

Assessment of Surface Water Quality for Drinking and Irrigation Purposes in Selected Parts of Ilorin, North Central Nigeria

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ABSTRACT: This study evaluates the suitability of surface water for drinking and irrigation purposes in selected parts of Ilorin, North Central Nigeria. Surface water samples were collected from sixteen (16) locations within the Asa River Basin and analyzed for physico-chemical parameters. Physical parameters such as pH, Total Dissolved Solids (TDS), and Electrical Conductivity (EC) were measured in situ, while cations and anions were quantified using Atomic Absorption Spectrophotometry (AAS). The results indicated that pH values ranging between 6.0 and 7.9 fall within permissible limits for drinking and irrigation purposes as per WHO and NSDWQ standards. TDS values ranged from 190 mg/L to 540 mg/L, with only one sample exceeding the NSDWQ limit of 500 mg/L. EC ranged between 130 μ S/cm and 770 μ S/cm, with 44% exceeding NSDWQ limits for drinking but meeting WHO standards for irrigation. Chemical analysis revealed that calcium (2.35 to 29.16 mg/L), magnesium (1.04 to 10.87 mg/L), sodium (6.06 to 20.98 mg/L), bicarbonate (18 to 96 mg/L), and chloride (1.99 to 26.90 mg/L), concentrations were within permissible limits for drinking water. Irrigation indices confirmed suitability for most samples, though some locations had limited suitability due to elevated sodium levels. The results emphasize continuous monitoring and effective water management to ensure long-term resource sustainability.

Keywords: Surface water quality, Drinking water standards, Irrigation suitability, Physical and chemical, parameters, Asa River Basin

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I. INTRODUCTION

Water is an essential natural resource for life and its sustainability, supporting drinking, agriculture, and industrial activities. Surface water, which includes rivers, lakes, streams, and reservoirs, plays a critical role in providing freshwater for various uses. Unlike groundwater, surface water is directly exposed to atmospheric, geological, and human influences, making it more susceptible to contamination. Human activities such as agricultural runoff, industrial discharges, and urbanization often introduce pollutants that degrade surface water quality (Chapman, 1996; UNESCO, 2006). Parameters such as turbidity, dissolved oxygen, and nutrient concentrations are essential in assessing water health (WHO, 2017).

Contamination of surface water can lead to severe environmental and public health impacts, including the spread of waterborne diseases, loss of aquatic biodiversity, and reduced agricultural productivity (EPA, 2019). As a vital component of the hydrological cycle, maintaining surface water quality is essential for sustainable development. While global studies have extensively examined surface water quality, localized research in areas like the Asa River Basin is limited. Moreover, existing studies often focus on either drinking or irrigation suitability, rarely addressing both simultaneously, despite their interlinked implications for human health and agriculture.

By analysing the physical and chemical parameters of surface water within Asa River basin, this study evaluates the quality and suitability of surface water for drinking and agricultural uses. It is also geared towards

identifying potential sources of contamination within the basin. Consequentially, this research provides critical insights for resource management, sustainable development and policy formulation in the study area.

II. DESCRIPTION OF THE STUDY AREA

The study area is located in Ilorin, the capital city of Kwara State, Nigeria. It lies within the Asa River Basin, which covers an area of approximately 1,040 km² (Oyegun, 1987). The study area is situated between latitudes 8°00'1" N to 8°30'1" N and longitudes 4°23'1" E to 4°36'1" E (Figure 1). Ilorin experiences a tropical climate with distinct wet (May to October) and dry (November to April) seasons.

The annual rainfall averages 1,200 mm, and the temperature is relatively uniform, peaking in the dry season (Oluyide et al., 1998). The vegetation predominantly consists of Guinea Savannah, characterized by grasslands interspersed with shrubs and trees (Oluyide et al., 1998). The Asa River being the primary water body is accompanied by several tributaries and reservoirs, including the Agba and Asa Dams. Land use in the area includes agriculture, fishing, and urban development, which influence water availability and quality (Oyegun, 1987).

The study area is part of the Basement Complex of southwestern Nigeria, dominated by Precambrian crystalline rocks (Rahaman, 1988). These include migmatites, gneisses, schists and granites, (Fig. 1). The Basement Complex rocks are known for their limited primary porosity and permeability, which have been enhanced locally by weathering and fracturing processes. The geological formations play a critical role in groundwater storage and movement (Adelana & Olasehinde, 2004). The geological structures, including fractures and joints, significantly influence the hydrogeology by acting as conduits for groundwater movement and storage (Rahaman, 1988; Adelana & Olasehinde, 2004).

