Studies on Water Quality in Suleja, Niger State for Domestic and Irrigational Purposes

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[1*]Amadi, A. N., [2]Obaje, N. G., [3]Goki, N. G., [1]Abubakar K. U., [4]Shaibu, I. and [5]Nwakife, C. N.

[1]Department of Geology, Federal University of Technology, Minna, Nigeria
[2]Department of Geology and Mining, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[3]Department of Geology and Mining, Nasarawa State University, Keffi, Nigeria
[4]Department of Geology, Federal University Gusau, Zamfara State, Nigeria
[5]Department of Chemistry, Federal University of Technology, Minna, Nigeria

*Corresponding Author's email: geoama76@gmail.com or an.amadi@futminna.edu.ng
Phone No.: +234-80377-29977

ABSTRACT

Geochemical evaluation of surface and groundwater in Suleja, a neighbouring town to Nigerian's Federal Capital Territory Abuja was investigated. A total of 40 water samples comprising of 25 hand-dug wells, 10 boreholes and 5 surface water were collected and analysed. Prior to the analysis, the physical parameters were determined in the field. The result of the water quality index revealed that the water in the area is poor in the order of: hand dug well > surface water > borehole. The poor quality can be attributed to the high loading of faecal contamination resulting from poor sanitary condition around the surface water and shallow hand-dug wells as well as weathering and bedrock dissolution in the course of groundwater movement. The water type in the area is fresh water with alkaline characteristics typical of bicarbonate type. Based on the computed value of sodium adsorption ratio, the water in the area is good for irrigational purposes. Education of the people on the health impacts of contaminated water and boiling of water is encouraged.

Keywords: Water Quality Assessment, Domestic, Irrigational, Suleja, North central Nigeria

INTRODUCTION

Water quality is evaluated from the physical, chemical, microbial and aesthetic points of view and it influences its uses for domestic, industrial and irrigational purposes (Amadi *et al.*, 2015).

Water is one of the most indispensable resource for the sustenance of life on earth. Studies have shown that there is increase in the demand for freshwater due to rise in population as well as the accelerated pace of industrialization in the last few decades (Olasehinde *et al.*, 2014; Nwankwoala *et al.*, 2014). The paucity of surface water and inadequate supply of pipe borne water in most cities in Nigeria has led to high demand for groundwater not only for its wide spread occurrence and availability but also for its moderately constant temperature, protection from surface contaminants which makes it a good source of drinking water (Amadi *et al.*, 2014; Abimbola *et al.*, 2002). This is part of the reason why groundwater is considered one of the purest forms of water available in nature and meets the overall demand for rural, semi-rural and urban people.

However, the various forms of unhealthy human activities over the years have made groundwater susceptible to contamination. Contaminants now find their way into groundwater through dumping of untreated industrial effluent, application of fertilizer and agro-chemicals, seepage of dumpsites, septic tank and pit-latrine. The proximity of Suleja to the Federal Capital Territory Abuja has led to the rapid rise in the population as well as in the establishment of many cottage industries, hence the need to evaluate the quality of the various sources of water in the area. The high cost of accommodation in Abuja also encouraged the low and medium class income earners to live in Suleja, where the house rent is moderately cheap. Surface water, hand dug wells and boreholes were subjected to physical, chemical and microbial analysis to ascertain their potability for domestic use as well as suitability for irrigational purposes in the present study.

The Study Area

The study area is part of Suleja and lies between longitudes 07°08'E to 07°12'E and Latitudes 09°08'N to 09°13'N (Fig. 1). It is accessible through Minna-Abuja road as well as Abuja-Kaduna road.

Climate and Vegetation

The annual total rainfall is in the range of 1100mm to 1600mm. Vegetation type is of Guinea Savannah and the area is mostly dominated by shrubs, tall grasses and trees especially along river channels (Dada, 2006).The area records its highest temperature of about 34 °C during the dry season, which occurs from November to March. During the rainy season, which spans from April to October, the maximum temperature drops to about 24 °C due to the dense cloud cover. Human sensibility to these temperatures is greatly affected by the relative humidity. During the dry season, relative humidity falls in the afternoon (Eduvie *et al*., 2003).

Geology of the Area

The study area is part of the Nigerian Basement Complex rocks which consist regionally of migmatite-gneiss complex, low grade schist belt and the older granites. However, the major rock types in the area investigated are granite-gneiss and granites (Fig, 1).

