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## Evaluation of suitability of tube well water for irrigation in Maiduguri Metropolitan, Borno State, Nigeria

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Groundwater contamination is gaining more concerns due to its direct and/or indirect impact on public health. Groundwaters from various sources are commonly used to irrigate vegetables in Maiduguri, Borno State. In this study, the physicochemical qualities of groundwater collected from 20 randomly selected tube wells in Maiduguri were evaluated for their suitability or otherwise for irrigation purposes. Selected wells were extensively used as sources of irrigation water. Standard procedures were followed during the analysis. The results revealed that the mean values of pH (6.6 to 8.0), calcium (2.6 to 5.2 meq/l), magnesium (2.6 to 5.0 meq/l), sodium (2.2 to 7.5 meq/l), carbonate (0.5 to 1.3 meq/l), bicarbonate (1.8 to 5.2 meq/l), chloride (0.9 to 2.9 meq/l), sulphate (2.8 to 9.8 meq/l), potassium (0.3 to 0.9 mg/l), Boron (0.1 to 0.6 meq/l) and nitrogen (1.9 to 4.8 mg/l) were all found to be within the acceptable limit for suitability of water for irrigation use based on Food and Agriculture Organization (FAO) recommendations. The results further revealed that, the values of electrical conductivity (0.3 to 0.7 ds/m), total dissolved solids (192 to 448 mg/l), sodium adsorption ratio (0.40 to 3.62), residual sodium carbonate (-1.3 to -7.6 meq/l), magnesium adsorption ratio (35.80 to 49.06%) and Kelly ratio (0.10 to 0.90) of the samples were within the safe limit recommended for irrigation water use. The quality of tube well waters in the study area can thus be regarded as good, and suitable for irrigation purposes, but similar analysis should be conducted on a routine basis to monitor the qualities of the waters toward safeguarding public health.

**Key words:** Tube well waters, physicochemical qualities, irrigation suitability, public health, Maiduguri.

### INTRODUCTION

The rise in the global population has resulted in a larger increase in water demand in recent decades. The increasing water demand from domestic and agricultural uses has led to overexploitation of groundwater,

particularly in arid and semi-arid regions that are commonly characterized by poor availability of water resources (Ebrahimi et al., 2016). Irrigated agriculture is the largest water consuming sector accounting for more

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than 70% of the total water consumption in most countries developed or otherwise, as opposed to the 30% used by industries and for domestic use (UN, 2009; FAO, 2011). In Nigeria, agriculture is equally the highest water consuming sector accounting for 69% of the total water withdrawal followed by the domestic sector with about 1.7 km<sup>3</sup> (21%) and the industrial sector with 0.8 km<sup>3</sup> (10%). The total irrigated area in Nigeria is about 975054 ha (Aquistat, 2010).

Ground water is generally assumed to be safe for usage because it is located below the soil surface and is usually not in contact with the atmosphere (Quist et al., 1988). However, ground water are often contaminated due to human activities such as improper waste disposal, poor sanitation, seepage of agrochemicals and mining close to boreholes and shallow wells (Salifu et al., 2013; Fianko et al., 2010; Jain et al., 2009; Carpenter et al., 1998).

Water quality is simply the characteristics of a water supply that will influence its suitability for a specific use such as irrigation or domestic use. Quality is a function of physical, chemical and biological properties of the water. In irrigation water evaluation, emphasis is given only on physical and chemical characteristics of water. Water quality concerns have often been neglected because good quality water supplies have been abundant and readily available. This situation is now changing in many parts of the world due to the increasing demand for fresh water to meet the demand for food and fibre for the growing population as well as the increasing competition from other non-agricultural sectors (FAO, 2011). High quality crops can be produced only by using high-quality irrigation water keeping other inputs optimal. Therefore, a better understanding of the irrigation water quality is critical to the management of water for long term productivity and for public health concerns. The quality of irrigation waters can vary considerably irrespective of their sources, depending on the type and concentrations of the pollutants in it (James et al., 2012; Al-Ahmad, 2013). The presence of appreciable quantities of chemical substances in solution above certain fairly well defined limit can reduce crop yield and deteriorate soil fertility.

