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An Empirical Evaluation of Surface and Ground Water Quality of River Chochi for Sustainable Food Production

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Abstract

This research aimed to empirically evaluate the surface and ground water quality of river Chochi for sustainable food production. The study targeted river Chochi in Yola South LGA, of Adamawa state. Along the river three (3) locations were selected where irrigation activities are intensively carried out namely Bole, Modire and Anguwa-Tabo respectively. At each of the location three samples of water were collected for both surface (river flowing water) and ground water (borehole water) in three periods of the season (May, August and November). A total of fifty four (54) water samples were collected using clean bottles and stored for laboratory analysis of water quality level. The data obtained were subjected to analysis of variance (ANOVA) using Statistical Application for Sciences (SAS, 2020). The results revealed that the water analysis the results revealed that the concentration of primary cations were in order of $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$ while for the anions increases in order of $HCO_3^- > SO_4^{2-} > Cl^- > CO_3^{2-} > NO^-_3$. The IWQI ratings indicate that suitability index for surface water irrigation practices were SAR, RSC, % Na, MH and PI, while the unsuitable index were KI, PS and RSBC respectively. Moreover, the suitable indices for ground water were found to be SAR, RSC, %Na, KI, PS and RSBC. Meanwhile the suitable indices are MH and PI respectively. Therefore, surface water source in the area is suitable for irrigation practices while the ground water is considered unsuitable and required treatment before usage.

***Keywords**: Evaluation, Ground, River Chochi, Water Quality, Yola.*

INTRODUCTION

Water is the most important input required for plant growth for agricultural production. Water is the most important input required for plant growth for agricultural production. Despite the abundance water resources, agricultural activities have suffered serious setback because of climatic variability as well as uneven distribution of the resources. Williams, (1999) the problem of irrigation water quality is most common in arid and semi-arid lands. He further noted that the amount of salt found in irrigation water generally is greater in arid and semi-arid areas than in humid and sub-humid areas. In response to climate change and the need to adapt to these changes, and ensure food security for the growing population, the people are migrating to semi-arid regions and adapting irrigation to supplement rain fed agriculture and ensure all year round production of food crops (Ngigi *et al*., 2001; Thuo *et al*.,2001).

In identifying water availability for irrigation, knowledge is required on both the quantity and quality; nevertheless, quality need has often been neglected especially in developing countries. Quality should generalize how substantially a water supply fulfills the needs of the planned user and must be assessed based on its suitability for the proposed use (Ayers and Westcot, 1985).

STATEMENT OF PROBLEM

Water required for irrigation of cropped land is being degraded in terms of quantity and quality due to ever-increasing demand for the use of water in the contemporary societies and its eventually leads loss of fertile soils and yield (Nishanthiny *et al.*, 2010).

River Chochi is a seasonal river which carries impurities as the water comes from a distance and is frequently use, it leads to a gradual accumulation of impunities such as heavy metals and salts which is use for agricultural activities such as irrigation and livestock farming.

The three locations along the River Benue is not an exception of saline intrusion of its surface and groundwater supplies are being increasingly polluted by agricultural, urban and industrial uses which in consequence affect human health through consumption of vegetables and crops derived from the contaminated water sources and the soil. However, no scientific findings that identified the status of surface and ground water sources along the irrigated farmlands of the river that could be used in solving the existing problem for sustainable food production for the growing population in the area. It is indeed imperative to assess the surface and ground water along Chochi River in Yola South LGA, of Adamawa State. Thus, this research work saddled to empirically evaluate the surface and ground water quality of river Chochi for sustainable food production.