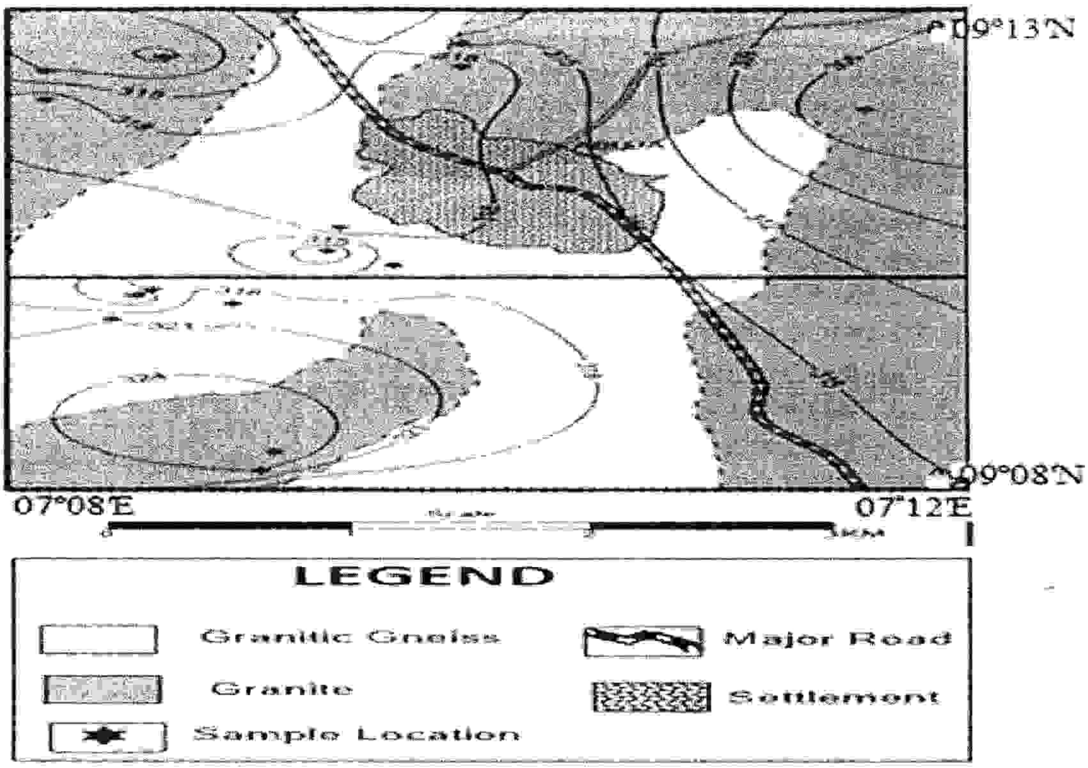

Fig. 1: Geology map parts of Suleja showing the sampled points

MATERIALS AND METHODS

Water Sampling

All samples were collected in sets of plastic and glass bottles for cation and anion analyses respectively. Both containers were washed with distilled water and few drops of HNO_3 were added to the plastic bottle for cation analysis in order to prevent loss of metals, bacterial and fungal growth. A total of 40 water samples comprising of 25 hand-dug wells, 10 boreholes and 5 surface water were strategically collected from the area and sent to the laboratory for analysis. The temperature, turbidity, conductivity and pH of water samples were also measured at the time of collection. The analysis was carried out at National Geosciences Research Laboratory, Kaduna, Nigeria. The APHA (2008) analytical procedure was adopted for the water sampling and analysis.

Statistical Analysis

The statistical summary of the analysed data was done using SPSS 12.0 version (Table 1). The Water Quality Index (WQI) was calculated using the National Sanitation Foundation (NSF) water quality index. The WQI was calculated from the point of view of suitability of the water for human consumption as shown in Table 2. The index has been widely used and applied to data from a number of different geographical areas all over the world to calculate WQI for various water bodies (Table

3). It is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers (Amadi *et al.*, 2012). It thus, becomes an important tool for the assessment and management of surface and groundwater. It provides a single number that expresses the overall quality of water at certain location and time based on several water quality parameters. It expresses complex water quality data into understandable information usable by common people.