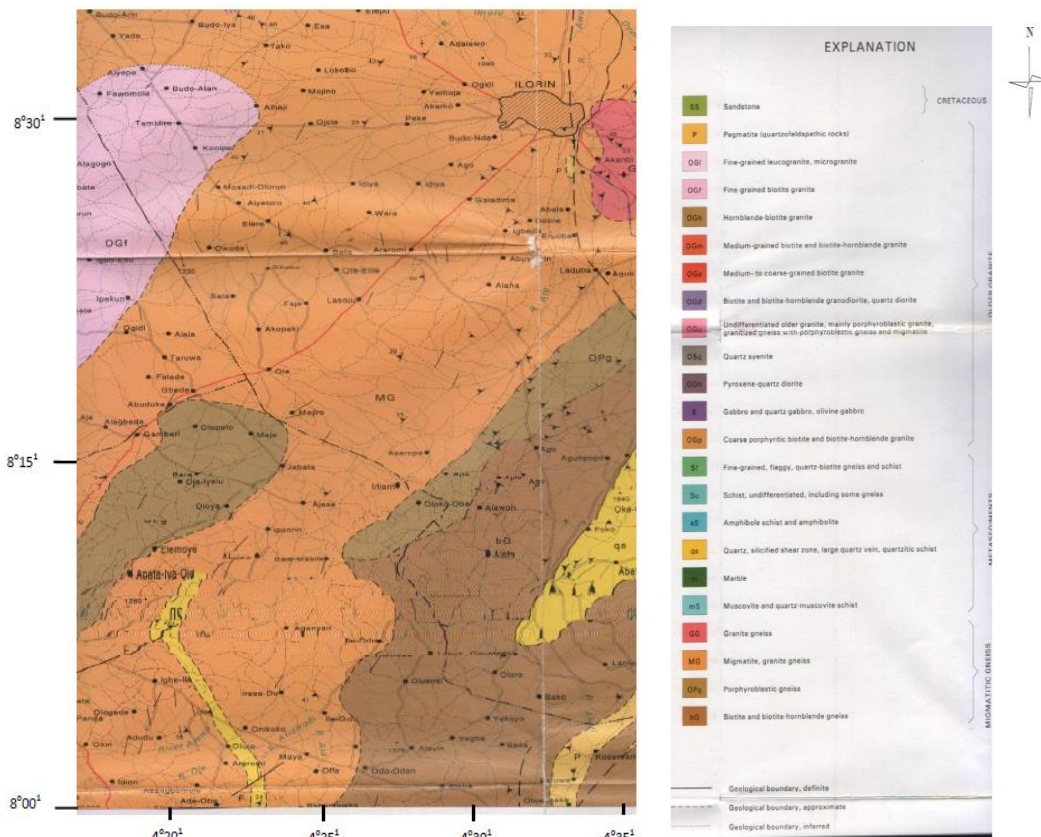


Figure 1: Geological Map of Study Area (Oluyide et.al 1998)

III. MATERIALS AND METHODS

3.1. Water Sampling and Analysis

Samples of surface water were collected from sixteen (16) locations within the Asa River Basin (Table. 1). All locations where surface water was collected are recorded with Global Positioning System (GPS) and are presented in Fig. 2. At each location, two samples were collected in 1liter polyethylene bottles pre-cleaned with distilled water. One sample was acidified with few drops of concentrated nitric acid to a pH < 2 to preserve it for cation analysis while other samples were left unacidified for anion analysis. Sampling procedures adopted in this

study followed standard protocols (APHA, 2017), to minimize air contamination during collection. The bottles were labeled and sealed immediately after filling, and stored in an ice-filled cooler for preservation during transportation to the laboratory.

Physical parameters such as pH, Total Dissolved Solids (TDS), and Electrical Conductivity (EC), were measured in situ using portable meters. These measurements were taken to provide immediate insights into the water quality at the sampling points. Water samples were analyzed for major cations (Ca^{2+} , Mg^{2+} , Na^+ , K^+) and anions (Cl^- , SO_4^{2-} , HCO_3^- , NO_3^-) using Atomic Absorption Spectrophotometry (AAS). This method ensured precise and reliable quantification of ionic concentrations. Analytical procedures adhered to the standard methods outlined by APHA (2017) to maintain data accuracy and comparability. The results were evaluated against the World Health Organization (WHO, 2017) and Nigerian standards for drinking and irrigation water. Statistical analyses, including correlation studies, were conducted to explore relationships between water quality parameters and identified potential contamination source.

