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ASSESSMENT OF SHALLOW WELL QUALITY FOR IRRIGATION: A CASE STUDY FROM LAGOS, NIGERIA

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ABSTRACT

The study assessed shallow well quality used for vegetable irrigation in Amuwo-Odofin and Ojo LGAs in Lagos state.15 samples were randomly collected from shallow wells. PH, electrical conductivity and total dissolved solids were measured in situ while calcium, magnesium, total hardness, sodium, potassium, chloride, bicarbonate, carbonates and sulfate was determined using standard methods. Result shows that the mean values of the examined parameters HCO_3,Ca/TH, pH, Mg/CO_3/Cl, EC,TDS/Na/K and SO_4 exceeded their level of detection in about 66.7%,60%,53.3%,46.7%,40%,33.3%, and 20% respectively. The mean value of pH7.45 indicates slightly alkaline condition while the measured EC fall under low enrichment of salts. TDS value indicates freshwater. The suitability of shallow well for irrigation purpose was assessed using KR, MR, %Na, RSC and SAR indices.KR ranged from 0.03-0.12meq/L and exceeded the computed KR in about 20%.KR was found to be suitable for irrigation purpose. MR ranged from 29.19 to 43.21meq/L and exceeded the computed MR in about 66.7% .The computed MR value are suitable for irrigation.% Na varied from 3.38 to 11.96meq/L. Approximately 33.3% of the mean %Na exceeded the computed %Na in the study area. RSC ranged between -0.66 and -4.38meq/L and all the samples fall in excellent category for irrigation purpose. SAR ranged between 0.05 and 0.5meq/L and exceeded the computed SAR in about 20%. Approximately 66.7% of the samples fall in low salinity while 26.7% and 6.7% falls under medium and high salinity zones respectively. The paper recommends adequate protection and thorough treatment of water for irrigation purpose.

Keywords: Assessment, Irrigation water, Water quality indices, Shallow wells, Lagos-Nigeria.

INTRODUCTION

The increasing rise in poverty, food insecurity and malnutrition shifting from rural to urban areas calls for renewed effort for alternative strategies of improved food production. About 200 million urban farmers are engaged in market gardening representing 15 to 20 percent of the world's food production (Armar-Klemesu, 2000).Urban agriculture contributes to food security and food supply safety in many ways. For instance, it serves as source of income and provides fresh vegetables, fruits and meat products in urban and peri-urban settlements. The major vegetables cultivated include; lettuce, cabbage, green pepper and spring onions among others (Keraita *et al.* 2002).

Globally, irrigated agriculture is the largest abstractor and predominant consumer of groundwater resource. The current population rise and increased demand for water for various uses have caused serious aquifer depletion and environmental degradation. The last 30 years have witnessed an increased withdrawal of groundwater use for irrigation especially in areas subject to dry seasons or droughts (Llamas, 2005). According to GWP (2012), irrigated agriculture is the largest abstractor and consumer of groundwater representing about 70% of water usage worldwide (Table 1).

Table 1. Global survey of groundwater irrigation

Region	*Groundwater Irrigation*		*Groundwater volume used*	
	(Mha)	*Proportion total*	*Km^3/a*	*Proportion total*
Global Total	112.9	38(%)	545	43(%)
South Asia	48.3	57(%)	262	57(%)
East Asia	19.3	29(%)	57	34(%)
South-East-Asia	1	5(%)	3	6(%)
Middle East and North Africa	12.9	43(%)	87	44(%)
Latin America	2.5	18(%)	8	19(%)
Sub-Saharan Africa	0.4	6(%)	2	7(%)

Source: Siebert *et al.* (2010)

Groundwater play a major role in human life and societal development (Mukherjee, 2005).The significance of groundwater resources for human consumption, agricultural and industrial uses as well as its quality has been widely researched (Thathy *et al.,* 2011). Increased knowledge of processes that controls chemical compositions of groundwater can improve the understanding of their uses. Groundwater abstraction for irrigation is very crucial for food security. Agriculture contributes immensely to food supply, employment and source of raw material for industries in most cities of the world. However, agricultural activities exert major influence on groundwater recharge quality through leaching of soil nutrients, contamination from pesticides and mobilization of salinity (Foster and Candela, 2008; GWP, 2012).

Sakar and Hassan (2006) assessed the water quality of hydrological basin in Bangladesh for irrigation uses using water quality index .They argued that bicarbonate and chloride had higher value that results to permeability and toxicity problems .They concluded that the water is suitable for irrigation purpose. Tathy *et al.* (2011) assessed the factors controlling the hydrological and suitability of irrigation water in SW Congo Brazzaville using index. They concluded that the water quality is suitable for irrigation. Several authors have studied the suitability of groundwater for irrigation uses the world over. Hussain *et al.* (2010) reviewed the guidelines for irrigation water quality and water management in Saudi-Arabia. They argued that there is high potential for the use of marginal groundwater quality for irrigation and reuse of wastewater after primary treatment for agricultural expansion in the area. Arabi *et al.* (2010) investigated groundwater quality for domestic and irrigation purposes in Gubrunde and environs in NE Nigeria using water quality indices. They infer that the groundwater quality is fairly suitable for agricultural purpose.