The suitability of water for irrigation depends upon the quality of the water, the soil type, the salt tolerant characteristics of the plants, climate and drainage characteristics of the soil. Irrigation using water of questionable quality will lead to problems of salinity, permeability and specific toxicity. A salinity problem occurs when the total quantity of dissolved salts in irrigation water is high enough that it accumulates in the root zone making it difficult for the plants to extract water resulting in reduced growth and wilting. The permeability problem with respect to water quality is noticed when the rate of infiltration is reduced by some salts to an extent that the plant is not given the right amount of water required. A toxicity problem occurs as a result of uptake

and accumulation of certain constituents from irrigation even when salinity is low.

In Maiduguri municipality, the common sources of water for irrigation are usually shallow rivers/ponds, and groundwater from tube wells and wash bores. Most of the rivers/ponds often get dried up untimely; thus inflicting a moisture stress on crops resulting in low yield and economic loss. Farmers in this region therefore, primarily rely solely on tube wells for irrigating their crops. The common crops irrigated include maize, onion, tomatoes, pepper, carrot, lettuce, cabbage and amaranthus among others. But groundwater contamination in relation to irrigation is one area that has not received adequate attention at in Maiduguri. Because of their toxicological importance in ecosystems and impact on public health, it is imperative to examine the quality of any water used for irrigation. This study was therefore was carried out to examine the quality of groundwater from tube wells water in Maiduguri Metropolitan area of Borno State, Nigeria with a view to determine their suitability or otherwise for irrigation purposes in semi-arid environment. The study will also find out areas with potential risk where water treatment could be needed before irrigation.

## MATERIALS AND METHODS

The study was carried out in Maiduguri Metropolitan area of Borno State, Nigeria, which is situated in the Sudano-Sahelian region of Northern Nigeria and located between latitude N11° 46'18" to N 11° 53' 21" and longitude E13° 03' 23" to E 13° 14' 19" (Figure 1). The area which is about 355 m above sea level lies within the Lake Chad Basin formation, which is an area formed as a result of down-warping during the Pleistocene period. This area is known for its dryness, with semi-arid climate or tropical grasslands vegetation. The climate is characterized by short wet season that last for about four months (July to October) and long dry season of 6 to 7 months (November to May). The average annual rainfall is around 640 mm and the temperature is high ranging between 20 and 40°C. The soil is predominantly sandy loam texture (Arku et al., 2011).

### Water sampling and analysis

Water samples were collected from twenty (20) different randomly selected tube wells that were extensively used sources of water irrigation in the study area. The water samples were taken using test bottles which were filled with water, labeled, corked and transferred to the laboratory for physico-chemical analysis. The samples were analyzed for pH, Calcium, Magnesium (Mg<sup>2+</sup>), Sodium (Na<sup>+</sup>), Carbonate (Co<sup>3-</sup>), Bicarbonate (Hco<sup>3-</sup>), Chloride (Cl<sup>-</sup>), Sulphate (So<sup>4-</sup>), Potassium (K<sup>+</sup>), Boron (B), Nitrogen (N), and Electrical conductivity (EC) using the procedures recommended in the standard methods for the examination of water and waste water (APHA, 1999). The pH and electrical conductivity were measured in the field using a pH and conductivity meters respectively. Calcium and magnesium were determined using Varian AA240 Fast Sequential Atomic Absorption Spectrometer. Chloride and Nitrogen were analysed using ICS-90 chromatography. Sodium and potassium were determined using a flame emission photometer. Carbonate and bicarbonate were determined by titration with HCL Sulphate was analysed by ion chromatography (DX-120, dionex) and Boron was analysed using ICP-MS (Ultra mass 700, Varian).



Figure 1. Study area.

While values of Total dissolved solids (TDS), Sodium adsorption ratio (SAR), Magnesium adsorption ratio (MAR) Residual sodium carbonate (RSC) and Kelly ratio (KR) were calculated using the relationships shown below.