A quality rating scale (q_i) for each parameter is assigned by dividing its concentration (C_i) in each water sample by its respective Nigerian Standard for Drinking Water Quality (S_i) and the result multiplied by 100 as shown in the formula: $q_i = (C_i / S_i) \times 100$

The Relative weight (w_i) was obtained by a value inversely proportional to the recommended standard (S_i) of the corresponding parameter according to the equation: $w_i = 1/S_i$

The overall Water Quality Index (WQI) was calculated by aggregating the quality rating (q_i) with unit weight (w_i) linearly.

$$WQI = \left(\sum_{n=1}^{i=n} q_i w_i\right)$$

Where:

q_i: the quality of the ith parameter.

w_i: the unit weight of the ith parameter and

n: the number of the parameter considered.

The overall water quality of an area is therefore obtained using the formular:

$$Overall\ WQI = \frac{\sum q_i w_i}{\sum w_i}$$

RESULTS AND DISCUSSION

The statistical summary of the Physico-chemical and microbial parameters analysed are shown in Table 1. The values of pH in the water from the study area ranged from 6.2 to 7.6 with an average value of 6.9. The mean value of pH falls within the permissible limit of 6.5-8.5 recommended by World Health Organization (WHO, 2008) and Nigerian Standard for Drinking Water Quality (NSDWQ, 2007). Temperature values ranged between 26.3°C and 29.2 °C with a mean value of 27.5 °C. High temperature enhances the solubility and mobility of metals. The concentration of electrical conductivity (EC) varied from 27.0 µS/cm to 1078.0 µS/cm with a mean value of 498.2 µS/cm. The total dissolved solid (TDS) accounts for the soluble solute in water and the concentration is of the order of 16.0 mg/L to 647.0 mg/L with an average value of 298.7 mg/L. The pH, EC and TDS are within the permissible limits of (NSDWQ, 2007) and (WHO, 2008), and indication that the water in the area are not contaminated by these parameters (Vasanthavigar *et al.*, 2010; Milovanovic, 2007).

Potassium and sodium are alkali earth metal and highly electronegative. The concentration of potassium ranged between 0.3 mg/L and 43.7 mg/L with a mean value of 16.3 mg/L while sodium varied from 0.5 mg/L to 125.0 mg/L with an average value of 48.2 mg/L. The values of sodium and potassium are low when compared with their maximum permissible limits of 200.0 mg/L and 100.0 mg/L respectively (WHO 2008; NSDWQ, 2007). Sodium is a dietary mineral for people suffering from diarrhoea. However, high concentration of sodium leads to increased blood pressure and arteriosclerosis. The value of calcium ranged from 21.9 mg/L to 241.4 mg/L with an average value of 113.9 mg/L while magnesium concentration varied from 0.1 mg/L to 38.6 mg/L with a mean value of 15.9 mg/L. The concentration of calcium in some locations was higher than maximum permissible limit of 200.0 mg/L. Calcium is a beneficial element and is needed for strong teeth and bone formation and its high concentration in water does not constitute any health hazard (Amadi *et al.*, 2014). The presence of calcium and magnesium ions in water is responsible for hardness of water (Ofodile, 2002).

Bicarbonate concentration ranged from 4.0 mg/L to 14.0 mg/L with a mean value of 6.6 mg/L as against the permissible limit of 100 .0 mg/L recommended by WHO (2008) while values of sulphate ranged between 8.0 mg/L to 21.0 mg/L with an average value of 11.8 mg/L and the values falls below the recommended maximum allowable limit of 100. 0 mg/L (NSDWQ, 2007). The chloride concentration varied from 5.0 mg/L to 121.0 mg/L with a mean value of 51.0 mg/L while the concentration of nitrate ranged from 1.2 mg/L to 6.8 mg/L with an average value of 3.9 mg/L. These values are below the maximum permissible limit of 250.0 mg/L and 50.0 mg/L for chloride and nitrate. The concentration of the major cations and anions were found to be below the allowable limit except calcium in few locations.