MATERIALS AND METHOD

The Study Area

River Chochi was situated in Yola South LGA, Adamawa State Nigeria on latitude 09^o 13 E and longitude 12^o 28 N which carries substantial amount of water beyond its capacity after heavy down pour consequently submerged the area. It has a river bed 158.461 m above mean sea level with an on low undulating terrain of 152-304 meters above the sea level with gentle undulation originated from Verre hill flowing from North-east down the North-west in an annular pattern from Bole to Anguwan-Tabo. The river is seasonal in nature which dries up before the onset of rainy season as a result of artificial rejuvenation constructed by the federal government to established River Chochi Irrigation Project since 1998 (Sadiq, 2019: Muhammed, *et al.*, 2012) and is the major tributaries to River Benue in the study area. The flat terrain bordering the river Chochi is a favorable locale for wide range of socio-economic activities such as farming, grazing, irrigation activities and settlement (Bole, Modire,Yolde-pate, Anguwan-Tabo and Damare areas). Hence it attracts a considerable proportion of population whose concentration and intensive irrigation production using the surface and ground water in the area.

Sample Collection Techniques

Water Sampling and Analysis

Two forms of water sample were used

1. Surface water samples which is the flowing water in the river and
2. Ground water sample which is the boreholes water along the river site

1. Surface water samples

At the three (3) selected locations water samples which is representative of the river water were collected in three different periods (May, August and October) which cover the rainy seasons. Thus, river water composition varies and changes with quantity, rate and nature of flow over a period. Table 1 described the duration of the water sampling techniques accordingly.

The water samples were collected using plastic bottles with screw caps the plastic bottles will be properly washed and rinsed to avoid contamination. The water samples were collected by lowering pre-cleaned plastic bottles into the bottom of the water body, 30 cm deep, and the sampling points will be approximately 100 m away from each other. From each of the three (3) locations, 3 water samples were collected at each of the location and at each period of the season. That is three (3) samples × 3 location = 9 samples/period × 3 periods = 27 samples. The total numbers of twenty seven samples were obtained for the laboratory analysis.

2. Ground water sample

Similarly, for the ground water sampling, at each of the three (3) locations, 3 water samples were collected at each of the location and at each period of the season. That is three (3) samples × 3 location = 9 samples/period × 3 periods = 27 samples. The total numbers of twenty seven samples were obtained for the laboratory analysis. The description was depicted on Table 1 below. **Table 1. Described the location, period and number of surface and ground water samples**

S/n	**Sample Location**	**Beginning of rainy season (MAY)**		**Middle of rainy season (AUGUST)**		**End of rainy season (NOVEMBER)**	
	Location	**Surface**	**Ground**	**Surface**	**Ground**	**Surface**	**Ground**
1	Bole	3 Samples	3 Samples	3 Samples	3 Samples	3 Samples	3 Samples
2	Modire	3 Samples	3 Samples	3 Samples	3 Samples	3 Samples	3 Samples
3	Ang-Tabo	3 Samples	3 Samples	3 Samples	3 Samples	3 Samples	3 Samples
4	Total	9 Samples	9 Samples	9 Samples	9 Samples	9 Samples	9 Samples
5.	Grand Total for Surface and Ground Water Samples in the Rainy Season **= 54 Samples**						

LABORATORY ANALYSIS

Water Analysis

The twenty seven (27) water samples of both surface and groundwater collected were analyzed in the laboratory by following the Ayers and Wilcox, (1995) guidelines on water quality for the following quality characteristics: pH, Electrical Conductivity (dS/m), Sodium (me/l), Potassium (me/l), Calcium (me/l), Magnesium (me/l), Carbonates (me/l), Bicarbonates (me/l), Chlorides(me/l), Sulphur oxides (me/l) Nitrate (me/l) and for the Irrigation water Quality Index (IWQI) eight (8) parameters were selected namely; Sodium Absorption Ratio (SAR), Residual Sodium Carbonate (RSC), percentage of sodium (%Na), Risk of Magnesium (MH), Permeability Index (PI), Kelly Index (KI) , Salinity Potential (PS) and Residual sodium bicarbonate (RSBC). These indices were calculated using recommended formular accordingly.

