

Assessment of quality of river Niger floodplain water at Jebba, central Nigeria: implications for irrigation

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Abstract: Preliminary hydro-chemical evaluation of River Niger Floodplain at Jebba, Nigeria was carried out using ICP/MS and AAS methods in order to assess its suitability for domestic and irrigation purposes. Relative abundance of cations concentration at the pond water, well water and stream water were: Na>Ca>K>Mg, Na>Ca>Mg>K and Ca>Na>K>Mg respectively while those of the anions were: Cl>HCO₃>SO₄>CO₃>NO₃, Cl>SO₄>HCO₃>CO₃>NO₃ and Cl>HCO₃>SO₄>NO₃>CO₃ respectively. The average values of Revelle Contamination Index for the water samples were greater than one, hence, the water is not good for human or domestic consumption. On the average, pond and stream waters range from soft to moderately soft while the well water is extremely hard (influence of lithology). The pond, well and stream waters are slightly alkaline with average value of pH as 7.8, 7.5 and 7.8 respectively. Interestingly, the calculated Indices: Sodium Adsorption Ratio, Magnesium Adsorption Ratio, Residual Sodium Carbonate, Residual Sodium Bicarbonate, Permeability Index, Kelly Ratio, Potential Salinity and Soluble Sodium Percentage, which could indicate the water quality for irrigation show that the water is safe for irrigation practices. However, caution must be made while using well W1 because it shows high value of Magnesium Adsorption Ratio (54.62) and high value of Kelly Ratio (1.06) which makes it unfit for irrigation purposes.

Key Words: water quality, pond water, well water, stream water, water quality for irrigation, river Niger

1. INTRODUCTION

Generally, floodplains are areas of extensive agricultural activities in the developing world such as Nigeria. Unfortunately, certain materials are being deposited on the floodplains from far and near altering the original chemistry of pond water and the soil in the areas. Most of the rivers overflow their banks thereby causing havoc to farm produce and invariably reduce the yield of agricultural products. The ponds and the adjoining rivers are being polluted by the floods. The assessment of irrigation water is therefore important for social-economic growth and development (Ishaku et al, 2011). However, the studies of water quality for human consumption and agricultural activities have not been given adequate attention in most parts of Nigeria, particularly the present study area. There is a need to pay full attention to the study of chemical composition of water for domestic and irrigation purposes (Suresh et al, 1991; Ishaku et al, 2011). The water composition may concentrate salts in soils or water and this may affect crop yield (Bernstein, 1975). Geo-genic factors could influence the concentration of ions in surface and underground water (Yousef et al, 2009). The abundance of major ions largely depends upon the nature of bedrocks, climatic conditions and mobility. The ions distribution is also influenced by the infinite complex surface and subsurface physicochemical environments (Aghazadeh and Mogaddam, 2010; Naseem et al, 2010). The physicochemical parameters of water can be used to assess its suitability for irrigation activities (Naseem et al, 2010). The aim of this paper is to evaluate the quality of pond, well and streams waters in Jebba floodplain and its implication for irrigation purposes and consumption by man and animals.

2. THE GEOGRAPHY AND GEOLOGY OF THE STUDY AREA:

The study area is situated within latitudes $9^{\circ}10'2''\text{N}$ and $9^{\circ}7'2''\text{N}$, longitude $4^{\circ}49'2''\text{E}$ and $4^{\circ}51'9''\text{E}$ (Figs. 1 and 2) at Central Nigeria. Crop farming and cattle rearing are the main agricultural practice in the area. The area is mainly drained by River Niger at Jebba and there are ponds scattered all over the floodplain which are being used for irrigation activities. The study area is marked by two distinct seasons, the rainy and dry seasons. The rainy season runs from April to November, while the dry season is from November to April. The annual range of rainfall in the wet season is about 1500mm.

The average annual temperature ranges between 35°C during the day and 25°C at night. The area lies within the Guinea Savannah vegetation belt of Nigeria characterized by scanty trees, shrubs and grasses because of the moderate annual rainfall.

Field mapping shows that the study area is situated across the basement complex of Nigeria on one part and the sedimentary basin (Bida Basin). The basement rocks comprise of migmatite gneiss, quartzite complex, granitoids and minor acid dykes while the sedimentary terrain consists essentially of sandstones, conglomerates and claystones of Campanian to Maastrichtian age.