Table 1: Statistical Summary of Water Samples from Hand dug Wells in Suleja Area

Parameters	Minimum	Maximum	Mean	Std Deviation	Variance	WHO	NSDWQ
pH	6.20	7.57	6.95	0.414	0.171	6.5-8.5	6.5-8.5
Temperature	26.00	26.20	26.05	0.071	0.005	Ambient	Ambien
Hardness	22.00	280.00	128.80	84.038	7062.4	200	150.00
Alkalinity	4.00	14.00	6.60	2.988	4.259		
Carbonate	0.00	0.00	0.00	0.000	0.00	200	200
Bicarbonate	4.00	14.00	6.60	2.988	4.259	100	100
Chloride	4.99	120.99	50.99	45.568	2076.44	250	250.00
Nitrate	1.20	6.81	3.872	2.232	4.980	50	50.00
Phosphate	0.18	1.00	0.53	0.322	0.104		
Conductivity	27.00	1078.00	498.17	398.512	158812	1000.0	1000.0

Turbidity	1.00	38.00	12.00	16.812	282.667	5.0	5.0
Sulphate	8.00	21.00	11.75	4.638	21.514	100	100.0
Calcium	21.87	241.38	113.943	70.910	5028.22	200	0,003
Magnesium	0.13	38.62	14.859	13.519	182.77	150.0	200
Sodium	0.45	125.03	48.230	45.594	2078.77	200.0	200.0
Potassium	0.28	43.67	16.259	15.218	231.589	100.0	100.0
Iron(III)	0.00	5.66	1.261	2.122	4.502	0.30	0.30
Copper	0.00	0.03	0.0074	0.012	0.00014	1.00	1.00
Zinc	0.00	0.66	0.0737	0.208	0.0432	3.00	3.00
Lead	0.00	0.23	0.0476	0.087	0.0076	0.01	0.01
Manganese	0.01	0.05	0.0303	0.013	0.00018	0.20	0.20
Dissolved Oxygen	3.50	8.70	7.06	1.706	2.909	6.00	5.0
Nickel	0.00	0.02	0.0123	0.006	0.00003	0.02	0.02
TDS	16.00	647.00	298.72	239.088	57163.10	500	500.00
Fluoride	0.00	1.07	0.21	0.358	0.127	1.50	1.50
Total coliform	0.00	308.00	95.6	110.010	12101.4	10.0	10.0
Faecal Coliform	0.00	86.00	30.60	38.132	1453.38	0.0	0.0
Faecal Streptococci	0.00	96.00	33.00	43.115	1858.89	0.0	0.0

The concentration of iron varied from 0.0 to 5.7 mg/L with an average value of 1.3 mg/L as against the permissible limit of 0.3 mg/L. High iron content in groundwater in the area does not constitute any health problem except impairment of the colour, odour and taste (Olasehinde *et al.*, 2004; Okunlola *et al.*, 2014). The concentration of copper varies from 0.0 – 0.026 mg/L with a mean value of 0.007 mg/L while the concentration of lead ranged from 0.0 – 0.2.3 mg/L with an average value of 0.048 mg/L as against their respective maximum permissible limit of 1.0 mg/L and 0.01 mg/L respectively. The concentration of copper and lead in some locations exceeds the maximum permissible limit and suggest possible contamination arising from urbanization. Indiscriminate dumping of metal scraps and lead-acid may be a contributing factor. The concentration of zinc varied from 0 – 0.665 mg/L with a mean value of 0.0737 mg/l while the concentration of nickel ranged from 0.002 – 0.021 mg/L with a mean concentration of 0.012 mg/L. The concentrations lie within the safe limit for potable water (NSDWQ, 2007).

The value of faecal coliform ranged from 0.0 – 86 cfu/100mL with an average value of 30.6 cfu/mL, the concentration of total coliform varied from 0.0 to 308.0 cfu/100mL with a mean concentration of 95.6 cfu/100mL while the value of faecal streptococci is in the order of 0.0-96.0 cfu/mL with an average value of 33.0 cfu/mL (Fig. 2). The fact that the different water sources (streams and hand-dug wells) contain bacteria is a confirmation that the water in the area is poor bacteriologically. It is an indication of faecal contamination of the water system in the area. The presence of faecal coliform, total coliform and faecal streptococci is proof that the water had contact with human or animal faeces. The poor sanitary condition in the area arising from leaky soakaway, unlined pit-latrine and defecation in open places are responsible for the microbial contamination of the water system in the area (Tiwari and Mishra, 1985; Ishaku, 2001).