Nata *et al.* (2009) assessed the suitability of groundwater for irrigation in Debre, Ethiopia using water quality index. The study revealed that most of the groundwater samples are suitable for irrigation .However, in some few areas, there is need for slight to moderate degree of restriction for irrigation purpose due to sodicity problem. Hulya and Nakoman

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(2010) evaluated shallow groundwater quality for irrigation purpose in Koprubasi, uranium area, Turkey using water quality index. They infer that the groundwater is suitable for irrigation. However, shallow groundwater located in uranium area is not recommended for irrigation.

Water used for irrigation purpose always contains dissolved substances known as salts. These include relatively small but important amounts of dissolved solids originating from dissolution or weathering of rocks and soil water percolates through them. Poor irrigation water quality results to various soil and cropping problems. Irrigation water quality problems are very complex. They include, salinity, permeability, toxicity, and miscellaneous (Ayers and Westcot, 1985). Each of these problems may affect crop singly or in a combination of two or more. The combination of these problems may be more difficult to solve and may affect crop production more severely than a single problem (Ayers and Westcot, 1985).Thus, the suitability of groundwater for agricultural purpose must take into consideration parameters such as, Sodium Adsorption Ratio (SAR), Electrical conductivity (EC), Total Dissolved Solids (TDS), Percentage of Sodium (%Na), Residual Sodium Carbonate (RSC), Magnesium Ratio (MR) among others.

The paper assessed shallow well quality for irrigation purpose using water quality indices.

Study Area

The study areas are located within Amuwo-Odofin and Ojo Local Government Areas (LGAs).Amuwo-Odofin Local Government Area (LGA) is located approximately on Latitudes $6^0$29'N and $6^0$27'N; Longitudes $3^0$14'W and $3^0$12'W. It is bounded by Ajeromi/Ifelodun LGA in the East, Isolo to the North, the Badagry Creek to the South and Ojo LGA in the West. The area occupies about 134.6 km^2 of land (Fig.1). The population is about 318.166 people (NPC, 2006). Unlike Ojo LGA, it is located approximately on Latitudes $4^0$15'N and $4^0$17'N; Longitudes $2^0$55'W and $2^0$12'W. It is bounded by Surulere LGA in the East, Apapa to the North, Eti-Osa to the South and Badagry LGA in the West. The area occupies about 134.6 km^2 of land with population of about 598, 0 71 people (NPC, 2006) (Figure. 1).

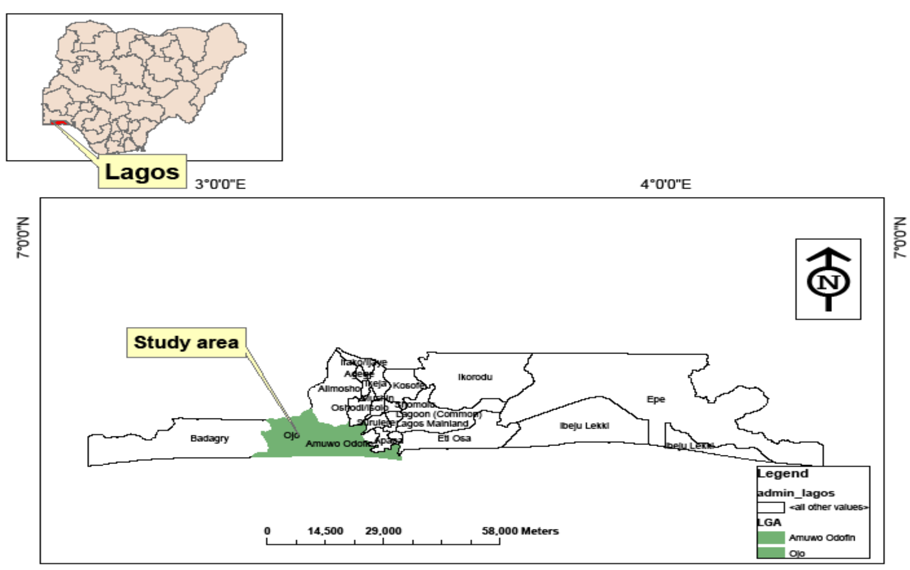

Figure 1. The study area

The two major seasons are recognized in the area are; dry season (between November and March) and wet season (April to October) with a short break in mid- August. Average temperature is about 27^0C with annual average rainfall of about 1,532 mm (Adetoyinbo and Babatunde, 2010). The dominant vegetation type consists of tropical swamp forest (fresh waters and mangrove swamp forests and dry lowland rain forest) (FEPA, 1997).