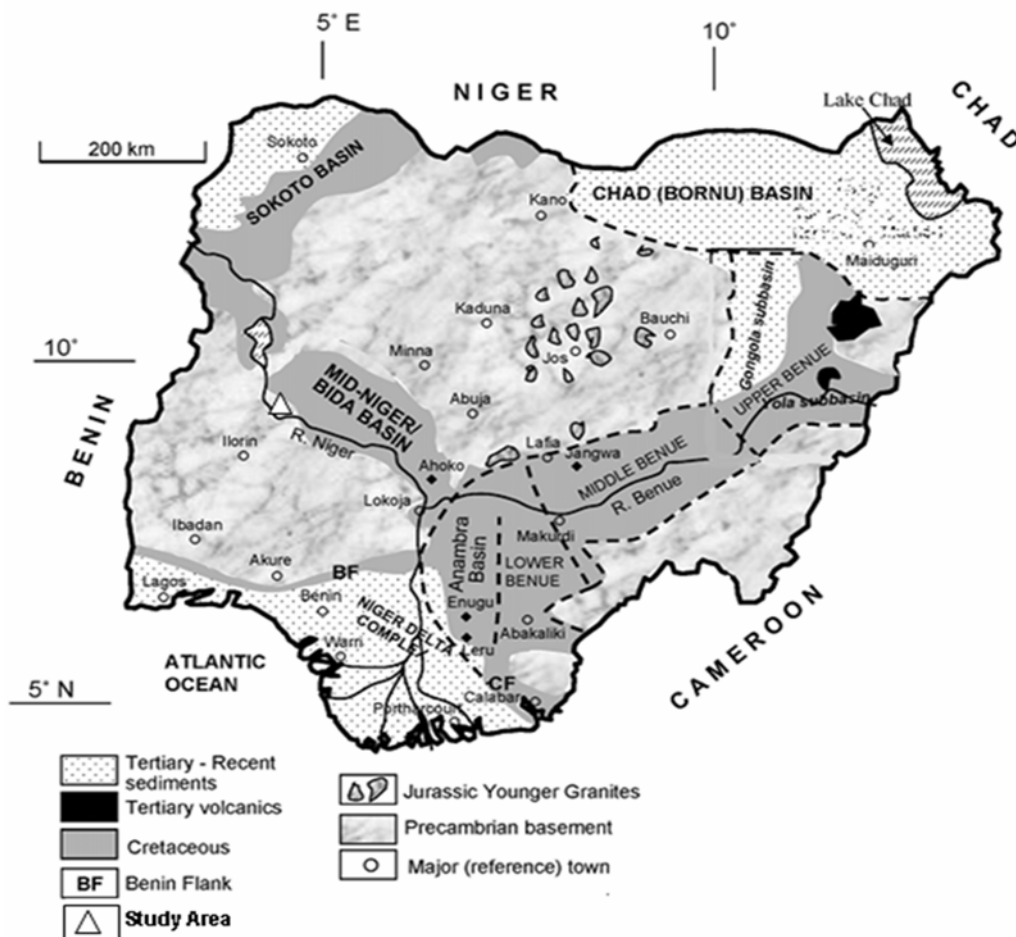


Figure 1: Geological Map of Nigeria (Obaje, 2004)

3. METHODOLOGY

Thirty five water samples were collected from surface water (ponds), well water and stream (27 from ponds, 6 from wells and 3 from stream- (Fig. 2). Sampling was carried out in the dry season. The water samples were analyzed for the various cations in ACME laboratory, Canada using

ICP/MS method while the anions were analyzed at Nigeria Geological Survey Agency, Kaduna, Nigeria.

The nitrate and sulphate were determined using DR 2010 Spectrometer, HACH Nitra over 5 reagent and sulphate reagent were used respectively. Chloride and the alkalinity were determined by titration. The TDS was calculated using TDS meter.

The Sodium Adsorption Ratio (SAR) was calculated using the equation of Richard (1954):

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}} \quad (1)$$

(All the ions are expressed in meq/l)

The Residual Sodium Carbonate (RSBC) was calculated according to Gupta and Gupta (1987);

$$RSBC = HCO_3^- - Ca^{2+} \quad (2)$$

(All the ions are expressed in meq/l)

Residual Sodium Carbonate (RSC) was calculated according to the following formula:

$$RSC = (CO_3 + HCO_3) - (Ca^{2+} + Mg^{2+}) \quad (3)$$

(All the ions are expressed in meq/l)

The Permeability Index (PI) was calculated according to Doneen (1964):

$$PI = 100 \times \frac{([Na] + [HCO_3]/1/2) / [Na] + [Ca] + [Mg]}{[Na] + [Ca] + [Mg]} \quad (4)$$

(All the ions are expressed in meq/l)

The Magnesium Adsorption Ratio was calculated using the following equation (Raghunath 1987):

$$MAR = \frac{Mg^{2+} * 100}{(Ca^{2+} + Mg^{2+})} \quad (5)$$

(All the ions are expressed in meq/l)

The Kelly Ratio (KR) was given by Kelly (1963):

$$KR = \frac{Na^+}{(Ca^{2+} + Mg^{2+})} \quad (6)$$

(All the ions are expressed in meq/l)

The Potential Salinity (PS) was calculated according to Doneen (1964) by the formula:

$$PS = Cl + 0.5 * SO_4 \quad (7)$$

(All the ions are expressed in meq/l)

The Soluble Sodium Percentage (SSP) was carried out by the following equation:

$$SSP = \frac{(Na^+ + K^+)}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} * 100 \quad (8)$$

(All the ions are expressed in meq/l)

The electrical conductivity was calculated from the following equation:

$$TDS = (0.64 * EC * 106) \text{ (Micro-mhos/cm)}. \quad (9)$$

(TDS is in ppm)