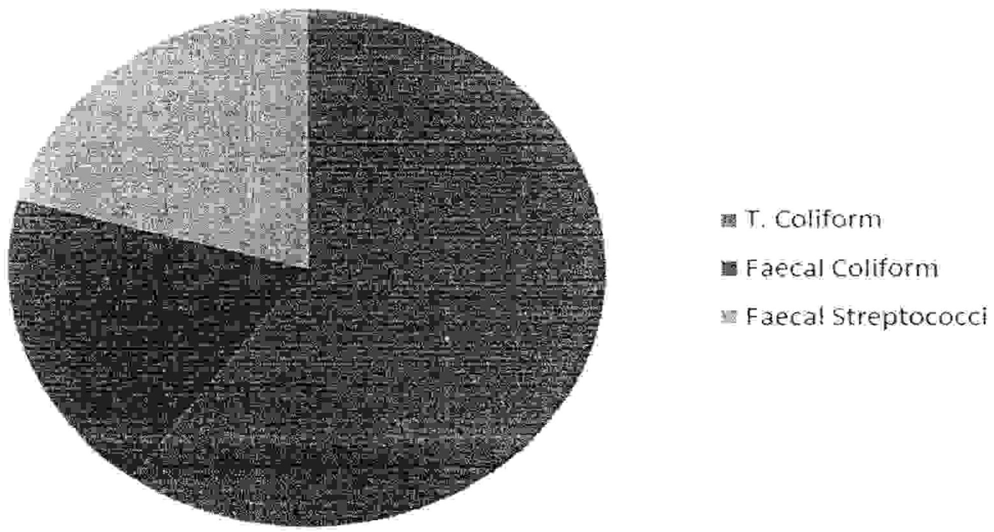

Fig. 2: Pie chart representations of bacteriological parameters analysed

Piper Trilinear Diagram

This method was devised by Piper (1944) to outline certain fundamental principles in a graphic procedure which appears to be an effective tool in separating analytical data for critical study with respect to sources of the dissolved constituents in water. The trilinear diagram illustrates the relative concentration of Cations (left diagram) and anions (right diagram) in each sample. The concentration of 8 major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, CO_3^{2-}, HCO^-_3 and SO_4^{2-}) are represented on a trilinear diagram by grouping the K^+ with Na^+ and the CO_3^{2-} with HCO^-_3, thus reducing the number of parameters for plotting to 6. On the Piper diagram, the relative concentration of the cations and anions are plotted in the lower triangles, and the resulting two points are extended into the central field to represent the total ion. The degree of mixing between freshwater and saltwater can also be shown on the Piper diagram. The Piper diagram (Fig. 3) can also be used to classify the hydrochemical facies of the groundwater samples according to their dominant ions. The water in the area is bicarbonate water type.