The classification and ratings of the selected IWQI used in this study was depicted on table 2 below;

Table 2. Classification of IWQI used in study area

S/n	Index	Range	Reference	Remark on quality
1	SAR	< 10 10-18 19-26 >26	Richards, 1954	Excellent Good Doubtful Unsuitable
2	Na %	< 20 20-40 40-60 60-80 > 80	Wilcox,, 1955	Excellent Good Permeable Doubtful Unsuitable
3	RSC	< 1.25 1.25-2.5 > 2.5	Eaton, 1950	Safe/Good Marginal/Double Unsuitable
4	RSBC	< 0 0 0-2.5 2.5-5 5-10 > 10	Gupta and Gupta, 1987	Satisfactory Satisfactory Satisfactory Satisfactory Marginal Unsuitable
5	PS	< 3 3-5 > 5	Doneen, 1964	Good Suitable Unsuitable
6	PI	> 75 % 25-75 % < 25 %	Doneen, 1964	Good Suitable Unsuitable
7	KI	< 1 > 1	Kelley, 1963	Suitable Unsuitable
8.	MH	< 50 > 50	Paliwal, 1972	Suitable Unsuitable

Source: (Azhari *et al.*, 2023)

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) using Statistical Application for Sciences (SAS, VERSION 2020).

RESULTS & DISCUSSIONS

Properties of Surface and Ground Irrigation Water Quality

The Concentration of Primary Cations in the Water Samples

Results on irrigation water quality are depicted on Table 3. It WAS revealed that both the surface and ground water the pH was neutral with mean values of 7.07 and 7.03 lower than the maximum value recommended by (World Health Organization, 2017). This pH of both the water sources may not affect the crop growth in the area. There is no significant difference between the surface and ground water source at P = 0.01. In addition, the mean values of EC were found to 65.92 and 62.08 describing low salinity damage. Thus, EC levels reflected by salinity damage are essential considerations in evaluating the suitability of water used for irrigation because of their effect on the osmotic pressure of the soil solution and the ability of plants to absorb water via their roots (Kadri,*et al.*, 2022). There is no significant difference between the surface and ground water source at P = 0.01 The Na^+ were observed to have mean values of 37.38 surface water and 40.66 for ground water. There is no significant difference between the surface and ground water source at P = 0.01. Meanwhile, the K^+ content of the surface water was 2.5 and 1.7 at ground water source. There is no significant difference between the surface and ground water source at P = 0.01. In addition, the Ca^{2+} was recorded with a mean value of 2.93 at surface water and 3.27 at ground water while Mg content was 1.78 and 1.31 at surface and ground water sources respectively. There is no significant difference between the surface and ground water source at P = 0.01. The trend of primary cations were found to have increase in order of $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$.The higher concentration of Na^+, Ca^{2+} and K^+ in the water sources could be related to chemical fertilizers , presence of large amounts of limestone, dissolved substances and other anthropogenic activities. This result agreed with report of by Azhari *et al.*, (2023).

The Concentration of Primary Anions in the Water Samples

The concentration s of primary anions of $CO^{2-}{}_3$ and $HCO^-{}_3$ for surface water was with the mean values of 6.89 and 33.22 while at ground water the values increases slightly to 6.95 and 40.84 respectively. However, There is no significant difference between the surface and ground water source at P = 0.01. In addition, the Cl^- and SO_4^{2-} content of surface water were 15.82 and 28.02 while at ground water was 14.90 and 25.78. There is no significant difference between the surface and ground water source at P = 0.01. The NO_{-3} content of the surface water was found to be 0.62 and 0.41 at ground water source. There is no significant difference between the surface and ground water source at P = 0.01. The trend of primary anions concentrations were found to have increase in order of $HCO_3^- > SO_4^{2-} > Cl^- > CO^{2-}{}_3 > NO^-{}_3$ respectively. The higher concentration of HCO_3^- in the water source is formed when carbonic acid dissolves carbonate minerals and silicate minerals while SO_4^{2-} levels may rise due to the depletion of sulfate minerals (such as gypsum), fertilizer inputs, and municipal Cl^- content may be due to waste deposition along the river site and can be attributed to Pliocene sediments. This finding is in conformity with the result of Azhari *et al.*, (2023).