The drainage system is characterized by Lagoons and waterways, barrier islands and sand beaches. The major River is Yewa River. The geology is underlain by recent sedimentary rock composed mainly of alluvial materials (Longe, 2011). Major human activities in the area include farming, fishing, trading among others. Around Abule-Ado, Finniger, Okokomaiko and also along Lasu-Isheri road around post service and Lagos State University (LASU), major farming activity is urban market gardening (Odumosu, 1999). Major crops planted includes, vegetables and lettuce while others crops include, garbage, onions, spinach etc. Major source of irrigation water is from shallow wells.

MATERIALS AND METHODS

15 shallow wells used for irrigation representing 9 samples from Amuwo-Odofin and 6 samples from Ojo LGAs were randomly selected for irrigation water quality assessment in the study area. Samples were collected in clean 1.5 litre polyethylene plastic bottles after being rinsed using the shallow well water to be sampled. The wells were agitated for about 10 minutes in order to remove stored groundwater in the well before sample collection (Todd and Mays, 2005). Samples were iced and transported to chemistry department, University of Lagos for laboratory analysis. The chemical analysis was carried out within 24 hours to avoid errors that may result from environmental factors (Todd and Mays, 2005).Shallow water well samples were measured for three in situ parameters including pH, Electrical Conductivity and Total Dissolved Solids. Samples were analyzed for eight major ions including Ca, Mg, Na, K, Cl, SO_4, HCO_3 and CO_3 (Table 2) using standard methods (APHA,1998).Co-ordinates of the sampling locations were recorded using Global Positioning System (GPS) and plotted using Arc Map 9.3 software to generate map of the sampling locations (Figure. 2).

Table 2. In situ measurement/ laboratory techniques

Parameters	*Measurement/laboratory techniques*
Electrical Conductivity	EC Dist 3(HI98303, Hanna model
pH	pHmeter(PH-102,RoHS model)
Total Dissolve Solids	TDS/TEMP TM Digital model.
Calcium and Total Hardness	Titrimetry method
Magnesium, Potassium and Sodium	Atomic Absorption Spectrophotometer (AAS) Hanna (HI 98180) model.
Chloride	Titrimetry method (using Potassium Chromate as indicator).
Sulfate	Spectrophotometry (HACH DR/2000 meter)
Carbonate and Bicarbonate	Titrimetry method (using standardized hydrochloric acid solution)

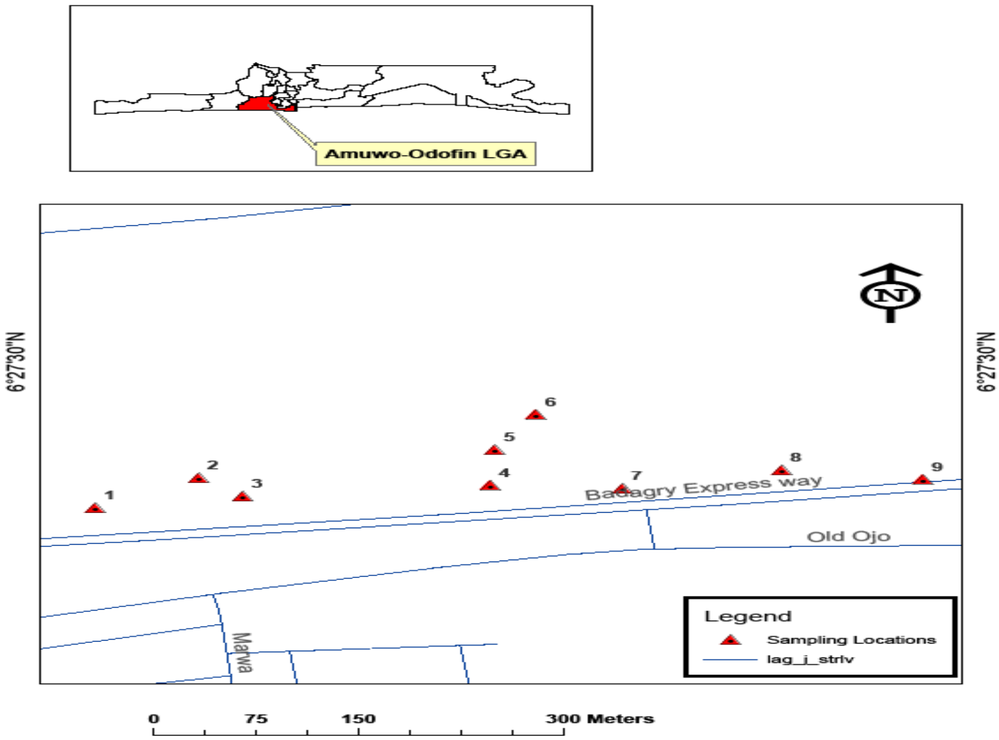

Figure 2a. Sampling Locations (Amuwo-Odofin LGA)