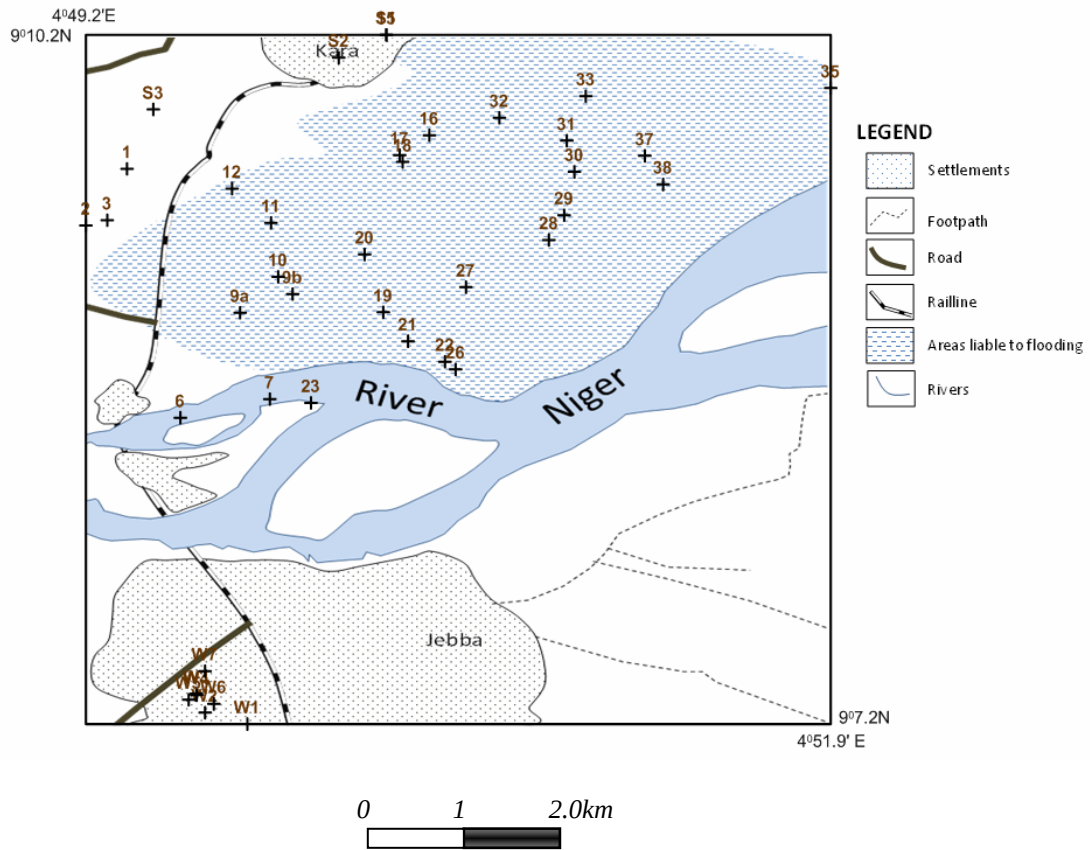


Figure 2: Location Map of the study area showing the sampling points.

4. RESULTS AND DISCUSSION

4.1 Water Type

The physicochemical parameters of the surface, well and stream water of Jebba were statistically analyzed and the results are presented in form of minimum, maximum, median, mean, standard deviation and variance (Table 1). In the pond water, the order of abundance of cation concentrations is $\text{Na} > \text{Ca} > \text{K} > \text{Mg}$ while the anion concentrations are $\text{Cl} > \text{HCO}_3 > \text{SO}_4 > \text{CO}_3 > \text{NO}_3$. Similarly, in the well water the order of abundance of cation concentration is $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$ and the anion concentration is $\text{Cl} > \text{SO}_4 > \text{HCO}_3 > \text{CO}_3 > \text{NO}_3$. Moreover, in the stream the order of increment of the cation concentrations is $\text{Ca} > \text{Na} > \text{K} > \text{Mg}$ and $\text{Cl} > \text{HCO}_3 > \text{SO}_4 > \text{NO}_3 > \text{CO}_3$ for the anions. Generally (on the average), the main type of water that exists in the area is Ca-Mg-Cl water type, Fig. 3 (Tweed et al, 2005).

4.2 Assessment of Water Contamination for Domestic Consumption

The degree of contamination of the water samples were determined using Revelle and geoaccumulation index. The calculation of the Revelle Index is based on the ionic ratio (Revelle, 1946):

$$\text{Cl} / (\text{CO}_3 + \text{HCO}_3) \text{ (in meq/l)} \quad (10)$$

Revelle index < 1 indicates good water quality. The average values of Revelle Indices in the pond water, well water and stream water are 4.12 (range= 0.86-9.45, Standard deviation=2.46), 20.06

(range=3.22-44.92; standard deviation=17.4) and 1.77 (range=1.43-2.15; standard deviation=0.36) respectively (Table 2). All the values calculated from the water samples are greater than 1. Hence, it is an indication that the water from the floodplain is not good for domestic consumptions.

Table 1: Statistical results for pond, well and stream water in the study area.

Pond Water						
	AVERAGE	MIN	MAX	SDV	VAR	MEDIAN
Cl, Meq/l	0.61	0.08	2.48	0.54	0.29	0.39
HCO ₃ Meq/l	0.14	0.07	0.36	0.06	0.00	0.10
CO ₃ , Meq/l	0.00	0.00	0.00	0.00	0.00	0.00
SO ₄ ,Meq/l	0.02	0.00	0.13	0.02	0.00	0.02
Ca, Meq/L	1.35	0.00	4.80	1.12	1.26	1.10
K, Meq/L	0.28	0.00	0.73	0.22	0.05	0.24
Mg, Meq/L	0.53	0.00	1.85	0.41	0.17	0.43
Na, Meq/L	1.24	0.00	6.28	1.28	1.63	0.98
Well Water						
	AVERAGE	MIN	MAX	SDV	VAR	MEDIAN
Cl, Meq/l	3.08	0.42	5.92	2.40	5.76	2.17
HCO ₃ Meq/l	0.12	0.10	0.16	0.02	0.00	0.11
CO ₃ , Meq/l	0.04	0.00	0.13	0.05	0.00	0.03
SO ₄ ,Meq/l	1.05	0.10	2.13	0.77	0.60	0.85
Ca, Meq/L	4.61	0.00	11.66	4.43	19.60	3.82
K, Meq/L	0.26	0.00	0.90	0.31	0.10	0.12
Mg, Meq/L	2.90	0.00	6.41	2.83	8.02	1.62
Na, Meq/L	3.20	0.00	9.79	3.31	10.97	2.51
Stream Water						
	AVERAGE	MIN	MAX	SDV	VAR	MEDIAN
Ca, Meq/L	0.9	0.7	1.2	0.3	0.1	0.9
K, Meq/L	0.1	0.1	0.1	0.0	0.0	0.1
Mg, Meq/L	0.2	0.2	0.3	0.0	0.0	0.2
Na, Meq/L	0.3	0.2	0.5	0.2	0.0	0.3
Cl, Meq/l	0.2	0.1	0.3	0.1	0.0	0.2
HCO ₃ Meq/l	0.1	0.1	0.1	0.0	0.0	0.1
CO ₃ , Meq/l	0.0	0.0	0.0	0.0	0.0	0.0
SO ₄ ,Meq/l	0.1	0.0	0.3	0.2	0.0	0.0

4.3 Water Quality Evaluation for Irrigation

The water quality for irrigation is considered using the following indexes.