Table 3. Results on Irrigation Water Quality

Location	pH	EC	Na^+	K^+	Ca^{2+}	Cl^-	$C0^{2-}_3$	HCO^-_3	SO^{2-}_4	NO^-_3	Mg^{2+}
Surface	7.07	65.92	37.38	2.5	2.93	15.82	6.89	33.22	28.02	0.62	1.78
Ground	7.03	62.08	40.66	1.7	3.27	14.9	6.95	40.84	25.78	0.41	1.31
Min – Max	6.34 - 7.62	51.6 - 72.16	27.79 - 56.52	0.81 - 4.79	0.59 - 7.36	2.35 - 39.95	2.10 - 39.35	24.53 - 66.65	0.016 - 52.5	0.018 - 2.3	0.56 - 3.76
S.E+	0.019	0.294	0.445	0.057	0.140	0.826	0.591	0.685	1.104	0.045	0.052
C.V %	4.96	8.26	20.52	49.35	81.08	96.75	153.74	33.28	73.90	156.55	60.94
P – value	0.402	0.102	0.784	0.9	0.991	0.199	0.821	0.591	0.311	0.421	0.211

Irrigation Water Quality Index (IWQI)

The surface and ground water suitability for irrigation purposes are calculated to determine the influence of minerals and salts on soil, which may affect plant growth by chemically lowering water intake via osmotic pressure changes or metabolic responses such as those caused by hazardous chemicals. The eight (8) hazard groups of IWQI were calculated these are Na%, SAR, RSC, RSBC, PI, KI, PS, and MH.

Sodium Absorption Ratio (SAR)

The results water quality index parameters are shown on Table 4. For the surface water Sodium Absorption Ratio (SAR) was revealed to be medium with mean values of 24.43 which might be suitable for irrigation practices while the ground water shows unsuitable condition with recorded values of 26.92. The salt concentration, or "alkali danger", which is expressed in the SAR, is a crucial factor for assessing the suitability of surface water for irrigation. The finding revealed high sodium content in the ground (> 26) water that might not be suitable for effective crop growth and on soil properties. Sodium Adsorption Rate (SAR) affects the soil, so irrigation water with high salt levels is of special concern and symbolizes the sodium danger because salt affects the soil. SAR also takes water from plants and decreases soil permeability (El-Rawy, *et al.*, 2019). This activity is particularly sensitive to finely structured soils, particularly those with high clay content as was earlier reported by Azhari *et al.*, (2023). Thus, the study areas are characterized with finer particles of loam and clay content.

Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate (RSC) content of both the surface and ground water shows unsuitability class for irrigation practices with mean values of 35.4 and 43.08 which is greater than the critical limit value (> 2.5) described Eaton, (1950) respectively. This result indicates the presence of residual carbonate (Pivi´c *et al.*, 2022) which causes a decrease in soil fertilization. This finding agreed with report of Azhari *et al.*, (2023) high RSC in water samples described as "unsuitable for irrigation" practices. Excessive bicarbonate and carbonate concentrations other than calcium and magnesium are alluded to as residual sodium carbonate (RSC) (Khanoranga; 2018) RSC is a valuable tool for examining the applicability of irrigation water. It is divided into three levels, according to the Eaton 1950 classification (Table 2) (Eaton,1950).

The sodium percentage (Na%)

The sodium percentage (Na%) is also used to assess the risk of sodium in soil and particle clogging. An excess of sodium with carbonate ions will help turn the soil into alkaline soil; in contrast, sodium mixed with chloride ions will accelerate the formation of saline soil, which ultimately worsens the infiltration capacity of the soil and reduces plant growth (Varol, *et al.*, 2021). The percent sodium (Na %) content was 89. 43 % with the surface water and 387.20 % with the ground water. These values are greater than critical limit (>80 %) proposed by Wilcox, (1955). The high concentration of Na+ in irrigation water tends to be absorbed by clay particles, displacing Mg^{2+} and Ca^{2+} ions. The exchange of soluble Na^{+} for Ca^{2+} and Mg^{2+} in the soil reduces permeability and ultimately leads to poor internal drainage. The restriction of air and water circulation during wet conditions affects soil hardness after drying (Tahmasebi, *et al.*, 2018 ; Azhari *et al.*, (2023) .