The values of total dissolved solids (TDS) were obtained using Equation 1 as contained in Food and Agriculture Organization (FAO, 1985):

$$TDS(mgl^{-1}) = EC(dSm^{-1}) * 640 \quad (1)$$

While the concentrations of SAR in the water samples were computed using Equation 2 (Richards, 1954).

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

Equation 3 as contained in Raghunath (1987) was employed to calculate MAR:

$$MAR = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \quad (3)$$

The values of RSC were evaluated using Equation 4 (Eaton, 1950):

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+}) \quad (4)$$

While KR was evaluated using the expression recommended by Kelly (1963) as in Equation 5:

$$KR = \frac{Na^{2+}}{Ca^{2+} + Mg^{2+}} \quad (5)$$

The results were subjected to statistical analysis using descriptive analysis.

## RESULTS AND DISCUSSION

The physicochemical properties of the tube wells water analyzed were presented in Table 1. The mean pH values of the analyzed water samples ranged from 6.6 to 8.0. The pH is commonly known as a measure of acidity or alkalinity of water. A pH scale is in the range of 1 to 14, with pH 1 to 7 being acidic and pH greater than 7 being alkaline. The normal range 6.5 to 8.4 (Table 2) this implies that the samples were alkaline. Lower pH values are undesirable as they trigger corrosion of irrigation

**Table 1.** The mean values of physicochemical properties of tube well waters in the study area.

Tubewell number	Depth (m)	pH	Ca <sup>2+</sup> (meq/l)	Mg <sup>2+</sup> (meq/l)	Na <sup>+</sup> (meq/l)	Co <sub>3</sub> <sup>-</sup> (meq/l)	HCo <sub>3</sub> <sup>-</sup> (meq/l)	Cl <sup>-</sup>	So <sub>4</sub> <sup>-</sup>	K <sup>+</sup> (mg/l)	B (mg/l)	N (mg/l)
1	45	7.2	4.6	5.0	7.5	0.5	5.2	2.8	8.2	0.8	0.6	4.1
2	45	6.7	4.3	4.8	5.2	0.8	4.8	2.6	9.6	0.5	0.4	4.8
3	60	7.3	3.8	4.1	4.8	0.5	3.2	2.2	9.8	0.3	0.1	4.4
4	66	7.1	4.3	3.8	3.8	0.9	4.6	1.8	5.0	0.7	0.5	3.8
5	63	6.7	5.2	4.4	2.6	1.0	2.8	1.6	4.2	0.7	0.3	3.6
6	48	7.1	3.8	4.6	3.8	1.0	5.0	1.9	2.8	0.9	0.4	3.9
7	45	7.2	3.9	3.4	3.2	1.1	2.2	2.0	5.6	0.6	0.2	4.7
8	42	6.8	3.4	3.2	2.9	1.1	3.4	2.9	6.4	0.6	0.6	2.8
9	69	7.5	5.2	2.9	2.2	0.7	3.4	1.4	8.0	0.5	0.3	2.5
10	66	7.7	4.0	4.3	3.0	0.6	4.0	1.3	6.8	0.4	0.5	3.2
11	60	7.5	3.6	5.0	5.0	0.8	4.0	1.2	7.3	0.6	0.2	3.0
12	48	7.3	3.4	5.0	4.3	0.9	4.6	1.5	7.6	0.6	0.2	4.0
13	51	6.7	2.8	3.8	2.3	1.0	4.6	2.5	3.9	0.9	0.5	4.1
14	54	7.2	3.0	4.1	2.4	1.1	2.0	2.4	4.7	0.9	0.1	2.6
15	57	7.8	4.2	2.6	6.0	1.3	1.8	1.0	5.8	0.3	0.2	2.7
16	60	7.5	2.6	3.4	5.5	1.1	2.2	0.9	9.0	0.3	0.3	1.9
17	60	6.6	3.7	4.8	2.8	0.9	2.4	1.3	9.5	0.8	0.6	2.0
18	63	8.0	5.0	4.6	3.5	0.8	4.6	2.8	6.8	0.8	0.4	3.2
19	66	7.4	4.3	3.6	4.8	0.6	3.6	2.7	7.7	0.6	0.6	4.3
20	72	7.1	4.5	4.9	4.3	0.8	4.4	2.3	7.0	0.5	0.5	4.7
SEE±	2.042	0.888	0.167	0.315	0.049	0.205	0.1446	0.446	0.044	0.0388	0.201	0.332
S.D	9.131	0.381	0.746	1.408	0.219	1.099	0.663	1.994	0.199	0.172	0.901	1.022