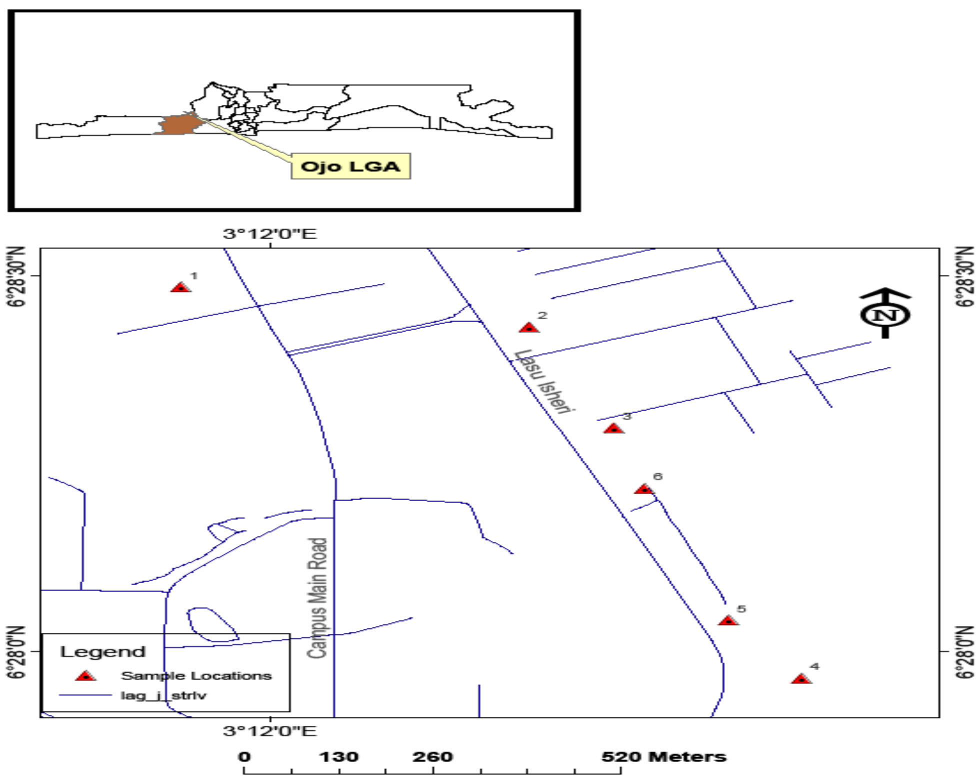

Figure 2b. Sampling Locations (Ojo LGA)

Evaluation of irrigation water quality was determined based on the application of:

a. Kelly Ratio (KR).It is given as: $Na/Ca + Mg$ .... (1)

b. Magnesium Hazard (MR).It is given as: $Mg/Ca + Mg\ x\ 100$ ......(2)

c. Sodium Percentage (%Na). It is given as: $Na + K/Ca + Mg + Na + K\ x\ 100$ ..(3)

d. Residual Sodium Carbonate (RSC). It is given as:

$(CO3 + HCO3) - (Ca + Mg)$....(4)

e. Sodium Adsorption Ration (SAR). It is given as: $\frac{\text{Na}}{\sqrt{(\text{Ca+Mg})}}/2$...... (5)

RESULTS AND DISCUSSION

The level of detected parameters and descriptive statistics of shallow well quality of the study area is presented in Table 3.The result revealed that the mean values of the examined parameters HCO_3, Ca/TH, pH, Mg/CO_3/Cl, EC, TDS/Na/K and SO_4 exceeded their level of detection in about 66.7%, 60%, 53.3%, 46.7%, 40%, 33.3%, and 20% in the study area respectively.

Table 3. Level of detected parameters and descriptive statistics of shallow well quality

	pH	*EC*	*TDS*	*Ca*	*Mg*	*TH*	*Na*	*K*	*HCO_3*	*SO_4*	*CO_3*	*Cl*
G1	7.51	221	146	40	12	58.6	3.01	1.7	4	6	10	32
G2	7.57	202	135	24	8	38.6	2.52	1.28	2	6	12	20
G3	7.34	227	150	38	14	58.6	2.96	1.42	6	7	14	26
G4	7.41	365	244	54	22	82.6	4.52	2.65	4	8	10	40
G5	7.3	198.9	133.1	22	10	38.6	2.16	1.17	4	6	14	28
G6	7.46	391	263	62	18	86.6	6.34	2.51	3	10	8	46
G7	7.75	704	471	52	20	78.6	9.08	4.29	4	20	16	38
G8	7.46	231	155	38	12	56.6	3.16	1.86	2	7	10	36
G9	7.57	774	518	64	16	86.6	12.15	3.29	4	16	10	50
G10	7.7	234	156	44	16	66.6	2.98	1.17	6	6	14	40
G11	7.59	312	208	46	14	66.6	3.72	1.56	4	8	12	28
G12	7.31	193.7	129.7	14	6	26.6	2.28	0.91	2	7	8	20
G13	7.43	213	142	26	12	44.6	2.39	0.92	2	8	10	18
G14	7.21	196.7	131.8	18	8	32.6	1.89	0.65	6	8	14	22
G15	7.17	80	53.3	10	4	20.6	0.56	0.18	4	3	6	8
Mean	7.45	302.89	202.39	36.8	12.8	56.2	3.98	1.7	3.8	8.4	11.2	30.13
Min	7.2	80	53.3	10	4	20.6	0.6	0.2	2	3	6	8
Max	7.8	774	518	64	22	86.6	12.2	4.3	6	20	16	50
C.V(%)	2.26	63.56	63.74	46.74	39.97	39.01	76.33	63.33	37.48	50.67	25.07	38.41