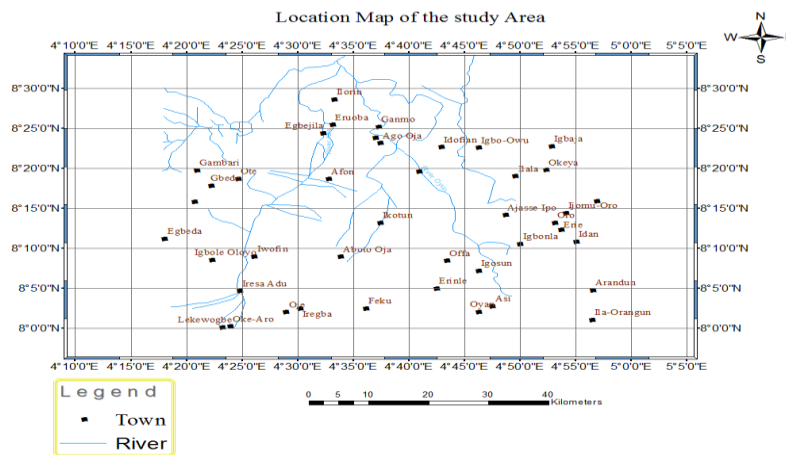


Figure 2: Location Map of the Study Area

Table 1: Sampling locations and their respective coordinates

Sample ID	Sampling Area	Northing	Easting
Loc1	Asa Dam	08° 25' 08.44"	04° 33' 21.01"
Loc2	Agba Dam	08° 28' 9.3"	04° 35' 1.12"
Loc3	Abatan	08° 26' 08.44"	04° 33' 21.01"
Loc4	Egbejila	08° 25' 37.5"	04° 32' 07.59"
Loc5	Iresadu	08° 04' 05.45"	04° 23' 58.90"
Loc6	Iregba	08°04' 25.10"	04°24' 29.04"
Loc7	Lekewogbe	08° 00' 06.23"	04° 23' 31.65"
Loc8	Ekororo	08° 04' 14.4"	04° 23' 16.5"
Loc9	Obe	08°03'00"	04° 25'00"
Loc10	Idi-Ape	08° 18' 1.5"	04° 21' 14"
Loc11	Aho	08° 17' 3.8"	04° 33' 5.1"
Loc12	Idandan	08° 20' 3.3"	04° 23' 01"
Loc13	Afon	08° 19'12.21"	04° 31' 49.00"
Loc14	Olowoko	08° 20' 20.8"	04° 31' 26.3"
Loc15	Ganmo	08° 24' 15.28"	04 26' 12.5"
Loc16	Ogbodo	08° 14' 00"	04° 25' 12.2"

IV. RESULTS AND DISCUSSION

4.1 Analysis for Physical Parameters

The physical parameters of the water quality across the study area are provided in Table 2.

4.1.1 pH

The pH values ranged from 6.0 to 7.9 for LOC1 to LOC16 the lowest values were recorded at LOC14 while the highest value was recorded for LOC3 and LOC16 (Table 2). These values fall within the permissible safe limit of

both NSDWQ and WHO of 6.5-8.6 and 6-8.5 respectively. The pH values obtained in all sampling locations are suitable for irrigation purposes because they fell below and within the permissible range for irrigation.

4.1.2 Total hardness

Hardness of water (mg/L) is an important measure of pollution. It is the measure of capacity of water to react with soap. The higher the water hardness the more soap is required to foam. The level of water hardness for the samples ranged between 14 mg/L and 120mg/L which fall below NSDWQ and WHO permissible limit (500 and 1000 mg/L) respectively. The samples are considered safe for human and livestock consumption.

4.1.3 Electrical Conductivity (EC)

The conductivity of the analysed samples ranged from 130 to 770 $\mu\text{s/cm}$. LOCs 3, 4, 5, 9, 10, 12, and 13 value fell below NSDWQ limit of 300 $\mu\text{s/cm}$ for drinking water while the values of other locations fell above NSDWQ limit. Also, the values for all locations fell within the permissible and safe level of WHO limit of 1000 $\mu\text{s/cm}$. With the value observed for NSDWQ, 44% of the water samples are not safe for consumption for human beings and livestock. If the EC of irrigation water falls below 700 $\mu\text{s/cm}$, it does not affect crop growth but at a value above 3000 $\mu\text{s/cm}$, it may cause severe damage (Ayers and Westcot, 1985). The result of the water analysis revealed that the surface water is suitable for irrigation. EC in water sample is an indication of dissolved ion.