SEE ± standard error of estimates and SD=Standard deviation.

pipes where they occur. High pH values above 8.5 are in most cases caused by high concentrations of carbonate and bicarbonate which is referred to as alkalinity. The values are similar to pH values of 6.3 to 8.1 for ground water reported by Salifu et al. (2017) in western region of Ghana.

### Calcium

The calcium concentrations of the analyzed samples were in the range of 2.6 to 2.5 meq/l. (Table 1). The values obtained were far below the recommended maximum usual range of 0 to 20 meq/l in irrigation water (Ayers and Westcott, 1985). Calcium contents relate to the hardness of water and it is an important water quality evaluation parameter that guides in the classification of water as either soft or hard. This implies that the groundwater samples analyzed are therefore suitable for irrigation. The values are in agreement with the calcium concentrations of ground water reported by Hakim et al. (2009)

### Magnesium

The magnesium concentrations in the water samples were in the ranged between 2.6 to 5.0 meq/l. The values

are within the acceptable range (0 to 5 meq/l) of values for suitability of water for irrigation as shown in Table 2. Narany et al. (2012) reported similar findings of magnesium concentrations (1.58 to 5 meq/l) in irrigation water sample. The water collected from the tube wells in Maiduguri can therefore be free of magnesium problem.

### Sodium

The sodium levels for the analyzed samples ranged from 2.2 to 7.5 meq/l (Table 1). These values are within the normal accepted ranges for sodium in irrigation water (Tables 2 and 3). Apparently, the ground waters in the tube wells are devoid of sodium problem. High sodium ions concentration in irrigation water will result into salinity problem that affects the permeability of the soil and results in infiltration problems. As continuous quantities of soluble salts accumulate in the root zone, it becomes difficult for the plants to extract water from the salty salt solution and this will result in poor growth performance and lower yields.

### Carbonate and bicarbonate

The levels of carbonate and bicarbonate in the water samples were found to ranged between 0.5 and 1.3 meq/l

**Table 2.** FAO guidelines for irrigation water quality interpretation (Ayers and Westcott, 1985).

Water constituents	Units	Degree of restriction on use		
		None	Slight to moderate	Severe
<b>Salinity</b>				
EC <sub>w</sub>	dS/m	<0.7	0.7-3.0	>3.0
TDS	mg/l	<450	450-2000	>2000
<b>Salinity, infiltration influence</b>				
SAR=0-3 and EC <sub>w</sub> =		>0.7	0.7-0.2	<0.2
SAR=3-6 and EC <sub>w</sub> =		>1.2	1.2-0.3	<0.3
SAR=6-12 and EC <sub>w</sub> =		>1.9	1.9-0.5	<0.5
SAR=12-20 and EC <sub>w</sub> =		>2.9	2.9-1.3	<1.3
SAR=20-40 and EC <sub>w</sub> =		>5.0	5.0-2.9	<2.9
<b>Specific iron toxicity</b>				
Sodium (Na <sup>+</sup> )	-	-	-	-
Surface irrigation	SAR	<3	3-9	>9
Sprinkler irrigation	meq/l	<3	>3	-
<b>Chloride (Cl<sup>-</sup>)</b>				
Surface irrigation		<4	4-10	>10
Sprinkler irrigation		<3	>3	-
Boron (B)		<0.7	<0.7-3.0	>3.0
<b>Miscellaneous effects</b>				
Nitrogen		<5	5-30	>30
Bicarbonate (HCO <sub>3</sub> )		<1.5	1.5-7.5	>7.5
pH		Normal range 6.5 to 8.4		

and 1.8 and 5.2 meq/l, respectively. These values and both within the acceptable limits are provided in Table 2. A high concentration of carbonate and bicarbonate in water increases the sodium adsorption ratio which translates to salinity problem

### Chloride

The chloride contents of the water samples analyzed ranged from 0.9 to 2.9 meq/l. The values obtained were less than 4 meq/l which indicated no restriction in the use of the source of water for irrigation based on the recommendation of Ayers and Westcott (1985) presented in Tables 2 and 3. Chloride is an essential element to plants, but needed at very low concentrations and it can be toxic to crops at high concentrations. High concentrations of chlorides affect the growth of plants by increasing the osmotic pressure, reduce water availability to plants and hence reduced crop growth and productivity.