Magnesium Danger Index (MH)

Paliwal *et al*. (1972) developed the Magnesium Danger Index (MH) to assess the magnesium in irrigation water.Ca^{2+} and Mg^{2+}, in general, keep the water balanced, although they behave differently in physiological systems. Risk of magnesium (MH) was generally suitable for both the surface and ground water with corresponding mean values of 37.79 and 28.60. These values are defined suitable for irrigation (< 50) which could not inhibits crop growth and soil respectively. It is reported that irrigation water with MH > 50 is usually due to the presence of replaceable Na^+ in the irrigated soil, which negatively affects soil quality and causes it to become alkaline due to the adsorption of large amounts of water between magnesium and clay particles, reducing the soil's ability to infiltrate and crop production (Ghazaryan, *et al.*, 2020).

Permeability Index (PI)

The Permeability Index (PI), developed by Doneen . (1964) can better reflect the effects of irrigation. Based on the parameters employed, water can be divided into three classes: excellent, good, and poor (Table 2). The permeability index (PI) was generally suitable (>75 %) for irrigation with surface (102.57 %) and ground (103.80 %) water sources based on the Doneen, (1964) classification. The use of water with high quantities of salt, calcium, magnesium, and bicarbonate alters soil permeability over time (El-Amier, *et al.*, 2021). This means that both surface and ground water is suitable for irrigation, and long-term irrigation will not affect soil permeability.

Kelley index (KI)

The Kelley index (KI) (Kelley, 1963) was used to assess irrigation water quality. The levels of Na^+, Ca^{2+} and Mg^{2+} in water are used to calculate the value of KI. A KI value >1 indicates that excess salt is hazardous for irrigation, but a KI value less than one indicates that water is good for irrigation (Masoud, *et al.*, 2022). The observed KI values in this studywere found to be unsuitable (>1) for the both the surface water (7.93) and ground water (8.87) respectively. This further shows that long-term irrigation will negatively impact soil permeability potentially resulting from sufficient cation exchange. This result is not in conformity with the report of (Gao, *et al.*, 2016) and Azhari *et al.*, (2023) who observed KI suitable for irrigation practices.

Potential salinity (PS)

Potential salinity (PS), which is the concentration of Chlorine plus half the concentration of Sulphur, is used as one of the classifications for assessing the suitability of water for irrigation (Doneen, 1964). The result from this study revealed that the salinity Potential (PS) of the water at both surface and ground water (43.84 and 40.68) was observed to be unsuitable for usage in irrigation based on the Doneen, (1964) classification. These values in potential salinity levels might be attributed to the presence of chlorides in agricultural and wastewater discharges in the study area.

Residual Sodium Bicarbonate Index (RSBC)

The residual sodium bicarbonate index (RSBC) has been proposed by Gupta and Gupta (1987) to express the risk of alkalinity. Generally, a bicarbonate concentration above 10.0 meq/L affects plant growth in several ways and deemed unsuitable for irrigation, while RSBC values less than 5 meq/L were considered satisfactory for irrigation practices. The Residual Sodium Bicarbonate (RSBC) content of the water is generally unsuitable for irrigation for both the surface and ground water having mean value of 30.29 and 37.57 accordingly. The finding is not in conformity with report of Azhari *et al.*, (2023) who recorded ranged values of RSBC from 1.03 to 4.06 meq/L with an average of 2.82 meq/L, which shows that all samples had RSBC values much lower than the acceptable level and may be used safely for irrigation. Similar results were also found by Amrani *et al.* (2022) in the region of Timahdite-Almis Guigou, Middle Atlas, Morocco.