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Min-minimum, Max-maximum, Std.dev-standard deviation, C.V-co-efficient of variation

NB:All units are in mg/L^{-1} except pH and EC.

The result shows that pH varied between 7.2 and 7.8 with mean value of pH7.45 indicating slightly alkaline condition (Todd and Mays, 2005). The determination of pH of water is useful for water treatment to address probable iron pipe corrosion (Hem, 1991).Electrical conductivity ranges between 80 and 774µScm^{-1} with mean value of 302.89µS/cm. Rao *et al.* (2011) classified EC as low enrichment of salts (EC<1,500 µScm^{-1} medium enrichment of salts if EC is between 1,500 and 3,000 µScm^{-1} ; and high enrichment of salts if EC>3,000 µScm^{-1}. Based on the measured EC of the samples all the shallow well water samples fall under low enrichment of salts (Table 4).

Table 4. Computed values of KR, MR, %Na, TH, PI, EC, SAR and TDS of the study area

Sample ID	*KR*	*MR*	*%Na*	*RSC*	*TH*	*EC*	*SAR*	*TDS*
G_1	0.04	33.10	5.52	-2.75	58.6	221	0.15	146
G_2	0.06	35.47	7.12	-1.62	38.6	202	0.16	135
G_3	0.04	37.80	5.14	-2.71	58.6	227	0.15	150
G_4	0.04	40.18	5.54	-4.26	82.6	365	0.18	244
G_5	0.05	42.83	6.06	-1.62	38.6	198.9	0.14	133.1
G_6	0.06	32.38	6.92	-4.38	86.6	391	0.26	263
G_7	0.09	38.81	10.64	-3.90	78.6	704	0.38	471
G_8	0.05	34.24	6.03	-2.68	56.6	231	0.16	155
G_9	0.12	29.19	11.96	-4.27	86.6	774	0.50	518
G_{10}	0.04	37.49	4.34	-3.18	66.6	234	0.14	156
G_{11}	0.05	33.42	5.53	-3.18	66.6	312	0.17	208
G_{12}	0.08	41.41	9.31	-1.03	26.6	193.7	0.18	129.7
G_{13}	0.05	43.21	5.29	-2.08	44.6	213	0.14	142
G_{14}	0.05	42.29	5.97	-1.23	32.6	196.7	0.13	131.8
G_{15}	0.03	39.74	3.38	-0.66	20.6	80	0.05	53.3
Mean	0.06	37.44	6.58	-2.64	56.2	302.89	0.19	202.39

The measured TDS showed a wide variation between 53.3 and 518mg/L^{-1} with mean value of 202.39mg/L^{-1}. The degree of TDS can be classified as fresh, if it is less than 1,000 mg/L^{-1}; brackish, if it is between 1,000 and 10,000 mg/L^{-1}; saline, if it is between 10,000 to 1,000,000 mg/L^{-1}; and brine, if it is more than 1,000,000mg/L^{-1} (Carroll, 1962). Based on this classification, the concentration of TDS value in the study area are less than 1,000 mg/L^{-1}. Thus, all the water samples are fresh (Figure 3).