### Sulphate

The sulphate concentrations of the tube wells water

ranged from 2.8 to 9.8 meq/l. Sulphate ion is a major contributor to salinity. However, sulphate is generally considered to be non-toxic except at very high concentrations where high sulphate may interfere with uptake of other nutrients. The source of water can safely be used for irrigation since the values obtained are within the 0 to 20 meq/l acceptable limit in irrigation water by FAO (Table 2).

### Potassium

The potassium levels in the analyzed water samples ranged between 0.3 and 0.9 mg/l and these values are within the acceptable range of 0 to 2 mg/l (Table 2) provided by FAO for irrigation purposes. Potassium is an important element when evaluating the suitability of ground water for irrigation. Reddy (2013) reported similar values for ground water in India.

### Boron

Boron concentrations for the water samples in this study

**Table 3.** Laboratory determinations needed to evaluate common irrigation water quality problems (Ayers and Westcott, 1985).

Water parameter	Symbol	Unit	Usual range in irrigation water
<b>Salinity</b>			
Salt content	-	-	-
Electrical conductivity	EC <sub>w</sub>	dS/m	0 - 3
Total dissolved solids	TDS	mg/l	0 - 2000
<b>Cations and anions</b>			
Calcium	Ca <sup>2+</sup>	meq/l	0 - 20
Magnesium	Mg <sup>2+</sup>	meq/l	0 - 5
Sodium	Na <sup>+</sup>	meq/l	0 - 40
Carbonate	CO <sub>3</sub> <sup>-</sup>	meq/l	0 - 1
Bicarbonate	HCO <sub>3</sub> <sup>-</sup>	meq/l	0 - 10
Chloride	Cl <sup>-</sup>	meq/l	0 - 30
Sulphate	SO <sub>4</sub> <sup>-</sup>	meq/l	0 - 20
<b>Nutrients</b>			
Nitrate-nitrogen	NO <sub>3</sub> <sup>-</sup> -N	mg/l	0 - 10
Ammonium-nitrogen	NH <sub>4</sub> <sup>-</sup> -N	mg/l	0 - 5
Phosphate-phosphorus	PO <sub>4</sub> <sup>-</sup> -P	mg/l	0 - 2
Potassium	K <sup>+</sup>	mg/l	0 - 2
<b>Miscellaneous</b>			
Boron	B	mg/l	0 - 2
Acid/Basicity	pH	1-14	6.0 - 8.5
Sodium adsorption ratio	SAR	-	0 - 15

ranged from 0.1 to 0.6 meq/l. Boron is one of the essential elements for plants growth that is required in relatively small quantities. But at higher concentration boron becomes toxic. Boron toxicity can be observed on sensitive crops at concentrations less than 1 mg/l and it was suggested that irrigation water particularly from ground water ought to be analyzed for the concentration of boron before crops are irrigated. Based on the recommendation of Ayers and Westcott (1985), irrigation water with boron concentrations of less than 0.7 meq/l can be safely used for irrigation without restriction (Tables 2 and 3). The values obtained therefore showed that the source of water is suitable for irrigation with regard to Boron problems.

### Nitrogen

The nitrogen levels in the analyzed samples were in the range of 1.9 to 4.8 mg/l (Table 1). Nitrogen in irrigation water is generally a fertility issue. Higher concentrations of nitrogen in irrigation water can result into quality problems in crops such as barley and sugar beets and excessive vegetative growth in some vegetables. However, these problems can generally be taken care

using appropriate fertilizer application and irrigation best management practices. The values obtained were found to be within the allowable limit for the use of water for irrigation presented in Table 2.