Table 4. Irrigation Water Quality Index (IWQI)

IWQI Parameters	SAR	RCS	% Na	MH	PI	KI	PS	RSBC
Surface water	24.43	35.4	89.43	37.79	102.57	7.93	43.84	30.29
Ground water	26.92	43.08	387.20	28.60	103.80	8.87	40.68	37.57

Ratings of Irrigation Water Quality Index (IWQI)

The irrigation water quality indicator is based on the ideal limits of eight (8) indices:, Na%, SAR, RSC, RSBC, MH, PI, PS and KI, (Table 5).Based on the IWQI ratings indicate that suitability index for surface water irrigation practices were SAR, RSC, % Na, MH and PI, while the unsuitable index were KI, PS and RSBC respectively. Moreover, the suitable indexes for ground water were found to be SAR, RSC, %Na, KI, PS and RSBC. While the suitable index are MH and PI as depicted on Table 7 respectively.

Table 5. Irrigation Water Quality Index (IWQI) Ratings

IWQI Parameters	SAR	RSC	% Na	MH	PI	KI	PS	RSBC
Surface water	Suitable	Suitable	Suitable	Suitable	Suitable	Unsuitable	Unsuitable	Unsuitable
Ground water	unsuitable	unsuitable	Unsuitable	Suitable	Suitable	Unsuitable	Unsuitable	Unsuitable

General Remarks of Irrigation Water Quality Index (IWQI)

According to the results of this study revealed that (Table 6) the about five (5) IWQI out of the eight (8) calculated indices were recognized as suitable and three (3) were defined as unsuitable for irrigation practices. Therefore, the suitability and unsuitability ratio of 5:3 described the suitability remarks for irrigation practices due to low to moderate toxicity levels of the combined water indices .In contrast, the ground water source revealed that only two (2) indices were recognized as suitable while six (6) indices were defined as unsuitable due to low ratio of suitability and unsuitability of 2: 6 respectively.

Table 6: General Remarks of Irrigation Water Quality Index (IWQI)

IWQI Parameters	Suitable	Unsuitable	Remarks
	✓	X	It may be suitable for irrigation practices due to moderate toxicity levels of the water indices
	✓	X	
Surface water	✓	X	
	✓	----	
	✓	-----	
	Suitable	**Unsuitable**	**Remarks**
	X	✓	It is unsuitable for irrigation practices due to high toxicity levels of the water indices
Ground water	X	✓	
	-----	✓	
	-----	✓	
	------	✓	
	------	✓	

CONCLUSIONS

This research work evaluates the soil physic-chemical properties and surface and ground water quality of river Chochi for sustainable food production. The soil properties of the studied area varied from sandy loam at Bole and clay at Modire and Anguwan Tabo characterized with high Bd and TP. The chemical properties shows moderately acidic to neutral pH, low TN and OM with medium to high exchangeable cations , TEB, TEA and PBS. The water sources (surface and ground) analysis revealed that the concentration of primary cations were in order of Na^+ >Ca^{2+} > K^+ >Mg^{2+} while for the anions increases in order of HCO_3^- > SO_4^{2-} >Cl^- > CO^{2-}_3 > NO_3.

The IWQI ratings indicate that suitability index for surface water irrigation practices were SAR, RSC, % Na, MH and PI, while the unsuitable index were KI, PS and RSBC respectively. Moreover, the suitable indices for ground water were found to be SAR, RSC, %Na, KI, PS and RSBC, meanwhile the suitable indices are MH and PI respectively. Surface water sources in the area is suitable for irrigation practices based on the ratio of 5:3 due to low to moderate toxicity levels of the combined water indices . The ground water source shows 2:6 of suitability and unsuitability ratio which described it as unsuitable for irrigation practices. Therefore, to improve soil fertility of the area, soil nutrients should be improve through application of soil amendment and integrated nutrient management for sustainable farming. Proper treatment should be done on the ground water sources for effective irrigation practices.

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