Table 2: Physiochemical parameter of surface water

Sample ID	pH	Hardnes (mg/L)	EC ($\mu\text{s/cm}$)	TDS (mg/L)	TA (mg/L)
LOC1	7.5	16	420	200	32
LOC2	7.8	16	450	305	28
LOC3	7.9	18	168	300	40
LOC4	7.6	54	210	456	74
LOC5	6.9	52	242	377	68
LOC6	6.8	38	338	200	60
LOC7	7.5	18	450	350	34
LOC8	6.4	20	356	253	44
LOC9	7.1	26	200	500	42
LOC10	6.7	10	230	190	50
LOC11	7.8	34	400	367	54
LOC12	7.0	78	130	196	88
LOC13	7.7	30	272	190	50
LOC14	6.00	120	305	500	96
LOC15	7.8	14	770	540	18
LOC16	7.9	18	343	223	28
NSDWQ	6-8.6	200mg/L	300	500mg/L	
WHO	6-8.5	500mg/L	1000	1000mg/L	120mg/L

4.1.4 Total dissolved solid (TDS)

Total dissolve solid is the concentration of all dissolved minerals in the water (Tahlawi et al., 2014). The TDS of the surface water samples ranged from 190 mg/L to 540 mg/L. Accordingly, values obtained for all the samples fell below the NSDWQ and WHO permissible limit of 500 mg/L and 1000 mg/L respectively except for LOC15 with value 540mg/L which is above the NSDWQ permissible limit. Dissolved minerals, gases and organic constituents may result into displeasing colour, odour and taste. High level of dissolved organic chemicals may deplete the dissolved oxygen in the water.

4.1.5 Total Alkalinity

Alkalinity of the surface water sample ranged between 18 mg/L to 96mg/L of CaCO_3 . At LOC14, the highest value of 96 mg/L was recorded whereas at LOC15, the lowest value of 18 mg/L was reported (Table 2). Although there is no NSDWQ limit, but all samples fell within the WHO limit of 120mg/L. Nevertheless, excessive alkalinity in water is not good for irrigation which may lead to damage of the soil and consequently leads to reduction in crop yield (Gyamfi et al., 2012).

4.2 Analysis of Chemical Parameters

The chemical parameters considered in this study are the cations such as calcium, iron, magnesium, potassium, and sodium (Ca^{2+} , Fe^{2+} , Mg^{2+} , K^+ , and Na^+) while the anions are chloride, bicarbonate, nitrite, phosphate and sulphate (Cl , HCO_3^- , NO_2^- , PO_4^{3-} and SO_4^{2-}).

4.2.1 Calcium

Figure 3 shows the calcium content of Asa River where the range of calcium in all the sample locations varies from 2.35 to 29.16 and a total of 154.67 (Table 3) which is within the NSDWQ and WHO calcium permissible values for drinking water which is 250mg/L and 500mg/L respectively. Calcium is a major constituent of igneous and metamorphic rocks. The major sources of calcium in surface water around granitic rocks and gneisses are plagioclase and pyroxene. The range of calcium content in groundwater is largely dependent on the solubility of calcium carbonate, sulphide, oxide and rarely chloride. Calcium content values higher than the recommended permissible values contribute to the hardness of water and excessive scale formation and the increase may be influenced by agricultural and industrial waste.

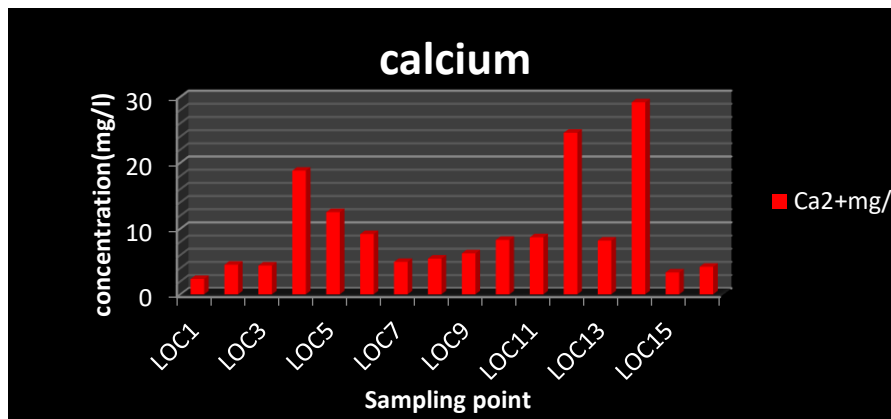


Figure 3: Concentration of Calcium (mg/L)