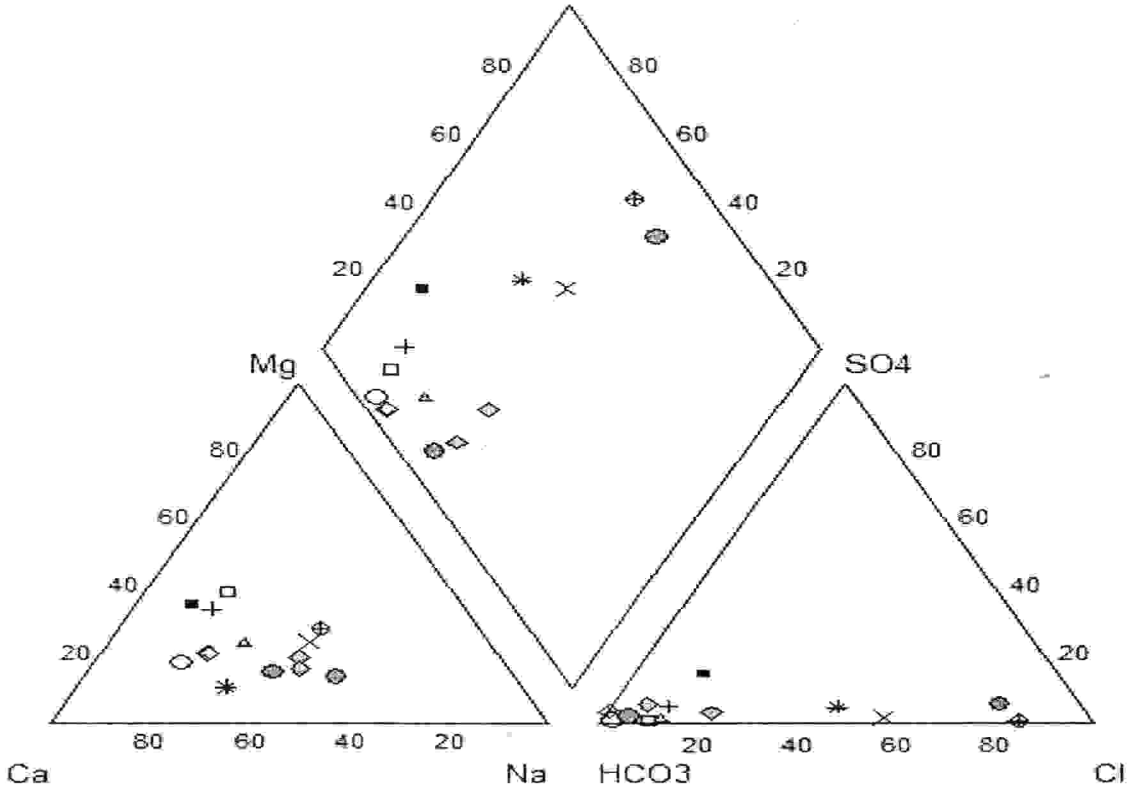

Fig. 3: Piper Trilinear diagram for Suleja

Schoeller-Plots

These semi-logarithmic diagrams were developed to represent major ion analyses in meq/L and to demonstrate different hydrochemical water types on the same diagram (Fig. 4). This type of graphical representation has the advantage that, unlike the trilinear diagrams, actual sample concentrations are displayed and compared. The shielding effect of elements arising from their combination like in the trillinear diagram is not repeated in Schoeller plots.

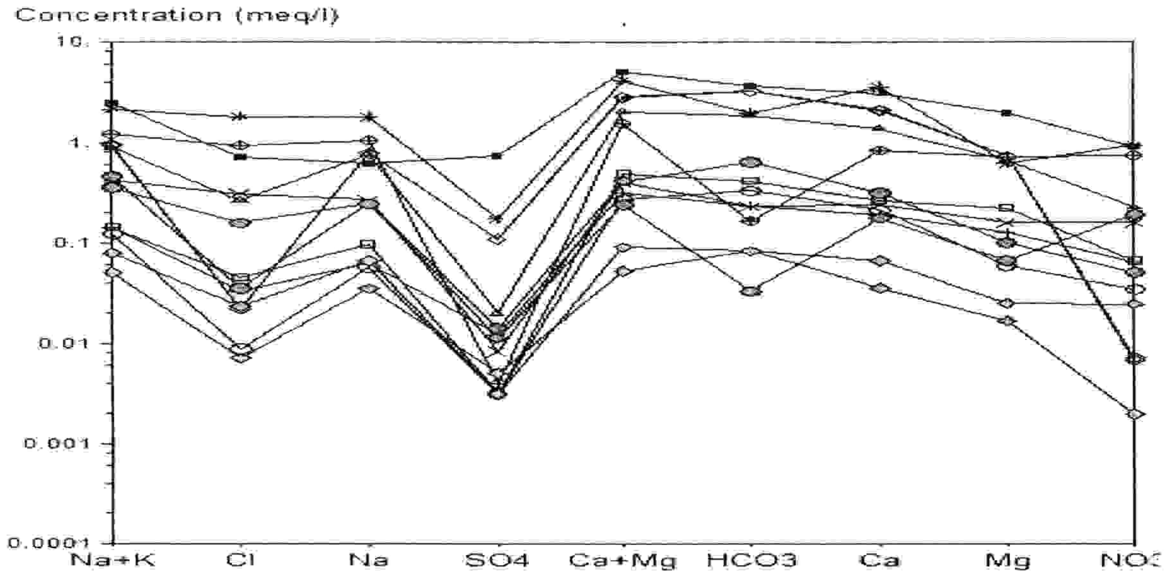

Fig. 4: Schoeller plots for Suleja

WQI Calculation

The overall WQI was calculated using the Weighted Arithmetic Index method with the formula: *Overall* $\text{WQI} = \frac{\sum q_i w_i}{\sum w_i}$

Where: q_i: the quality of the ith parameter,

w_i: the unit weight of the ith parameter

$$Overall\ \text{WQI} = \frac{\sum q_i w_i}{\sum w_i} = \frac{20103.758}{160.83}$$