Sodium Adsorption Ratio (SAR): The suitability of water for irrigation purposes can be determined by SAR values because it measures alkali/sodium hazard to crop. If irrigation water is high in Na⁺ and low in Ca²⁺ the ion-exchange complex may be saturated with Na⁺. This might lead to the destruction of the soil structure due to the dispersion of the clay particles (Todd, 1980; Joshi et al, 2009) and consequently could reduce the plant growth. In addition, studies have shown that excess salinity reduces the osmotic activity of plants (Subramani et. al, 2005; Ishaku et al, 2011). In the study area, the value of SAR in the pond varies from 0.34-1.37 with an average of 1.37(sdv=1); in the wells it varies from 0.83-4.55 with an average of 1.82 (sdv=1.37); and in the stream, it varies from 0.29 to 0.60 with an average of 0.43 (sdv=0.16) table 1. Since the values are generally less

than 5, it is regarded as excellent for irrigation practices. The result obtained is similar to that of Obiefuna & Sheriff (2011) and Tathy et al., (2011) in Pointe-Noire, South- West Congo-Brazzaville which made it fall into category CI-S1, C2-S1 and C3-S1 indicating low alkali hazards and excellent irrigation water (Figs. 8 and 9). The water can be used for irrigation on almost all soil types with no danger of the development of harmful levels of Sodium hazard.

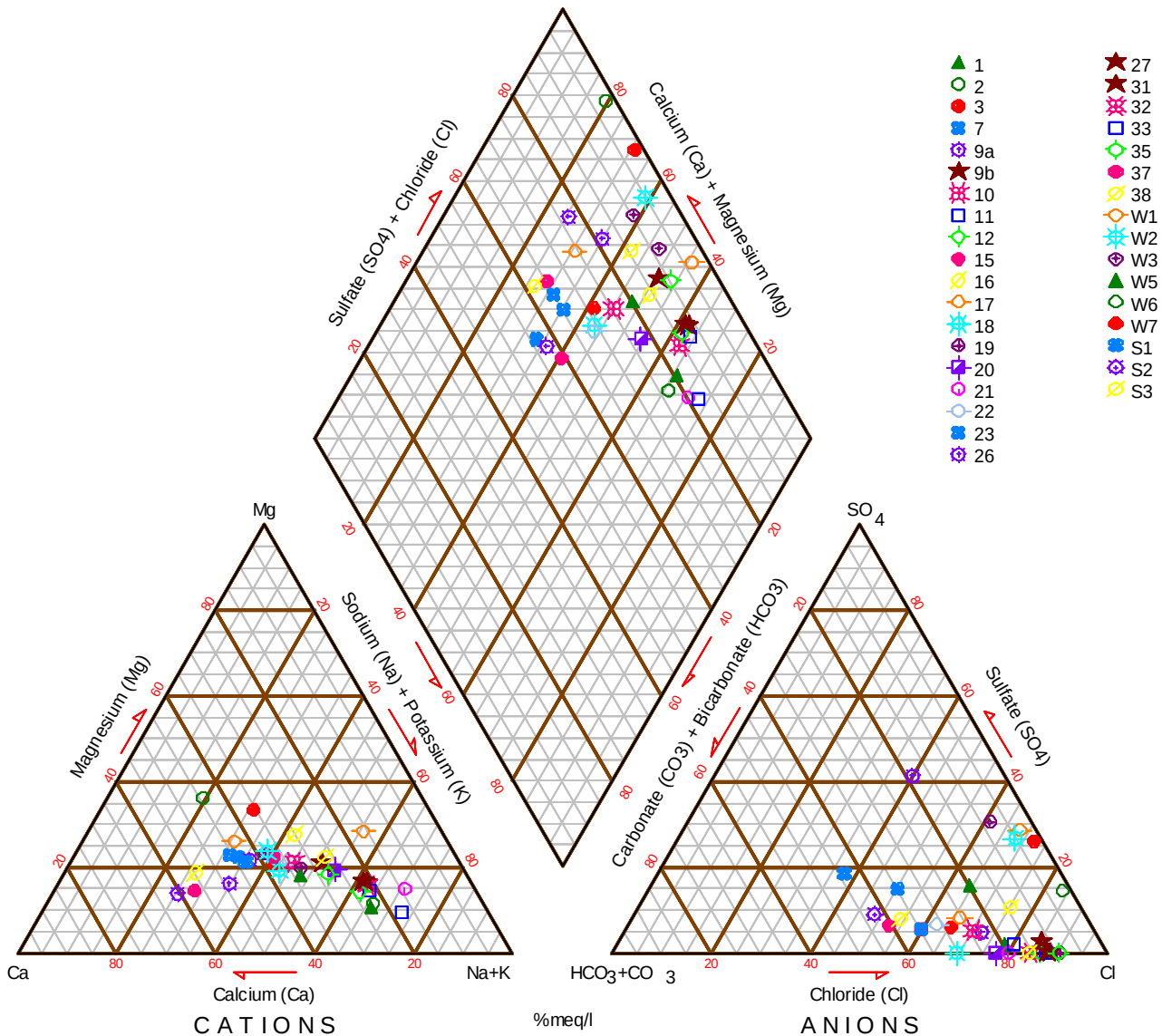


Figure 3: Piper diagram of water chemistry in the study area (Tweed et al., 2005).

Residual Sodium Carbonate (RSC): This parameter is used for the assessment of the effect of carbonate and bicarbonate on the quality of water for agricultural purposes (Aghazadeh et al, 2010; Ishaku et al, 2011). Water with high RSC has high pH and therefore, land irrigated with such water becomes infertile due to the deposition of excess bicarbonate (Eaton, 1950; Obiefuna et al, 2011). A negative RSC indicates that sodium buildup is unlikely since sufficient Ca^{2+} and Mg^{2+} are in excess of what can be precipitated as carbonate whereas positive RSC indicates that sodium buildup in the soil is possible. In the study area, the RSC is negative showing that Na^+ buildup is unlikely with practically no Na^+ hazard and therefore classified as fit for irrigation. The result is similar to the negative value obtained by Naseem et al (2010) and Tathy et al (2011). Fig. 5 shows the spatial distribution of RSC in the study area. Persistent use of water having $\text{RSC} > 2.5 \text{ meq/l}$ results to salt build up which hardened soils (Nishanthiny et al, 2010; Naseem et al, 2010).