Table 3: Descriptive statistics of cations and anions

Parameters	Range	Sum	Mean	SD	NSDWQ	WHO (2017)
Ca ²⁺	2.35-29.16	154.67	9.67	7.86	200	500 mg/L
Fe ²⁺	0-5.46	49.13	3.07	1.89	0.3	0.3mg/L
Mg ²⁺	1.04-10.87	46.73	2.92	2.36	0.2	50mg/L
K ⁺	0.50-7.12	38.38	2.39	1.76		200mg/L
Na ⁺	6.06-20.98	144.87	9.05	3.60	200	200mg/L
Cl ⁻	1.99-26.90	116.67	7.29	6.38	250	250mg/L
HCO ₃ ⁻	18-96	782	48.86	21.17	240	Variable
NO ₂ ⁻	0-0.02	0.12	0.01	0.07	0.2	0.2mg/L
PO ₄ ³⁻	0.03-0.25	1.74	0.11	0.06		
SO ₄ ²⁻	2.00-10.00	71	4.44	2.16	500	400mg/L

4.2.2 Iron

Iron is a very common element found in many of the rocks and soils of the earth's crust. It is also an essential element for animal growth. From Table 3, it is noticed that the values of iron ranges from 0 to 5.46 mg/L. All Samples except LOC4, 12 and 14 (Figure 4) are within the maximum permissible levels NSDWQ guidelines. The possible sources of total iron may be related to the weathering and dissolution process of pyrite resulting in the production of iron oxide along with clay minerals. Also, the open nature of surface water system suggests that oxidation of iron mineral by oxygenated recharge water may also be responsible for removal of iron into solution. High concentration is only of importance from the aesthetic point of view. The undesirable effects include water discoloration, fixtures, laundry and appliances staining, dark scale in pipe and water heater and undesirable taste in beverages.

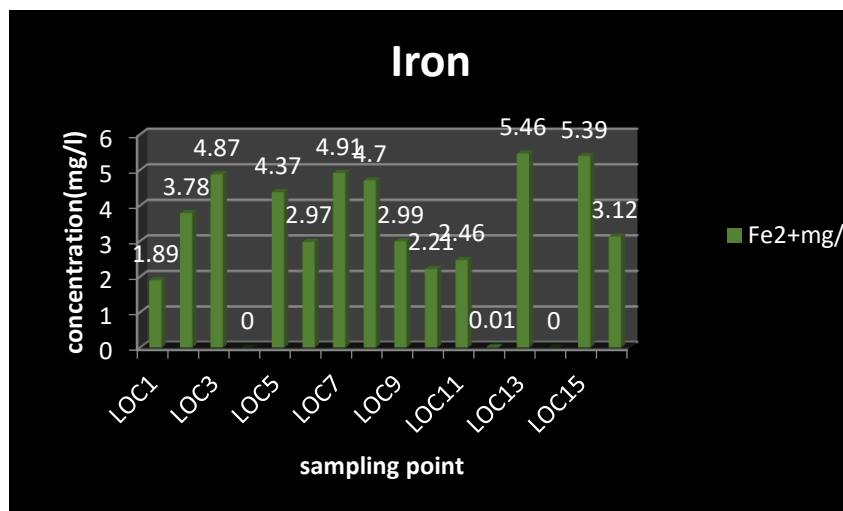


Figure 4: Concentration of Iron (mg/L)

4.2.3 Potassium

Analysis of water samples in the study area indicated that potassium value varies between 0.50 to 7.12 mg/L (Table 3). It was observed that potassium content falls within WHO standard and higher than NSDWQ. Although potassium is nearly as abundant as sodium in igneous rocks, its concentration in surface water is comparatively lower than sodium (nearly one-tenth or one-hundred that of sodium). This is due to the fact that the minerals rich in potassium are highly resistant to decomposition by weathering. Probable source of potassium is from the fertilizer or industrial waste.

4.2.4 Sodium

Sodium content ranges from 6.06 to 20.98 mg/L with an average value of 9.05mg/L (Table 3). These values fall within the 200mg/L concentration for the maximum permissible levels recommended by WHO and NSDWQ. Sodium has been observed to be an important constituent for determining the quality of irrigation water. Sodium bearing minerals like albite, oligoclase, nepheline and sodalite weather to release the primary soluble sodium products. Most sodium salts are readily soluble in water, but take no active part in chemical reactions.

