and economic losses for farmers and contaminated irrigation water can contribute to the spread of waterborne diseases within the community.

Given the identified problems, this study aims to assess the quality of irrigation water sources in Bade Local Government Area, Yobe State and their suitability for agricultural use.

II. MATERIALS AND METHOD

A. Location

This study was conducted in Gashua, Bade Local Government Area of Yobe State. Gashua is located within the Latitude 12.8765° N and longitude 11.0316° E. The State is situated in the Sudan Savanna ecology with an annual rainfall of about 500mm-800mm concentrated almost entirely in July to October and mean daily temperatures (minimum and maximum) range between 38°C and 43°C in rainy season [5]. Land use around the area is basically agriculture. Crops such as millet, sorghum, soya beans, rice and vegetables like carrot, tomato, onion and red pepper are grown.

Water Sampling Locations
Surface water:
Latitude = 12.86041°
Longitude = 11.04321°
Underground water:
Latitude = 12.86309°
Longitude = 11.00883°

B. Water Sampling

Samples were collected from 3 surface water and 3 underground water source using sampling plastic bottles. Water sampling from surface water body was carried out by inserting the bottle into the water body allowing the mouth of the bottle to face upstream. The bottle was then plunged downwards to about 30cm below the water surface, the neck of the bottle was tilted slightly upward to let it fill completely. Where there is no current, the bottle was push forward horizontally until it is filled, carefully after collecting the sample the bottle cap was used to cover it.

Sampling the underground water, the water pump used in lifting water was operated continuously for 5 minutes to let the water flush the fittings and the pipes. The water sample was then allowed to flow directly into the sampling bottles, capped and covered.

C. Water Analysis

Carbonate (CO_3) and Bicarbonate (HCO_3) were determined by titration with 0.01N sulfuric acid (H_2SO_4) and chloride was determined by 0.01N silver nitrate ($AgNO_3$) titration. Sulfate (SO_4) is to be analyzed by turbidimetric procedure using barium chloride and determined by spectrometer. The Parameters such as electrical conductivity (EC), temperature and pH were determined on the site (in situ test) with standard calibrated portable pH/EC/TDS/temperature meter made by Hanna instrument, HI 93703. The analysis for Physio-chemical properties such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NO_3, SO_4, and Cl^{-} with other parameters were the major ions in ground and surface water of the study area were determined using atomic absorption spectrophotometer (AAS) [6]. The concentration was analyzed and calculated the irrigation index based on the standard method as:

Sodium Absorption Ratio (SAR) = (1)

Where all the concentrations are in meq/L of sodium, calcium, and magnesium ions.

The Residual Sodium Carbonates (RSC) was calculated as:

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

Where, all concentration is in meq/L.

Kelly's Ratio (KR) was calculated from the formula given in equation and all concentrations were expressed in meq/l.

$KR = Na^{+} / (Ca^{2+} + Mg^{2+})$ = (3)

Permeability index (PI) was calculated by using the following formula.

$PI = 100 \times (Na^{++} \sqrt{} HCO_3^{-}) / (Ca^{2+} + Mg^{2+} + Na^{+})$, unit in meq/l. = (4)

Based on the PI values, the irrigated water can be classified as Class I (>75 %), Class II (25–75 %) and Class III (<25 %).

D. Data analysis

Data obtained were subjected to statistical analysis to compare the means of properties between surface and underground water sources. The analysis was carried out using STAR software.

III. RESULTS AND DISCUSSION

A. pH, EC, TDS, Acidity and Total Hardness

The pH is the expression of the acidic and alkaline nature of the water sample. The pH value of the water samples in the study area lies in between 5.64 and 5.99. This showed that the samples belonged to moderately acidic class and is slightly below the safe limit for irrigation purpose (6.0 – 8.4), similarly the EC values of < 0.7dS/m and <450 mg/l of TDS (Table 1) for both surface and underground irrigation water sources indicated non-saline and not restricted for irrigation [7].

Table 1. The pH, EC, TDS, Acidity and Total Hardness of the surface and underground water in Gashua, Yobe State

Water Sources	pH	EC (dS/m)	TDS (mg/l)	Acidity (mg/l)	Total Hardness (mg/l)
Surface Water	5.99	0.0833b	50.22b	0.1273b	74.20b
Underground Water	5.64	0.1737a	100.73a	0.1523a	82.69a
Pr (>f)	0.067	0.0001	0.0001	0.0014	0.0054

B. Water Quality Based on the Cations Concentrations

The concentration of cations lies from 16.63 to 19.24 mg L^{-1} for Ca^{2+}, 13.77 to 23.69 mg L^{-1} for Mg^{2+}, 9.83

to 23.07 mg L^{-1} for Na^+, and 5.28 to 7.16 mg L^{-1} for K^+ (Table 3). In irrigation water, the permissible limit for Ca^{2+}, Mg^{2+}, Na^+, and K^+ is 80, 35, 200, and 30 mg L^{-1}, respectively [8, 9]. Based on these permissible limits, all the water samples were fit for irrigation purpose.