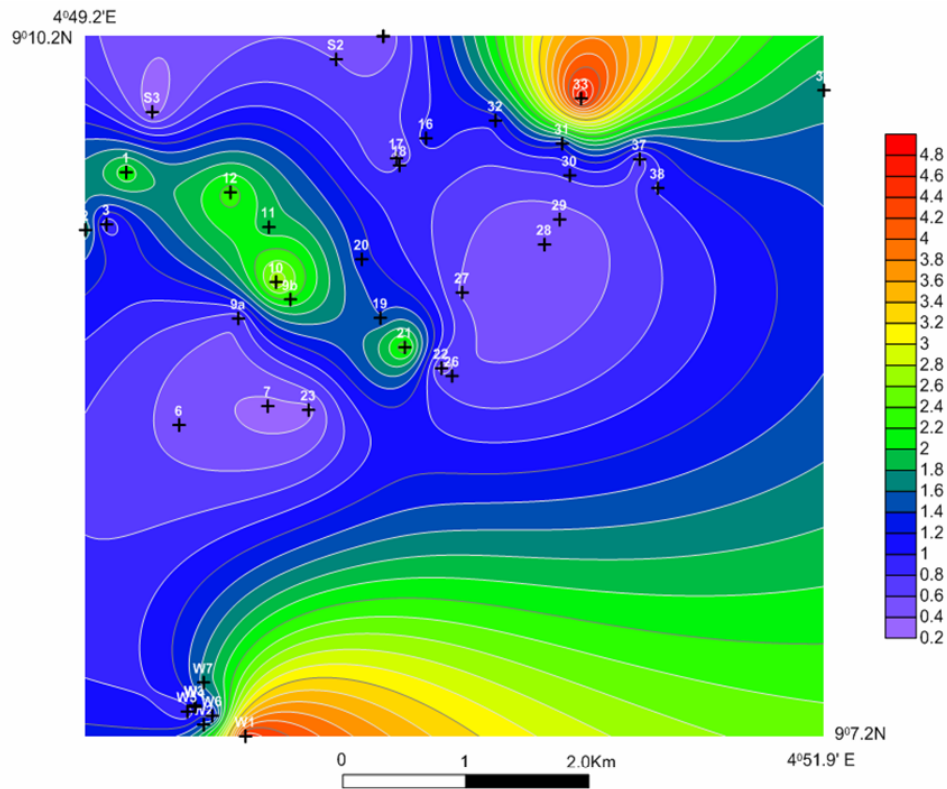


Figure 4: Spatial Distribution of SAR in the Study Area.

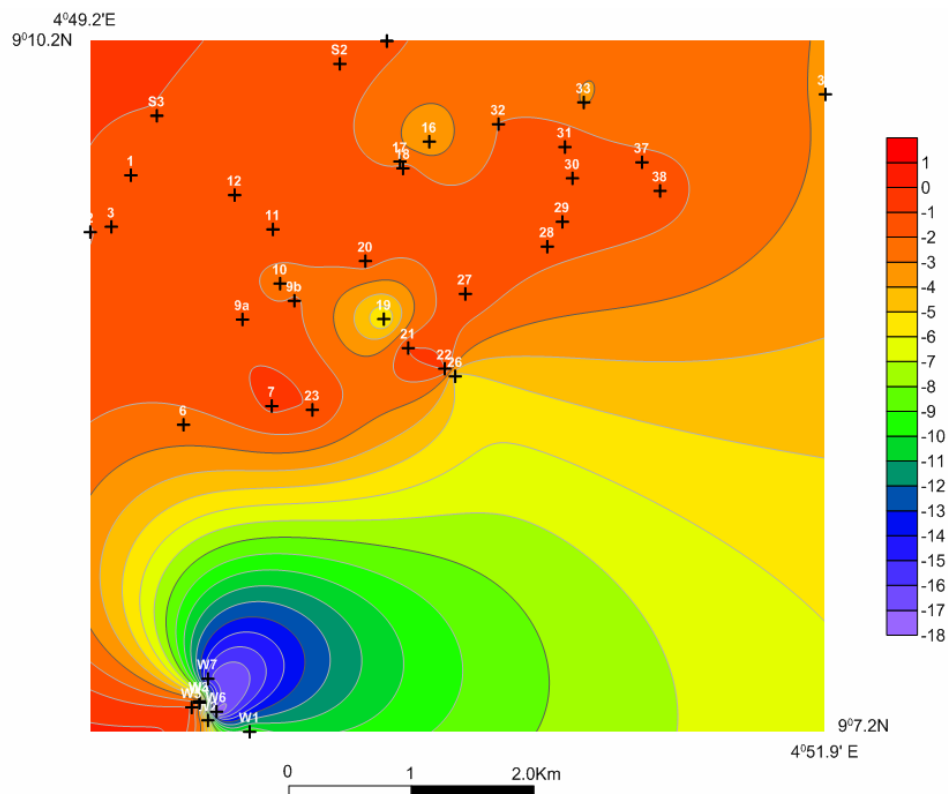


Figure 5: Spatial Distribution of Residual Sodium Carbonate in the Study Area.

Chloro-alkaline Indices (CAI): It is very important to know the changes in chemical composition of water as it travels from one formation to the other. Positive CAI values suggest replacement of Na^+ and K^+ in water by Mg^{2+} and Ca^{2+} from country rock through Base Exchange reaction and it is negative when there is an exchange of Mg and Ca ions of the water with Na and K of the rock

(Ishaku et al, 2011; Nagaraju et al, 2006). The CAI indices 1 and 2 calculated show that 7.4% of the surface water sample is positive and 92.6% negative. The stream gives 100% negative values and the wells give 50% positive values and 50% negative values. The implication of negative chloro-alkaline indices on the water is that there is an exchange of Mg and Ca ions in the water with Na and K ions of the surrounding rocks (lithology) and this may have adverse effect on the water because the concentration of Na and K ions in the water would automatically increase which might influence the hardening of the soil. This poses difficulty in absorption (uptake) of dissolved nutrients from the soil by the plants/crops. The statistical summary is presented in Table 2.

Potential Salinity (PS): According to Doneen (1964), PS value less than 3 meq/l is suitable for irrigation purposes. From the study area, the pond and the stream water are generally less than 2 meq/l, which show that they are very good in irrigation practices unlike most of the wells having an average of 4.03 meq/l (range=0.75-7.19; sdv=2.75 - Table 2). Nevertheless, they are also good for agricultural purposes.

