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Hydrochemistry and Water Quality of Tazerbo Wellfield, Line 300, SE Libya

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ABSTRACT

Some areas in Libya depend on municipal water wells, which extract water from nearby shallow aquifers, besides water from the Great Man-Made River, which is considered the largest source of drinking water in Libya, as well as some desalination plants. The main work of this study is to understand the most significant geochemical processes controlling groundwater quality and to evaluate the groundwater quality criteria for irrigation and drinking of Tazerbo Wellfield, Line 300, SE Libya. The nine groundwater samples were taken from nine wells numbered from (310–318) in the studied wells. The Great Man-Made River Authority's lab performed the analysis of water samples. There are three aquifers in studied wells: shallow, intermediate, and deep. The result showed the studied ground water was characterized by fresh water (Na Ca HCO_3 type). All the parameters of irrigation, such as EC, SAR, KR, Na%, and PI, are good to excellent for irrigation uses. The origin of major ions weathered from silicate rocks. The concentration levels of (Mn) and (Fe) are above the acceptable limit for drinking water and should be treated before pumping to the pipelines. The pH in the studied water is considered acidity water, and it is classified as mainly somewhat corrosive. Many tools have been used to remove these contaminants (e.g., oxidation with chlorine, ozone, or green sand filters).

الهيدروكيمياء و جودة المياه في حقل أبار تازربو، خط 300، جنوب شرق ليبيا

فرج العشيبي فارس فتحى

تعتمد بعض المناطق في ليبيا على آبار المياه البلدية، والتي تستخرج المياه من طبقات المياه الجوفية الضحلة القريبة، إلى جانب مياه النهر الصناعي الذي يعتبر أكبر مصدر لمياه الشرب في ليبيا، وكذلك بعض محطات تحليه المياه. يتمثل العمل الرئيسي لهذه الدراسة في فهم أهم العمليات الجيوكيميائية التي تتحكم في جودة المياه الجوفية وتقييم معايير جودة المياه الجوفية للري والشرب في حقل بئر تازربو، الخط 300، جنوب شرق ليبيا. تم أخذ عينات المياه الجوفية التسعة من تسعة آبار (310–318) في الآبار المدروسة. أجرى مختبر هيئة النهر الصناعي تحليل عينات المياه. توجد ثلاث طبقات مياه جوفية في الآبار المدروسة: الضحلة والمتوسطة والعميقة. أظهرت النتائج أن المياه الجوفية المدروسة تتميز بأنها مياه عذبة (نوع HCO3 Ca Na). جميع معلمات الري، مثل EC، وSAR، وKR، و%Na، وPI، جيدة إلى ممتازة لاستخدامات الري. أصل الأيونات الرئيسية نجا من صخور السيليكات. إن مستويات تركيز (Mn) و (Fe) أعلى من الحد المقبول لمياه الشرب ويجب معالجتها قبل ضخها إلى خطوط الأنابيب. يعتبر الرقم الهيدروجيني في المياه المدروسة ماء حموضة، ويصنف بشكل رئيسي على أنه مسبب للتآكل إلى حد ما. تم استخدام العديد من الأدوات لإزالة هذه الملوثات (مثل الأكسدة بالكلور أو الأوزون أو مرشحات الرمل الأخضر).

INTRODUCTION

The Great Man-Made River is the major source of water for drinking and irrigation in Libya. 90% of Libyans reside along the northern shore, that obtains around six million m^3 of water per day from the Great Man-Made River Project (GMRP) (Lenghi et al. 2008). Since its establishment in 1983, the GMRP has developed significant water supply well fields, including five phases (Fig. 1). This work will be concentrated in Phase I, which is referred to as (Tazerbo Wellfield. The studied wells are located in a desert area close to the southernmost edge of the Sarir plain, almost covering an area of 1000 km². The Hercynian uplifts, which divide the basins of Sirt and Al Kufrah and extend northeast to southwest, are site to the Tazerbo Wellfield. The flow coming from 108 Tazerbo Wellfield wells will be discharged into a collector pipeline, that will transfer it to the header tank of Tazerbo. These wells are separated into three 50 km long parallel lines with 36 wells. Every line consists of two sections. In the second line, the well numbers are 301-318 and 401-418; in the third line, they are 501-518 and 601-618. In the first line, the well numbers are 101–118 and 201–218. The study well considered the second line that started from 301 to 318. The Wellfield's production wells are between 460 and 580 meters deep overall (El Mabrouk and Sali 2006).