4.2.5 Magnesium

Natural water contains magnesium which is one of the most common elements in the earth's crust. It is present in all natural waters. It is an important contributor to water hardness. The sources of magnesium in natural water are dolomites and mafic minerals (amphibole) in rocks. The solubility of dolomite in water depends on the composition. But the magnesium is always lower in water than calcium as a rule because its solubility in water is around five times that of calcium. The range of magnesium varies from 1.04 to 10.87mg/L and has an average of 2.92 mg/L (Table 3) with the highest concentration in location 14 (Figure 5). This is an indication that Asa River has high magnesium content which is above the recommended level suggested by NSDWQ. Occurrence of Calcium and Magnesium above the recommended level can result into water hardness. Unregulated intake of magnesium may lead to gastro-intestinal irritations.

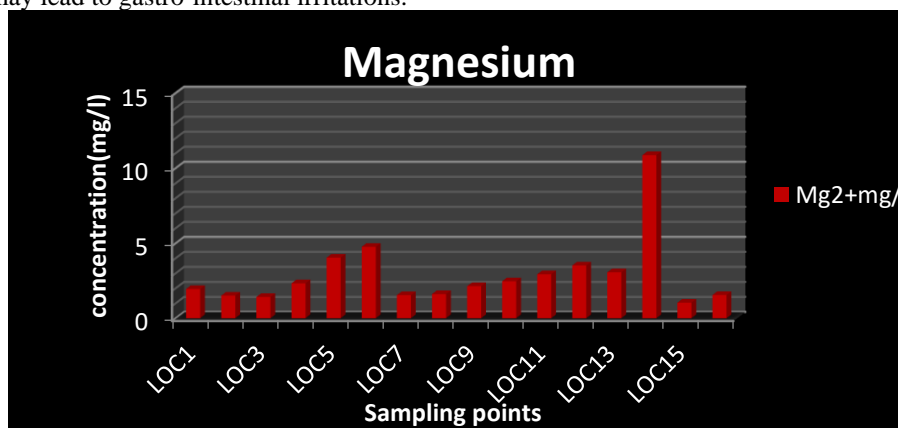


Figure 5: Concentration of Magnesium (mg/L)

4.2.6 Chloride

Chloride is usually present in relatively small amounts in all natural waters, likewise, it can be derived from human sources. Chloride is not effectively removed by the septic systems and therefore, remains in their effluent high concentration. Chloride in water is known to cause no health hazard; hence, it is readily available in almost all potable water. Table 3 shows the content of Asa River within the study area have low chloride content that is below the NSDWQ and WHO recommended value which is 250mg/L. The considerable reduction in chloride content of the surface water is connected with lack of industrial and sewage pollution in the area, but a significant increase in its concentration suggests fecal pollution. High amount of chloride in the surface water has a significant consequence on water taste and corrosiveness of the water pipes.

4.2.7 Bicarbonate

The concentration level of bicarbonate ranges between 18mg/L and 96mg/L, average of 48.86mg/ L (Table 3). In the WHO (2005) standard for drinking water, there is no specification for its level of concentration but it falls within the range of NSDWQ limit which is 240mg/L. Possible sources of bicarbonate in water are carbondioxide of the air and organic matter while its stability in water however depends on the pH of the water.

4.2.8. Nitrite

The total nitrite content in Asa River has a value ranging from 0 to 0.02 and this falls within the 0.2 mg/l concentration for maximum permissible level of WHO and NSDWQ. Values higher than this amount form nitrosamines which are considered to be carcinogenic. The maximum nitrite value can be seen in LOC7 and LOC12 (Figure 6).

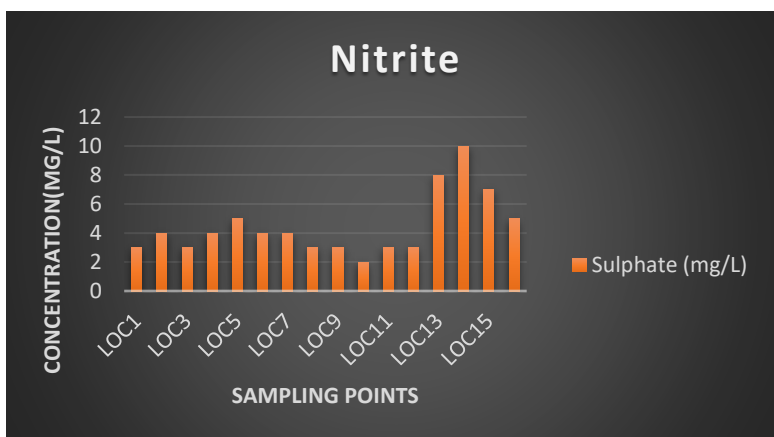


Figure 6: Concentration of Nitrite (mg/L)

4.2.9 Phosphate

Asa river show a relatively low phosphate content of 0.3mg/L, this value is lower than WHO and NSDWQ recommended level for phosphate. Phosphate, a non-constituent of water is formed during certain biological transformation to form phosphates and also found in fertilizer. Phosphates belong to nutrient substances that limit the process of photosynthesis in plant. Its high content is due to the runoff of fertilizer occasioned by unmonitored farming practice across the study area.