Soluble Sodium Percentage (SSP) and Permeability Index (PI): The percentage of sodium in soil water for irrigation is an important factor for the study of sodium hazard which can also influence the permeability of the soil. It is also useful in the determination of the quality of water for agricultural purposes. Consequently, high percentage of sodium ion in water may stunt plant growth and reduces soil permeability (Joshi et al, 2009; Obiefuna et al, 2011). From the study area, the surface water falls into category III of the Wilcox limit (Wilcox, 1950), with a range of 19-67%, average=43% and the sdv gives 14%. The well water and the stream water fall into category II of the same limit and are considered to be good for irrigation practices while the pond are regarded as fair for irrigation. Doneen (1964) assessed the suitability of water for irrigation based on the permeability index. Class I and Class II have maximum permeability >75% which are concluded good for irrigation while third category has 25% maximum permeability as unsuitable for irrigation purpose (Nagaraju et al., 2006). In the study area, PI varies in the surface water from 19-68% with an average of 42% (sdv=15); in the wells, it ranges from 16-52% with an average of 34% (sdv=6); and in the stream, it ranges from 23-34% with an average of 30% (Table 2). Water can be classified into class I, II and III according to Nagaraju et al (2006) based on PI values. On the average the PI values for the surface (pond), well and stream water fall within class II which could be regarded as suitable for irrigation purposes. However, wells 6 and 7 fall within class III which is not suitable for irrigation.

Kelly Index (KI): Kelly index is one the parameters used for the classification of water for irrigation purposes. Sodium measured against calcium and magnesium was considered by Kelly (1957, 1963) for calculating Kelly index. The values for the surface water range from 0.21-1.83 with an average of 0.70 (sdv=0.47); in wells, it ranges from 0.18-1.06 with an average of 0.51 (sdv=0.30); and in the stream, it ranges from 0.19-0.35 with an average of 0.28 (sdv=0.08 – Table 2). Hence, on the average, the values are below the permissible limit of 1.0 and are therefore considered suitable for irrigation purposes.

Magnesium Adsorption Ratio (MAR): This is considered to be one of the most important qualitative criterion in determining the quality of water for irrigation (Gupta et al, 2012). If Magnesium is more than necessary in the water, there will be adverse effect on crops yields as the soil becomes more saline (Joshi et al, 2009). Magnesium of ratio <50% is suitable for irrigation while Magnesium of Ratio >50% is not suitable for irrigation purposes (Paliwal, 1972). Results from the study areas show that all the water samples are below the permissible limit of 50% except W1 that gives a value of 54.62%. Hence, on the average, the water is very suitable for irrigation purposes. The value obtained is within the range Naseem et al 2010 obtained in their research paper titled: Groundwater geochemistry of Winder Agricultural farm, Balochistan, Pakistan and assessment for irrigation water quality.

Total Dissolved Solid (TDS): This reflects the amount of mineral contents that dissolve in water. TDS affects suitability of water for domestic, industrial or agricultural activities. High concentration of dissolved solid may cause adverse taste effects. Also, TDS may deteriorate domestic plumbing and appliances. In the study area the concentration value of surface water ranges from 28-400ppm

with an average of 135ppm (sdv=90ppm); in the wells, it ranges from 88-676ppm with an average of 400.29ppm (sdv=261.33); and in the streams, it ranges from 31-67ppm (sdv=19.09). The TDS values of the water in study area fall within the WHO (2008) standard of 1000ppm. The water is therefore good for agricultural purposes.

Boron Concentration: The occurrence of Boron in toxic concentrations in certain irrigation waters makes it necessary to consider this element in assessing the water quality. Boron is a constituent of practically all natural surface and groundwater but, the concentrations vary from several traces to parts per million. It is essential for plant growth but may be exceedingly toxic at certain concentrations slightly above optimum. Many plants made normal growth in sand cultures with a trace amount of Boron (0.03-0.04ppm) and that injury often occurred in cultures containing 1ppm (Eaton, 1950). In the study area, the concentration of Boron is generally less than 1ppm which makes the water quality excellent and suitable for irrigation purposes.

Wilcox diagram: Wilcox (1948) used % sodium and specific conductance in evaluating the suitability of water for irrigation purposes. Sodium –percentage determines the ratio of sodium to the total cations. All concentration values are expressed in meq/L. Water samples from the study area show that the water are good for irrigation except the sample W₁ which is one of the well samples. It falls within permissible to doubtful (Fig. 8). This may be due to the fact that the water sample is gotten from well close to the dumpsite and as a result of increased anthropogenic activities around the well. The leachate from the dumpsite and the domestic sewages are percolated into the shallow well.

4.4 Source of Dissolved Ions

The source of the dissolved ions in the water could be determined by adopting the Gibb's diagram (Fig. 8). It is a plot of the Ratio of $\text{Na}^+ / (\text{Na}^+ + \text{Ca}^{2+})$ against TDS for the cations. For the anions, it is the plot of $\text{Cl}^- / (\text{Cl}^- + \text{HCO}_3^-)$ against TDS which is used for the determination and suitability of water for drinking and irrigation purposes and to determine the source of the pollutants. As shown in Fig. 6, the main source of the cations is predominately weathering of the country rocks and there is a little effect of precipitation. The anions fall into evaporation, crystallization and rock dominances.