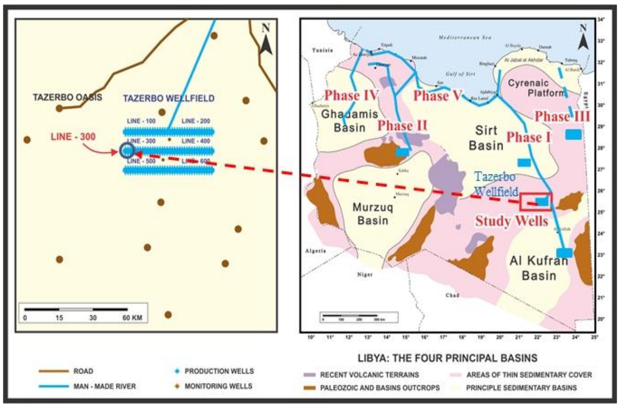

Fig. 1: Location map of the studied wells and geological basins in Libya (modified from Hallett 2002).

REGIONAL GEOLOGY

The study area, which refers to a stratigraphic sequence attributed to part of the Al Kufrah Basin, mainly composited of siliciclastic rocks deposited from the Cambrian to the Cretaceous (Fig. 2). The wellfield is located above the presented (Caledonian) north-west-south transects aligned with an uplift, which marks the border among the Al Kufrah and Sirt basins and the south-west-north-east position of the Hercynian uplift's southern border (Wright et al. 1982; Hallett 2002; Salah and Fawzi 2022). Additionally, the wellfield is near the Late-Cretaceous collapse of the Sirt Basin and the ensuing Tertiary marine sediments. Consequently, a block of Eocene clay that starts next to the wellfield, throws northern, and rapidly thickens, transected and overlapped the pretertiary sediments of the Al Kufrah Basin (Pim and Binsariti 1994; Hallett 2002). Based on a geological interpretation employing multiple observation wells, the principal and major (unconfined) aquifer of the Al Kufrah Basin is the post-Tassilian (Nubia continental deposits), which pull out to the Tazerbo region at a thickness of approximately 700 m.

HYDROGEOLOGY AND STRATIGRAPHY

During the construction of the water well, the surface and intermediate aquifers have been isolated in order to use the water from the deep aquifer. The lithological of sedimentations gained by the drilled wells which indicate that the Upper Silurian (Acacus Formation) deep aquifer characterized by unconsolidated coarse-grained sandstone, comprising quartz with some black iron oxide and some siltstone components. The Tadrart Formation, an aquitard Lower Devonian, lies above the aquifer that characterized by reddish green siltstone, very fine sandstone and contained some strikes of mudstone. The aquitard is overlying by intermediate aquifer of Upper Devonian (Binem Formation) that characterized by sand stone (Fig. 2). The aquifer is overlying by the aquitard Eocene (Formation?) that is included calcareous sandstone with strikes of red iron. This aquitard is above by surface aquifer Pleistocene (Formation ?) that contained sandy gravel. (Fig. 3) indicates the geological cross section of the studied wells from the west to eat that is lied between Al Kufrah and Sirt basins. Many works have been done on Tazerbo Wellfield include (Al Faitouri and Sanford 2015; Nawal et al. 2017; Mostafa et al. 2021).

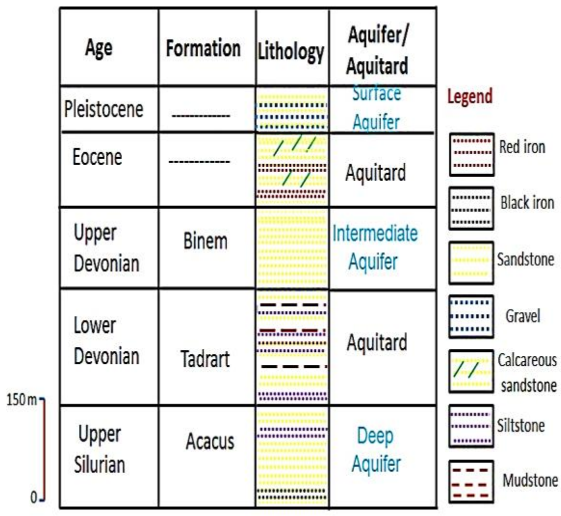

Fig. 2: Columnar section of the studied wells.

However, most of the previous works dealt with hydrochemistry and management of ground water in Tazerbo Wellfield. This work aims are as follows; 1) To assess the ground water for irrigation uses. 2) To identify hydrochemistry processes that control the groundwater quality. However, the suitability of groundwater for irrigation and drinking was evaluated by determining its physiochemical and irrigation properties.