### Electrical conductivity (EC)

The EC values of the analyzed samples in this study ranged from 0.3 to 0.7 dS/m (Table 4). According to Ayers and Westcott (1985), groundwater with EC value greater than 3 dS/m is termed "Fair" and would greatly affect crop productivity or yield. Water is termed "Good" if the EC is in the range of 0.7 to 3 dS/m. While water with EC value of less than 0.7 dS/m is classified as "Excellent" for irrigation.

Electrical conductivity is one of the most important parameter for determining the suitability of water for irrigation. It is a measure of EC simply refers to the ability of a substance to conduct electric current. Water that is free from salt strongly resists the passage of an electric current. Most of the salts in water are present in their ionic forms and are capable of conducting current. The more the quantities of dissolved salts in water the higher

**Table 4.** Values of EC (dS/m), TDS, SAR, MAR, RSC and KR.

S/N	EC	TDS	SAR	MAR	RSC	KR
1	0.3	192	0.54	45.28	-4.9	0.11
2	0.4	256	0.54	44.07	-6.2	0.11
3	0.3	192	0.45	43.16	-5.8	0.10
4	0.4	256	0.50	46.19	-2.6	0.12
5	0.3	192	0.40	45.83	-5.8	0.10
6	0.6	384	0.92	48.04	-4.2	0.21
7	0.5	320	0.65	38.10	-7.2	0.14
8	0.6	384	1.16	48.48	-2.1	0.32
9	0.6	384	1.09	35.80	-4.0	0.27
10	0.7	448	1.52	48.72	-3.7	0.44
11	0.6	384	2.50	44.33	-4.9	0.27
12	0.6	384	1.17	49.06	-5.1	0.41
13	0.6	384	0.69	37.50	-2.4	0.63
14	0.6	384	1.17	39.29	-5.3	0.29
15	0.5	320	0.69	48.60	-7.6	0.15
16	0.4	256	2.40	39.08	-5.4	0.57
17	0.6	384	1.25	48.00	-6.7	0.28
18	0.7	448	1.64	47.92	-4.2	0.38
19	0.3	192	3.62	45.45	-1.3	0.90
20	0.6	384	0.68	48.00	-7.3	0.14

its conductivity value. EC is frequently expressed in decisiemens per meter (dS/m) and microsiemens per centimeters ( $\mu\text{S/cm}$ ). Since the values of EC obtained were less than 0.7 ds/m (Table 2), the groundwater in the sampled tube wells can be classified as excellent for irrigation.

#### Total dissolved solids (TDS)

TDS of the tube wells water in the study area were in the range of 192 to 448 mg/l (Table 4). Total dissolved solids (TDS) simply refer to any dissolved minerals, salts, metals, cations, or anions in water (Lamgenegger, 1990). It is an important parameter that indicates the general nature of salinity of the water. The use of a water source with very high salinity level increases the osmotic potential of the soil water. An increase in the osmotic pressure of the soil solution increases the amount of energy, which plants must use to take up water from the soil. As a result, respiration is increased and the growth and yield of most plants decline progressively as osmotic pressure increases. Based on Ayers and Westcott (1985) degree of restriction on use of water classification, water with TDS values less than 450 mg/l are described as "None" and considered suitable or good for irrigation (Tables 2 and 3). Evidently, the sampled waters can be described as excellent for irrigating purposes.