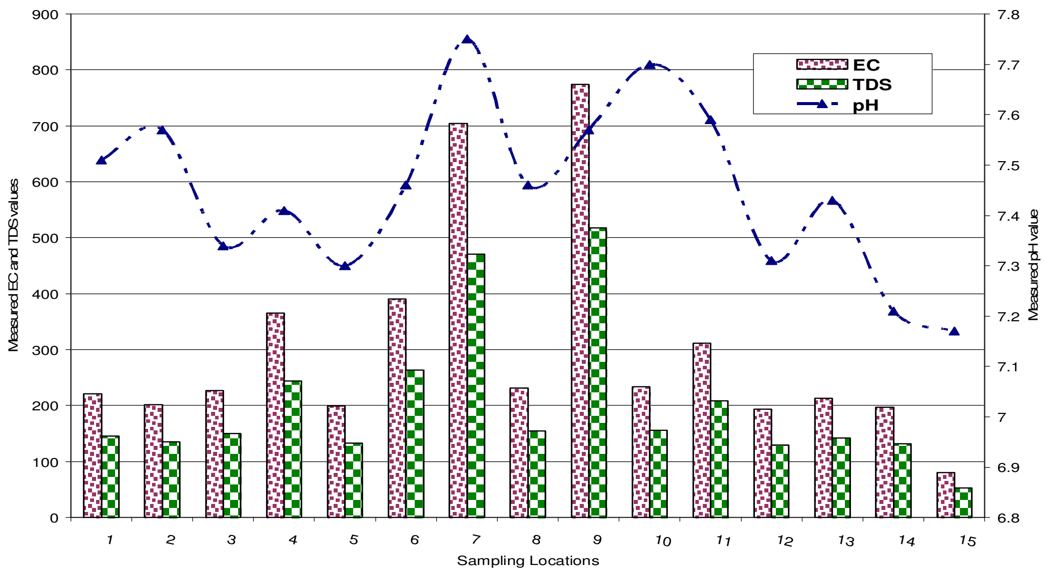

Figure 3. Measured in situ parameters in the study area

Total hardness ranges between 20.6 and 86.6mg/L^{-1} with mean value of 56.2mg/L^{-1} in the study area. TH is an important criterion for determining the suitability of water for varied purposes (Karanth, 1987). Heath (1998) classified TH as soft, if it is between 0 and 60mg/L^{-1}, moderately hard between 61 and 120mg/L^{-1}, hard between 120 and 180mg/L^{-1}, very hard if it is above 180mg/L^{-1}. Thus, approximately 73.3.3% and 26.7% of the sampled wells are soft and moderately hard respectively (Table 4).

The major cations Ca, Mg, Na and K varied between 10 and 64, 4 and 22, 0.6 and 12.2, 0.2 and 4.3mg/L respectively while the major anions HCO_3, SO_4, CO_3 and Cl varied from 2 to 6, 3 to 20, 6 to 16 and 8 to 50mg/L^{-1} respectively. The dominant major cations are in the order of: $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ while the dominant anions are in the order of: $Cl^{-} > CO_3^{2-} >$ SO4 > HCO_3 (Figures 4 and 5) respectively.

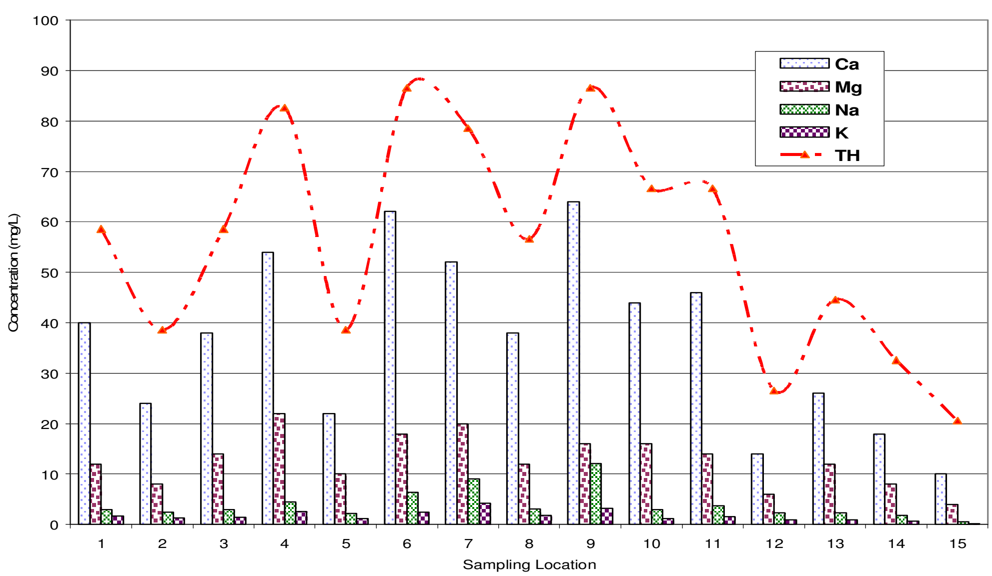

Figure 4. Concentration of cations in the study area

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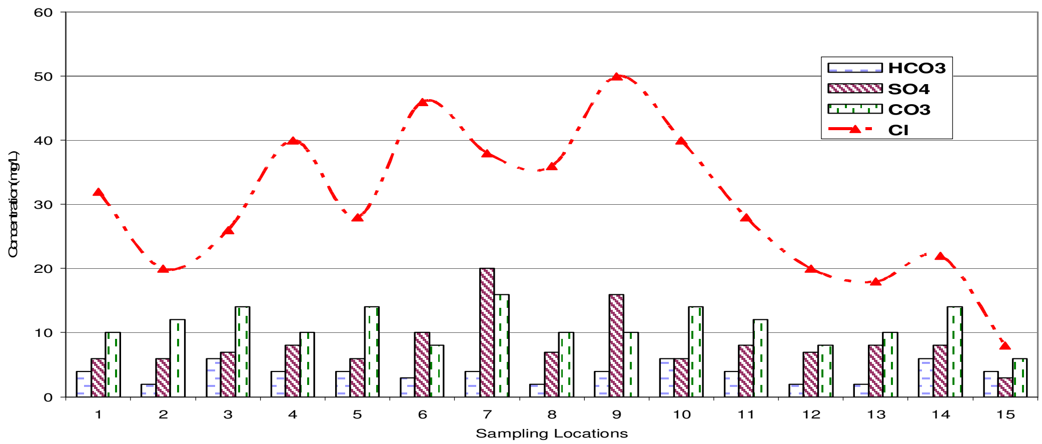