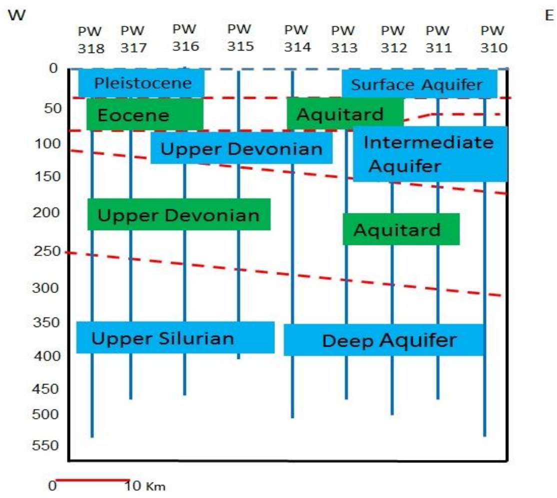

Fig. 3: Geological cross section from 310 to 318 (modified from GMMP SNCL 1999).

MATERIALS AND METHOD

In order to assess the chemistry of the groundwater, nine samples of groundwater were extracted from nine wells. The samples were put in polyethylene containers that had been cleaned with groundwater samples before being filled and appropriately labelled. After calibrating the meter with standard buffers of the corresponding parameter, pH, electrical conductivity (EC), and total dissolved solids (TDS) were calculated using conductivity and pH meters. To remove suspended sediments, the samples were filtered using 0.5-µm Millipore filter paper in a vacuum filtration equipment. Titrmetric methods were used to determine HCO_3 and Cl, and gravimetric methods were used to determine SO4.Ca, Mg, Na, Fe, Mn, and K were measured by the AAS Hitachi-5000 (Table 1). The APHA (2005) recommendations were followed in performing the chemical analysis. Using Gibb's ratio, the most important factors influencing the chemistry of the groundwater in the wells during study were determined. To identify the origin of the chemical history of groundwater, by plotting the major inons and cations, hydrochemical facies and the Schoeller (1977) diagram are used. The Great Man-Made River Authority's lab performed the analysis. (Fig. 4) summarized the average concentration data of the ground water samples in the studied wells.

Table 1: Data from the chemical examination of the ground water wells of study (concentrations in mg/l, but for EC in µs/m).

	Well NO.									
Parameters	310	311	312	313	314	315	316	317	318	WHO (2018)
T	31.9	29.8	29.9	29.6	29.3	30	30.9	30.9	30.4	-
PH	6.3	6.1	6.3	6	6.18	6.03	6.3	6.14	6.19	8
EC	306	338	346	339	345	347	310	301	306	2500
TDS	199	220	225	220	224	226	204	196	199	500
TH	73	78	80	76	80	80	78	80	88	500
HCO_3	150	144	151	132	130	145	100	137	130	600
T AlK	102	103	105	106	110	104	102	99	95	200
Na	19	17	19	21	17	18	18	23	20	200
K	26	27	26	29	22	26	22	19	27	150
Ca	10	9	12.4	10	10	13.2	9.2	12.8	13	200
Mg	11.4	14	11.9	12	13.4	11.4	11.7	13	13.4	150
Fe	3.7	3.3	3.72	3.5	3.2	3.37	3.39	3.99	4	0.3
Cl	25	20	25	23	25	25	20	20	30	250
SO_4	28	27	31	23	28	28	27	33	29	600
Mn	0.16	0.16	0.16	0.23	0.19	0.13	0.12	0.13	0.13	0.08

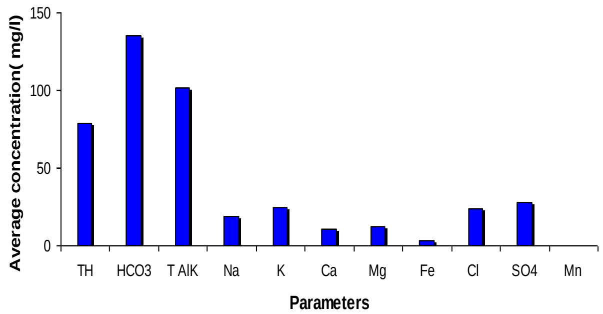

Fig. 4: The average concentration data of the studied wells.

RESULTS AND DISCUSSION

To assess the water quality for irrigation were used the following parameters:

Electrical Conductivity (EC)

The electrical conductivity (EC) dealings the amount of material dissolved in water and it is the mean value 30.3°C ranges from 301 to 347 respectively, According to The US Salinity Laboratory (1954) classified the ground water into four classes in (Table 2). The result samples are considered as good quality for irrigation.

Sodium absorption ratio (SAR)

The measurement of Na level in relation to Ca and Mg in the soil-water phase, which affects soil characteristics and plant growth, is known as the Sodium Absorption Ratio (SAR). Following is an equation that can be used to calculate the sodium adsorption ratio (SAR).

$$\mathbf{SAR = Na / \sqrt{(Ca+Mg)/2}}$$

(Where concentration is in mg/l).

Table 2: Groundwater categories as classified by the EC (from US Salinity Laboratory 1954).