$= 125.01$

Table 2: Computed Water Quality Index parameters

Parameters	*Ci*	*Si*	*Qi*	*Wi*	*Qiwi*
pH	6.95	7.50	92.67	0.133	12.32
Hardness	128.80	200.0	64.40	0.005	0.322
Chloride	50.99	250.0	20.40	0.004	0.082
Nitrate	3.872	50.0	7.744	0.020	0.155
Phosphorous	0.53	5.0	10.60	0.200	2.120

Conductivity	498.17	1000.0	49.82	0.001	0.049
Sulphate	11.75	100.0	11.75	0.001	0.0118
Calcium	113.94	200.0	56.97	0.005	0.285
Magnesium	14.86	200.0	9.91	0.007	0.069
Sodium	48.23	200.0	24.12	0.005	0.121
Potassium	16.26	100.0	16.26	0.010	0.163
Iron(III)	1.260	0.3	420.0	3.333	400.97
Copper	0.007	1.0	0.74	1.000	0.74
Zinc	0.074	3.0	2.46	0.333	0.818
Lead	0.048	0.01	100.0	100.0	7600.0
Manganese	0.030	0.2	15.15	5.000	75.75
Nickel	0.012	0.02	61.5	50.00	3075.0
TDS	298.72	500.0	59.74	0.002	0.119
Fluoride	0.210	1.5	14.0	0.667	9.338
Total Coli Form	95.60	10.0	956.0	0.100	95.60
Faecal Streptococci	33.00	0.0	0.0	0.030	0.000

Table 3: Water Quality Classification Based on WQI Value

WQI value	Water quality
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Unsuitable for drinking

The calculated WQI indicates that the water in the area is poor in quality and needs treatment before drinking and it is attributed to widespread bacteriological contamination due to poor sanitary condition as well as geogenic contamination arising from weathering and bedrock dissolution. Water quality management through education of public on health implications of polluted water and enforcement of necessary law that would help in the protection of water system is advocated.

Irrigational Quality Calculations

The quality test for water for irrigation purposes is the calculation of the sodium adsorption ratio (SAR), which is a measure of the solidity of the soil determined through quantitative chemical analysis of water in contact with it. Sodium hazard results when the excess amount of carbonate and bicarbonate in water reacts with sodium in soil (Amadi *et al.*, 2015). The SAR was calculated using the formula: $SAR = [Na+] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}$

Based on the computed SAR values, the water samples fall within the low sodium hazard (S1) in United States Salinity diagram (Fig. 5, Wilcox, 1950). Over 89% of the water samples fall in the C1-S1 region which implies that the water in the area is very good for irrigation purposes. The suitability of water for irrigation decreases across C1 to C4 and S1 to S4 (Fig. 5). The values of electrical conductivity (EC), residual sodium bicarbonate (RSBC), sodium adsorption ratio (SAR) and soluble sodium percentage (SSP) as shown (Fig. 6), further confirms the fact that the water in Suleja area is good for irrigation purposes.