4.2.10 Sulphate

Sulphate occurs in water as an inorganic constituent as well as dissolved H₂S. It is not a noxious substance although high sulphate content in water may have a laxative effect. Figure 7 shows the sulphate content of the surface water around the study area. It is observed that the sulphate content is lower than the WHO and NSDWQ standard value for drinking water which is 250mg/L and 500mg/L respectively. The sulphate is supplied to the groundwater by the reaction of water with the sulphate containing rock and also by biochemical oxidation of sulphides. Sulphate causes non-carbonate hardness in water, severe scaling in pipes and gastro-intestinal irritation.

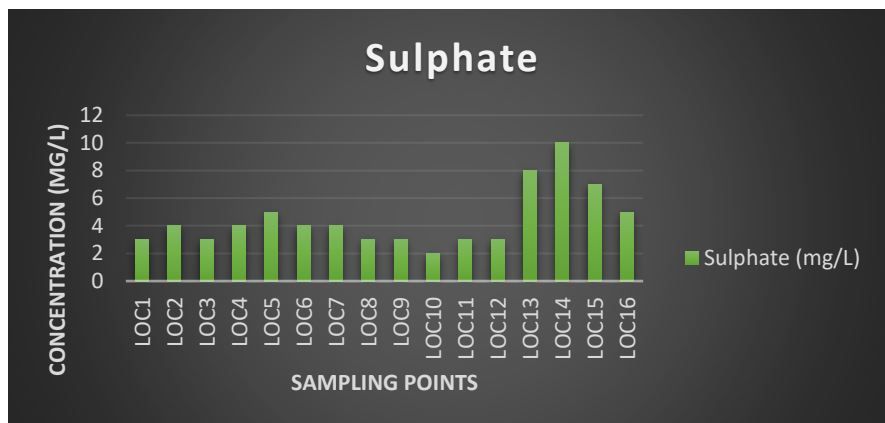


Figure 7: Concentration of Sulphate (mg/L)

4.3 Hydrochemical Facies of Water Sample in the Study Area

The piper diagram in Figure 8 shows the relative concentration of major cations and anions. Two principal water types comprising Calcium- Magnesium- Chloride – Bicarbonate which is a region of temporary hardness and Sodium- Potassium- Carbonate- Bicarbonate which primarily composed of alkali carbonate were delineated. It is also revealed from the piper diagram that various rock types present within the aquifers are calcite, dolomite, rhyolite and basalt.

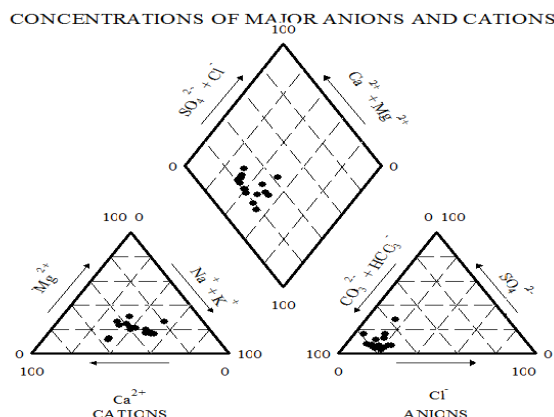


Figure 8: Pipers Diagram Showing the Concentration of the Major Cations and Anions

4.4 Assessment of Surface Water Quality for irrigation Purposes

4.4.1 Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio indicates the effect of relative cation concentration on sodium accumulation in soil. The potential for sodium hazard increases with high sodium adsorption ratio. The SAR content of the study area water samples as shown in Table 4, range between 0.56 and 1.07. All the water samples fall within the water class grade “excellent” hence the water samples are fit for irrigation purposes according to SAR water class (Table 5).

4.4.2 Kelley’s Ratio (KR)

Kelley’s ratio was used to evaluate water based on level of sodium measured against calcium and magnesium. The calculated KR values ranged between 0.19 and 0.54 % (Table 4) which indicate that all the water samples fell within the suitable grade class of KR. This implies that all the surface water samples are good for irrigation purposes.