Figure 5. Concentration of anions in the study area

The pattern of relative variation (C.V %) shows that EC, TDS, Na and K are heterogeneous in nature (Table 3). Thus, these parameters must be monitored to ensure the sustainability of water resources management in the area.

Irrigations Water Quality Assessment

Excessive concentrations of dissolved ions in the water used for irrigation affect plants and the physical and chemical activity e.g. lowering the osmotic pressure in the plant structural cells that may prevent water from reaching the branches and leaves, and consequently reduction in agricultural productivity (Rao *et al.*2011).

Irrigation water quality can be determined using four major criteria namely; TDS, EC, relative proportion of sodium to other cations expressed as SAR, concentration of certain elements like Na, Cl, B, and RSC (Sakar and Hassan, 2006). The quality of shallow well samples of the study area was assessed to determine its suitability for irrigation purpose using KR, MR, %Na, RSC and SAR indices.

The mean KR ranged from 0.03-0.12meq/L (Table 4). Kelly (1963) suggested that the ratio for irrigation water should not exceed 1.0meq/L. The mean value exceeded the computed KR values in about 20% at locations G_7, G_9 and G_{12} in the study area (Fig.6).However, the KR obtained in the study area was found to be within the recommended limit showing a good balance of Na, Ca and Mg. This result shows a good tilth condition of soil with no permeability problem.

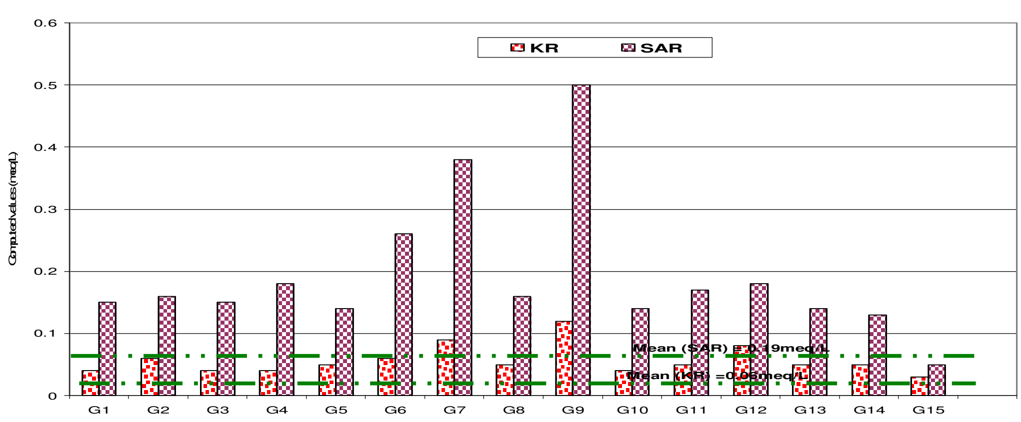

Figure 6. Computed KR and SAR indices of the study area

SAR is important parameters for determining the suitability of irrigation water quality. The computed value of SAR is between 0.05 and 0.5meq/L from the shallow wells of the study area (Table 4).The USSLS's diagram classifies irrigation water quality into 16 zones for water quality assessment , where the salinity hazard (C) is divided into four sub-zones, such as low salinity hazard (C1, <250 μScm^{-1}), medium-salinity hazard (C2, 250 to 750 μScm^{-1}), high-salinity hazard (C3, 750 to 2,250 μScm^{-1}), and very-high-salinity hazard (C4, >2,250 µS/cm).This classification represents good, moderate, poor, and very poor water classes respectively. Approximately 66.7% of the shallow well water samples (1 to 3, 5, 8, 10, 12-15) fall in the zone of C1 (low salinity) while 26.7% and 6.7% falls under zone C_2(medium salinity) and C_3(high salinity) respectively.

According to USSL (1954), sodium hazard (S) can be classified into four sub-zones, such as low-sodium hazard (S1, <10), medium-sodium hazard (S2, 10 to 18), high-sodium hazard (S3, 18 to 26), and very-high sodium hazard (S4, >26), representing good, moderate, poor, and very poor classes respectively .The computed SAR shows that all the samples are suitable for irrigation purpose. However, the mean SAR value exceeded the computed SAR in about 20% at locations $G_{6, \ 7 \text{ and } 9}$ in the study area (Fig.6).