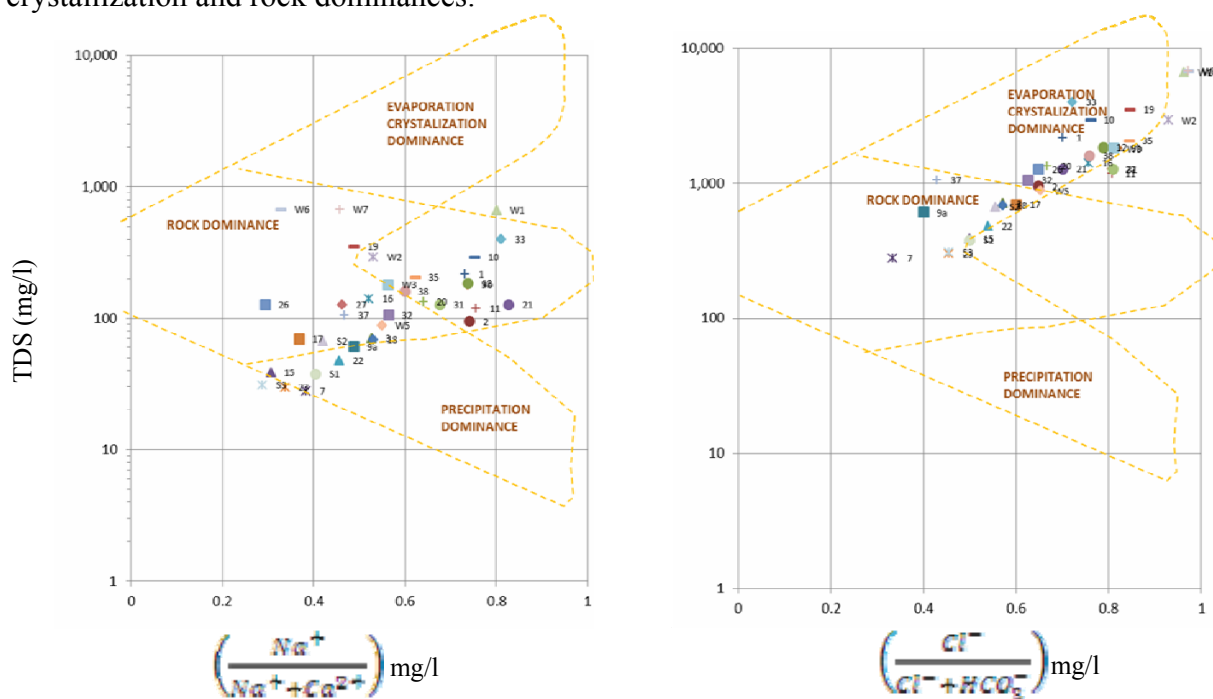


Figure 6: Mechanisms governing groundwater and surface water chemistry (Gibbs, 1970)

Table 2: Summary of the Interpreted Indices for Rating Irrigation Water Quality

Pond water						
	AVERAGE	MIN	MAX	SDV	VAR	MEDIAN
CIA-1	-1.40	-3.74	1.00	1.03	1.05	-1.39
CIA-2	-2.41	-6.67	1.87	1.86	3.47	-2.19
PI	41.61	18.71	68.36	14.60	213.24	37.43
PS, meq/l	0.71	0.23	2.48	0.52	0.27	0.45
TDS, ppm	135.43	28.00	400.00	90.10	8117.50	127.00
B, ppm	0.01	0.00	0.02	0.00	0.00	0.01
SAR	1.37	0.34	4.79	1.00	1.00	1.08
SSP	42.94	19.49	66.77	14.11	199.13	41.72
ESP	33.88	16.45	60.75	13.95	194.56	30.83
MAR	28.92	13.35	41.26	6.15	37.83	28.96
KR	0.70	0.21	1.83	0.47	0.22	0.51
EC, CALCULATED, $\mu\text{mhos/cm}$	2.00	0.41	5.90	1.33	1.76	1.87
RSC, meq/l	-1.95	-6.15	0.07	1.38	1.90	-1.51
RSBC, meq/l	-1.36	-4.71	0.07	1.06	1.11	-0.98
Revelle Index, R	4.12	0.86	9.45	2.46	6.06	3.29
Well water						
	AVERAGE	MIN	MAX	SDV	VAR	MEDIAN
CIA-1	-0.04	-0.63	0.62	0.49	0.24	-0.03
CIA-2	0.26	-0.71	2.31	1.12	1.26	-0.06
PI	33.81	15.90	51.95	12.82	164.39	35.32
PS, meq/l	4.03	0.75	7.19	2.75	7.56	3.09
TDS, ppm	400.29	88.00	676.00	261.33	68292.57	293.00
B, ppm	0.02	0.00	0.04	0.01	0.00	0.02
SAR	1.82	0.83	4.55	1.37	1.87	1.38
SSP	34.64	15.90	51.44	12.53	157.06	36.56
ESP	30.32	15.36	51.25	12.10	146.47	30.83
MAR	35.67	26.63	54.62	10.30	106.16	32.64
KR	0.51	0.18	1.06	0.30	0.09	0.49
EC, CALCULATED, $\mu\text{mhos/cm}$	5.90	1.30	9.96	3.85	14.84	4.32
RSC, meq/l	-8.60	-17.94	-1.16	6.91	47.71	-7.15
RSBC, meq/l	-5.26	-11.56	-0.82	4.32	18.68	-3.91
Revelle Index, R	20.06	3.22	44.92	17.40	302.62	13.14
Stream water						
	Average	MIN	MAX	SDV	VAR	MEDIAN
CIA-1	-0.45	-0.65	-0.25	0.20	0.04	-0.44
CIA-2	-0.29	-0.45	-0.20	0.14	0.02	-0.22
PI	30	23.22	34.25	5.85	34.20	32.10
PS, meq/l	0.49	0.29	0.82	0.29	0.08	0.37
TDS, ppm	45.33	31.00	67.00	19.09	364.33	38.00
B, ppm	0.009	0.005	0.013	0.004	2×10^{-5}	0.008
SAR	0.43	0.29	0.60	0.16	0.03	0.39
SSP	25.94	20.86	29.08	4.44	19.68	27.87
ESP	20.29	15.05	24.89	4.95	24.53	20.94
MAR	20.59	18.10	24.97	3.81	14.51	18.69
KR	0.28	0.19	0.35	0.08	0.01	0.30
EC, CALCULATED, $\mu\text{mhos/cm}$	0.67	0.46	0.99	0.28	0.08	0.56
RSC, meq/l	-8.11	-1.38	-0.75	0.31	0.10	-1.04
RSBC, meq/l	-0.82	-1.11	-0.53	0.29	0.08	-0.83
Revelle Index, R	1.77	1.43	2.15	0.36	0.13	1.72