4.4.3 Soluble Sodium Percentage (SSP)

The percentage soluble sodium calculated range between 18.12 and 37.5 which indicates that all the water samples fell below 50. This showed that all the water samples are suitable for irrigation purposes.

4.4.4 Permeability Index (PI)

The permeability of soil is affected by long-term use of irrigation water and is influenced by sodium, calcium, magnesium and bicarbonate contents in the soil (Vasanthavigar et al., 2010). The calculated PI values ranged

between 44.21 and 93.16. Based on Doneen 1964 classification (Table 5), only water samples from locations 12, 13 and 14 are suitable for irrigation purposes, while water sample from other locations are not suitable for irrigation purposes because they have values greater than 60.

4.4.5 Magnesium Adsorption Ratio (MAR)

The values of the magnesium adsorption ratio of surface water in this study ranges from 16.81 to 48.81 % indicating that they are within the acceptable limit of 50 % ((Paliwal,1972). The waters are therefore, considered suitable due to low magnesium adsorption ratio which does not have harmful effect on soil when it is less than 50%.

4.4.6 Residual Sodium Bicarbonate (RSBC)

RSBC was calculated according to Gupta and Gupta (1987). The residual sodium bicarbonate values of water samples from the study area vary from -0.62 to -3.62meq/L. The residual sodium bicarbonate values are less than 3.0meq/L and are therefore considered safe for irrigation purposes.

V. CONCLUSION

Bicarbonate is the dominant anion as shown from its sum of 782 mg/L of the total anion content of Asa River and range of value which is 18 to 96 mg/L. Chloride is next in abundance with a total of 116.67 mg/L and range of value which is 1.99 to 26.90 mg/L of the total anionic content. Also, Nitrite has the least sum of 0.12 mg/L and range value of 0 to 0.02 mg/L. Calcium is the dominant cation with a sum of 154.67 mg/L and range value of 2.35 to 29.16 mg/L whereas sodium with total of 144.87 mg/L and range value of 6.06 to 20.98 mg/L is next in abundance to calcium. Iron has a sum of 49.13 mg/L and it ranges from 0 to 5.46 mg/L. The potassium and magnesium content range from 0.50 to 7.12 mg/L and 1.04 to 10.87 mg/L respectively. The relatively low concentration of these cations is reflected in the anion content especially bicarbonate and chloride. The chemical analyses show the samples obtained from Asa River are enriched in anions more than the cations. With bicarbonate being the dominant anion in Asa River, it is suggested that the excess bicarbonate ions in the water results from the CO₂ charged/recharged water during precipitation.

Table 4: Irrigation parameters for each sample location

LOCATION	SAR	KR	SSP	PI	MAR	RSBC
LOC1	0.70	0.47	37.5	80.23	58.18	-0.62
LOC2	0.79	0.47	34.58	79.69	35.71	-0.91
LOC3	0.88	0.54	37.38	99.03	34.33	-0.22
LOC4	0.60	0.20	19.86	61.25	16.81	-3.09
LOC5	1.07	0.39	29.63	70.08	34.74	-2.35
LOC6	0.57	0.22	20.56	65.22	45.88	-1.90
LOC7	0.79	0.46	32.72	83.33	33.78	-1.05
LOC8	0.83	0.46	33.33	93.16	32.50	-1.26
LOC9	0.69	0.35	27.61	78.63	36.08	-1.31
LOC10	0.63	0.28	25.45	74.05	32.52	-1.65
LOC11	0.65	0.28	24.16	73.41	35.56	-1.76
LOC12	0.64	0.19	19.68	48.60	19.21	-3.62
LOC13	0.56	0.24	21.43	49.51	37.88	-1.64
LOC14	0.84	0.19	18.12	44.21	38.09	-4.48
LOC15	0.74	0.52	35.06	72.37	34.00	-0.62
LOC16	0.65	0.39	31.31	76.84	38.24	-1.07

Table 5: Classification of water to evaluate its suitability for irrigation

Parameters	Range	Irrigation Class
SAR (Ayers and Westcot, 1985)	<10	Excellent
	10-18	Good
	18-26	Fair
	>26	Poor
SSP (Tood, 1980)	<20	Excellent
	20-40	Good
	40-80	Fair
	>80	Unsuitable
MAR (Paliwal,1972)	<50	Suitable
	>50	Unsuitable

RSBC (Gupta and Gupta 1987)	<2.5 >2.5	Suitable Unsuitable
PI (Doneen,1964)	<60 >60	Suitable Unsuitable
KR (Kelly,1946)	<1 1-2 >2	Suitable Marginal Unsuitable

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