#### Sodium absorption ratio (SAR)

SAR values of the water samples in this study ranged

from 0.40 to 3.62 (Table 4). Todd (1980) and Sadashivaiah et al. (2008) classified irrigation water with SAR value less than 10 meq/l as "Excellent" for irrigation usage and those with SAR values in the range of 10 and 18 meq/l are termed "Good". While water with SAR values ranging from 18 and 26 meq/l and greater than 26 meq/l are classified as "Doubtful" and "Unsuitable", respectively. SAR is an important water quality parameter that shows the effect of relative cation concentration on sodium accumulation in the soil. Therefore, SAR is a more reliable method for the assessment of water quality for irrigation with respect to sodium hazard based on the fact that, it is more closely related to exchangeable sodium percentage compared to simple sodium percentage (Tiwari and Mansour, 1988). High concentrations of sodium affect the physical and soil structure by dispersing the clay particles which results in the formation of crusts, waterlogging and reduced permeability (Kelly, 1951; Suarez et al., 2006; Vasanthavigar et al., 2012). The values obtained are less than the SAR value of 10 which is designated as excellent for irrigation use by Todd (1980) and Sadashivaiah et al. (2008). Al-Ahmadi (2013) reported lower SAR values (0.3 to 3.5) similar to the results of this study.

#### Residual sodium carbonate (RSC)

Table 4 also shows that the residual sodium carbonate values of the samples ranged from -1.3 to -7.6 meq/l.

RSC is a term used by Eaton (1950) to express bicarbonate hazard in water in order to ascertain the suitability or otherwise of the source of water for irrigation. Water with high bicarbonate concentration may result in the precipitation of calcium and magnesium as well as increase in the relative proportion of sodium in the water in the form of sodium carbonate. Eaton (1950) and Richard (1954) termed water with RSC values of less than 1.25 meq/l as safe for irrigation. While water with an RSC values in the range of 1.25 and 2.5 meq/l is termed marginal and could be used with good irrigation management techniques and soil salinity monitored by laboratory analysis. But water with RSC values greater than 2.5 meq/l are classified as unsuitable for irrigation. The values obtained are less than 0 and this revealed that the source of water is very good for irrigating crops based on Bishnoi et al. (1984), Eaton (1950) and Richard (1954) classification of water quality for irrigation. The RSC values of this study are similar to the findings of Zaidi et al. (2016) which reported lower RSC values of less than 1.25.

### Magnesium adsorption ratio (MAR)

MAR values for the analyzed samples were found to have ranged between 35.80 and 49.06% (Table 4). Szabolics and Darab (1964) and Raghunath (1987) considered magnesium content as an important parameter in evaluating the suitability of water for irrigation. Calcium and magnesium do not behave the same in the soil, and magnesium was found to deteriorate the soil structure especially when the water is highly saline. FAO (2008) reported that high concentration of magnesium promotes a higher development of exchangeable sodium in irrigated soils. The values obtained were less than 50% that was recommended by Gupta and Gupta (1987) and Raghunath (1987) as suitable for irrigation.

### Kelly's ratio (KR)

The result finally revealed that the KR values of the samples were in the range of 0.10 and 0.90. KR is an important parameter recommended by Kelly (1963) for the evaluation of water quality for irrigation. The parameter is based on the concentration of  $\text{Na}^{2+}$ ,  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  in the water. According to this evaluation method, irrigation water with a KR value greater than one indicates an excessive level of sodium in the water and is therefore considered unfit for irrigation. On the other hand, irrigation water with a KR value of less than 1 indicates that the water is free from sodicity hazard, and is suitable to be used for irrigation purpose. This indicates that tube wells from where water samples were collected are good sources of irrigation water.

### Conclusion

The study evaluated the suitability of tube well waters for irrigation purposes and found that, there were no conflict between the values of the parameters studied and the standard values. The pH level of water samples from tube wells analyzed were within the acceptable limit for suitability of water for irrigation based on FAO recommendations. The concentrations of Calcium, Magnesium, Sodium, Carbonate and Bicarbonate, Chloride, Sulphate, Potassium, Boron and Nitrogen contents of the analysed water samples were all found to be within the acceptable limit recommended by Ayers and Westcott (1985) for suitability of water for irrigation. EC and TDS values of the water samples analyzed were all found to be within the recommended limits for suitability of water for irrigation based on Ayers and Westcott (1985) classification. SAR values of the analyzed water samples were less than the SAR value of 10 recommended as excellent for irrigation usage. The values of RSC, MAR and KR all fall within the allowable limits. This suggests that the source of water can safely be used for irrigation and there is indication of the need to conduct any pre-irrigation treatment. Public health is thus safe.

### CONFLICT OF INTERESTS

The authors have declared any conflict of interests.

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