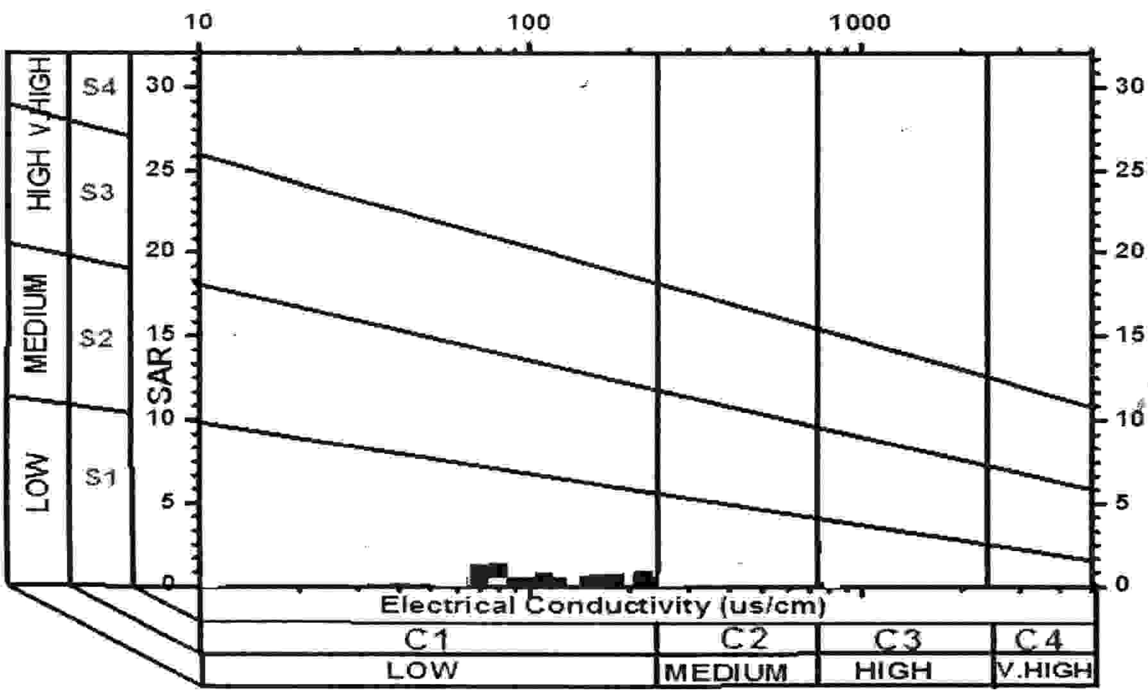

Fig. 5: Sodium Adsorption Ratio (SAR) and salinity hazard plot for Suleja

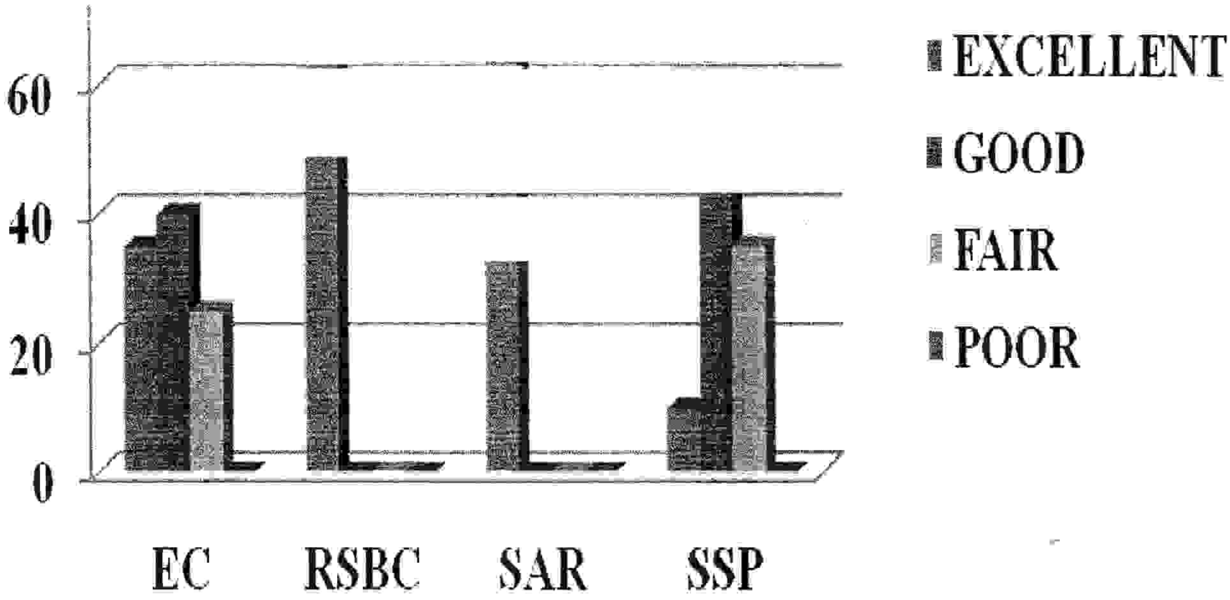

Fig. 6: Index rating of Irrigation Parameter in Suleja

Conclusion and Recommendation

The water sources in Suleja were investigated from the point view of assessing their suitability for domestic and irrigational purposes. The result of the analysis indicates that the water in the area is poor domestically but good irrigationally. The degree of deterioration is highest in hand dug wells, followed by surface water while boreholes are the least affected. Lack of hygiene such as open defecation, dumping of refuse near surface water and hand dug wells were identified as being responsible for the impairment of the water system in the area. The people living in the area were advised to maintain good sanitary condition and ensure that the water is boiled before consumption as bacteria does not withstand elevated temperature.

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