Szabolcs and Darab (1964) suggested that if MR exceeds the value of 50meq/L, water with such a value is considered to be harmful and hence is unsuitable for irrigation because it adversely affects crop yields. Magnesium damages soil structure when the water contains high Na and high salinity which consequently affects crop yields (Rao *et al.,*2011). The computed MR ranged from 29.19 to 43.21meq/L (Table 4) .Thus, all the computed MR are less than 50meq/L in the study area and hence they are suitable for irrigation. However, the mean MR exceeded the computed MR in about 66.7% at locations $G_{2\text{-}5,\ 7,\ 10}$ and$_{12\text{-}15}$ in the study area (Figure 7).

The computed value of % Na varied from 3.38 to 11.96meq/L in the shallow well samples of the study area (Table 4). Generally, % Na should not exceed 60meq/L in the irrigation water for better crop yields. The computed %Na is less than 60meq/L in the shallow well samples of the study area. Approximately 33.3% of the computed %Na was above the %Na mean value in the study area (Figure 7).

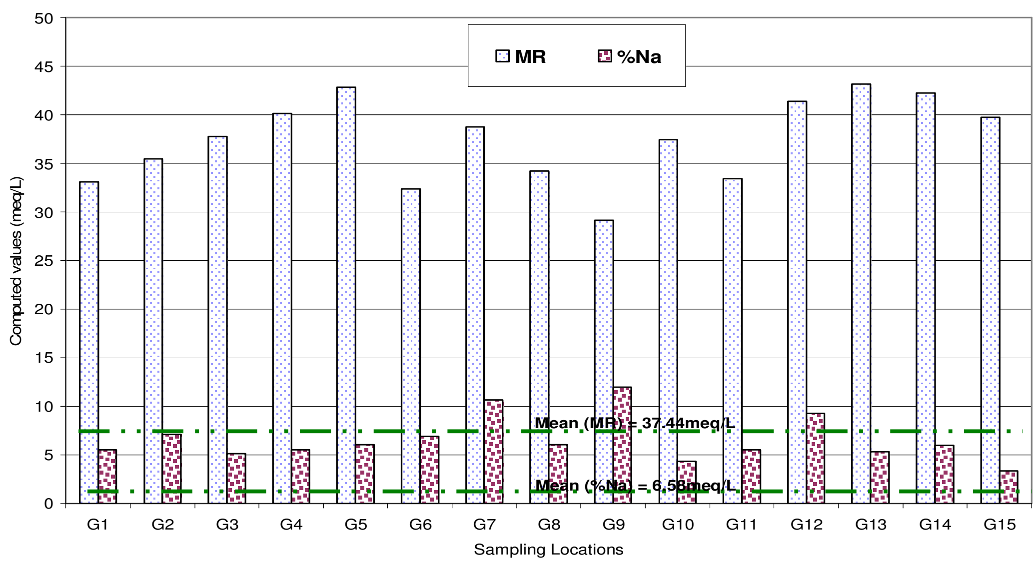

Figure 7. Computed MR and %Na indices in the study area

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Water with high concentration of bicarbonate ions has the tendency for Ca and Mg to precipitate as carbonates. The RSC index was applied to characterize the effect of high concentration of bicarbonate ions (Eaton, 1950). According to Eaton (1950), if the RSC value is less than 1.25 meq/L, it is suitable, if the RSC value is between 1.25 and 2.50 meq/L; marginally suitable; and unsuitable if the RSC value is more than 2.50 meq/L. High RSC value leads to increase of adsorption of Na^+ in soil, which reduces the soil permeability and hence do not support plant growth (Rao *et al.*,2011).The computed RSC value ranged between -0.66 and -4.38meq/L (Table 4). Since the RSC values are negative (i.e. carbonates are less than the alkaline earths) and less than 1.25 meq/L, then the shallow well water samples of the study area fall in excellent category for irrigation purpose.

CONCLUSION

Based on the statistics of the shallow well water quality samples, the findings shows that the mean values of HCO_3, Ca/TH, pH, Mg/CO_3/Cl, EC, TDS/Na/K and SO_4 exceeded their level of detection in about 66.7%,60%,53.3%,46.7%,40%,33.3%, and 20% respectively. This suggests that the water quality from the study area is gradually deteriorating therefore, adequate protection must be put in place to reduce the rate of deterioration. Also, the application of organic and inorganic fertilizer, insecticides/ pesticides should be monitored to avoid runoff into the shallow wells used for irrigation. Unlike the computed irrigation indices, the findings showed that all the indices were suitable for irrigation purpose. However, the mean values of MR, %Na and KR/SAR exceeded the computed values of these variables in about 66.7%, 33.3% and 20% respectively. This implies that parameters such as Ca, Mg, and Na are relatively higher compared to other parameters in the study area. Thus, there is need for proper monitoring of organic and inorganic fertilizer to check the level of dissolved salts in the soil within the study area. The paper recommended runoff control techniques and periodic monitoring of water quality testing for agricultural activity in the study area.

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