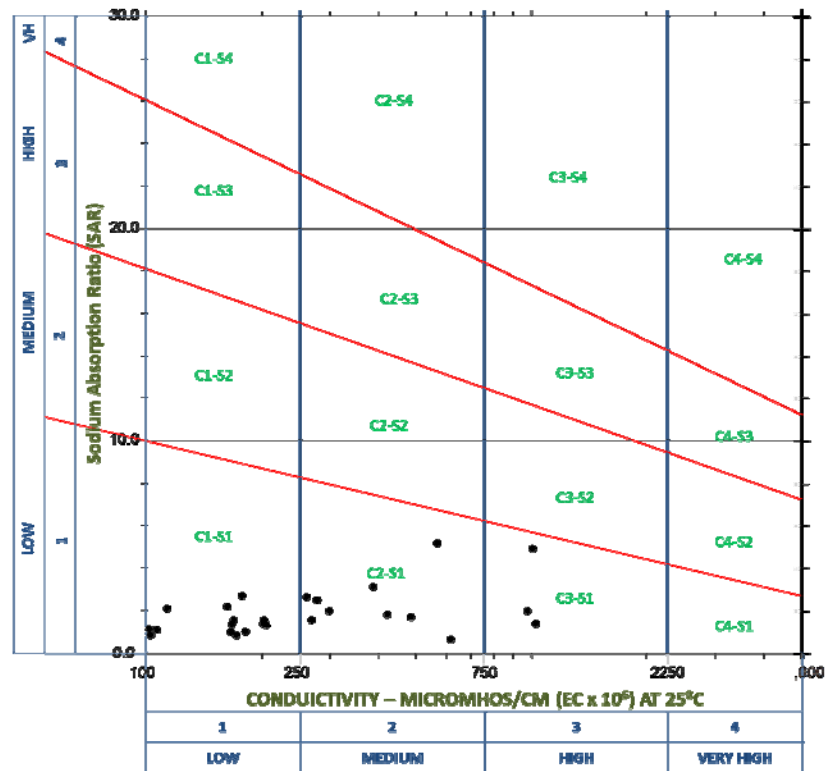


Figure 7: Rating of water samples in relation to salinity and sodium hazard

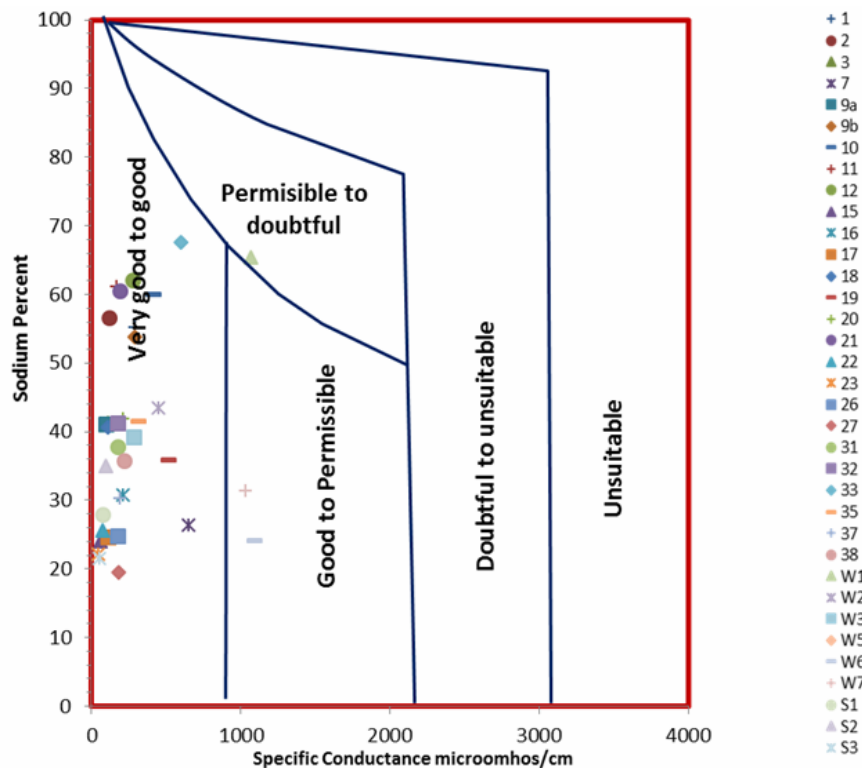


Figure 8: Rating of water samples on the basis of electrical conductivity and percent sodium (Wilcox, 1955)

5. CONCLUSION

The hydrochemistry of pond, well and stream displays $\text{Na} > \text{Ca} > \text{K} > \text{Mg}$, $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$, $\text{Ca} > \text{Na} > \text{K} > \text{Mg}$ and $\text{Cl} > \text{HCO}_3 > \text{SO}_4 > \text{CO}_3 > \text{HNO}_3$, $\text{Cl} > \text{SO}_4 > \text{HCO}_3 > \text{CO}_3 > \text{NO}_3$, $\text{Cl} > \text{HCO}_3 > \text{SO}_4 > \text{NO}_3$

>CO₃ trend, respectively. The interpretation of hydrochemical analysis reveals that the surface and steam water range from soft to moderately soft. However, the wells are extremely hard. The hardness of the wells may be as a result of the lithology of the underlying area and the excess of Ca²⁺ makes the water hard. In the Gibbs' diagram (Gibbs, 1970), the cations fall within the zone of rock weathering and precipitation while the anions fall within the zone of rock weathering, evaporation and crystallization. The main type of water that exists in the area is Ca-Mg-Cl water type. Low value of SAR suggests non-hazardous effect of the water and RSC value indicates no sodium ions build-up. The value calculated using Revelle index rings a bell for domestic usages. Since the value average values obtained is greater than one, it is not suitable for domestic consumption.

Hence, based on the average values, the water samples are only suitable for irrigation rather than domestic purposes.

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