Table 2. Concentrations of the cations in the water samples

Water Sources	Ca^{++}	Na^+	K^+	Mg^{++}
	(mg/L)			
Surface Water	16.63b	9.83b	7.16a	13.77b
Underground Water	19.24a	23.07a	5.28b	23.69a
Pr (>f)	0.0032	0.0001	0.0003	0.0003

C. Water Quality Based on the Anions Concentrations

The permissible limit for NO_3^- is 150 mg L^{-1}, while PO_4^- is 5 mg L^{-1} [10]. The concentrations of NO_3^- and PO_4^- are below the limits for both the surface and underground water sources (Table 4) as such the water are safe for irrigation purposes. The permissible limit for anions HCO_3^-, CO_3^{2-} and Cl^- is 150 mg L^{-1} [11]. The values of HCO_3^-, CO_3^{2-} and Cl^- in the samples varied from 85.27 to 146.81, 22.88 to 45.60 mg L^{-1} and 288.73 to 395.71 mg L^{-1}, for surface and underground irrigation water sources respectively (Table 3). The results revealed that HCO_3^- and CO_3^{2-} levels are within the safe limit, while the level of Cl^- were observed to be above the limit as such unfit for irrigation purpose.

Table 3. Concentration of anions in the water sources

Water Sources	NO_3^-	SO_4^-	PO_4^-	Cl^-	HCO_3^-	CO_3^{2-}
	(mg/l)					
Surface Water	10.68	5.58a	0.3923a	288.73b	85.27b	22.88b
Underground Water	10.65	25.71b	0.3323b	395.71a	146.81a	45.60a
Pr (>f)	0.8944	0.0001	0.0025	0.0001	0.0001	0.0001

D. The Water Quality Indices

Sodium Absorption Ration (SAR) was 0.5683 me/l in surface water and 0.8313 me/l from underground water indicating low values and excellent quality and suitable for irrigation. The Residual Sodium Carbonate (RSC) was 1.02 me/l for surface water and 1.00 me/l for underground water. The RSC values also showed a good quality irrigation water (Table 4). Permeability Index (PI) indicated unsuitability for surface water (75.98%) which is above the 60% threshold, while the underground water is suitable (40.61%). This shows that long term usage of surface water for irrigation may affect the soils permeability [11]. The Kelly Ratio, though significantly different the values for both water sources were of good quality for irrigation (below 1.00 meq/L). Potential Salinity (PS) was 8.68 and 11.43 meq/L for surface and underground irrigation water sources (Table 4). The PS values fall within Suitable for medium & coarse textured soils.

Table 4. Sodium absorption Ration (SAR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP), Permeability Index (PI), Kelly Ratio, and Potential Salinity (PS) of the various irrigation water sources in Gashua, Yobe State.

Water Sources	SAR	RSC	SSP	KR	PS		PI
	(meq/L)						(%)
Surface Water	0.5683b	1.02	27.38a	0.3773a	8.68b		75.98a
Underground Water	0.8313a	1.00	25.61b	0.3440b	11.43a		40.61b
Pr (>f)	0.0001	0.7576	0.0403	0.0398	0.0002		0.0001

CONCLUSION

The soils of all the sampled farms belonged to moderately acidic class, the EC and TDS values for both surface and underground irrigation water sources indicated non-saline and not restricted for irrigation. The permissible limit for Ca^{2+}, Mg^{2+}, Na^+, and K^+ were not exceeded as such suitable for irrigation. The concentrations of NO_3^-, PO_4^-, HCO_3^- and CO_3^{2-} levels are within the safe limit, while the level of Cl^- were observed to be above the limit as such unfit for irrigation purpose. Sodium Absorption Ration (SAR) was within accepted limit and suitable for irrigation. The RSC values also showed a good quality irrigation water. Permeability Index (PI) indicated unsuitability for surface water, which is above the 60% threshold, while the underground water is suitable. The Kelly Ratio showed good quality waters for irrigation as well as Potential Salinity (PS) for surface and underground irrigation water sources fall within suitable class for medium and coarse textured soils.

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