Class	Water quality	Salinty	EC (m/cm)	Use in irrigation
C1	Excellent	Low	250	Can be used for almost all crops and for almost all kinds of soils
C2	Good	Medium	250 - 750	Can be used if a moderate amount of leaching occurs: normal salt tolerant plants can be grown without much salinity control
C3	Fair	High	750 - 2250	Can be used in soils with restricted drainage. Special precautions and measures are to be undertaken for salinity control
C4	Poor	Very High	2250	Generally not suitable for irrigation

The water samples during investigation exhibit SAR values below 10, with an average of 7.83, suggesting that they belong to the excellent for irrigation (Table 3).

Table 3: Sodium Adsorption Ratio (SAR) classifications of ground water categories (from Gholami and Srikantaswamy 2009).

Water quality	SAR
Excellent	< 10
Good	10 - 18
Moderate	18 - 26
Hazardous	> 26

Kelley's index (KR)

In order to evaluate the irrigation water quality, Kelley (1940) and Paliwal (1967) developed an essential factor based on the stage of Na measured in opposition to Ca and Mg. While water with a KR of less than one is only thought to be acceptable for irrigation, water with a KR of more than one indicates an excess of sodium and is not suited for irrigation (Table 4). The studied water is <1 (0.8, in average) which reflects is appropriate for irrigation proposes. This parameter was calculated as the following:

$$KR = Na/(Ca+Mg)$$

(Where concentration is in mg/l).

Table 4: Ground water categories as described by Kelley (1940).

Water quality	KR
< 1	Suitable for irrigation
> 1	Unsuitable for irrigation

Percentage sodium (Na%)

The sum of sodium is frequently used to evaluate whether the quality of water is proper for irrigation. Hakim et al. (2009) recommends a maximum sodium percentage (% Na) of 60 % for water irrigation. The following formula can be used to calculate the sodium percentage (Na %):

$$Na\% = (Na*100)/(Ca+Mg+Na+K)$$

(Where concentration is in mg/l).

The (Na %) in the studied wells varied from 2420 to 26.04% (average 28.28 %), which is considered as suitable for irrigation (Table 5). The plot of analytical information on Johnson and Zhang (1990) diagram concerning Na % and EC show with the purpose of samples fall between excellent and good quality for irrigation (Fig. 5).

Table 5: Groundwater types categorized by Na percentage (from Hakim et al. 2009).

Water quality	Na %
< 60	Suitable for irrigation
> 60	Unsuitable for irrigation

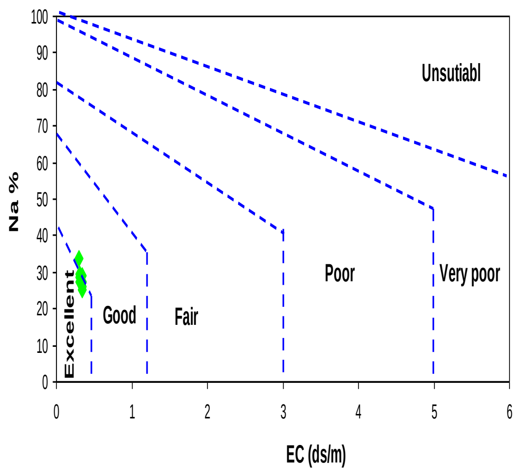

Fig. 5: Irrigation water classification based on EC against Na% and its agricultural appropriateness (modified from Johnson and Zhang 1990).

Permeability Index (PI)

Soil permeability may be reduced by using high-salinity irrigation water over an extended period. According to Nagaraju et al. (2006), irrigation water with a permeability of more than 75% is classified as class I; permeability ranging from 50 to 75% is classified as class II; and permeability less than 25% is classified as class III, meaning it is not suitable for irrigation. According to this classification, the samples considered as class II (PI is 72.09, in average). An analysis of the irrigation parameters statistically displayed in the (Table 6).

Table 6: A statistical analysis of the irrigation parameters of the wells according to investigation.

Well NO.	SAR	KR	Na%	PI
310	8.20	0.80	28.70	77.30
311	7.00	0.74	25.30	72.50
312	7.70	0.78	27.40	72.30
313	8.90	0.95	29.10	75.50
314	7.00	0.73	27.20	70.00
315	7.20	0.73	26.20	70.50
316	7.80	0.86	29.50	72.00
317	9.00	0.89	33.90	71.10
318	7.70	0.76	27.20	67.60
Max	9.00	0.95	33.90	77.30
Average	7.83	0.80	28.28	72.09
Min	7.00	0.73	25.30	67.60

Composition of water

Plotting the concentration of main anions and cations in the Piper (1944) trilinear diagram was used to characterize the groundwater facies in the study wells. Six hydrofacies were identified by Tweed et al. (2005) based on the classification of the water sample in the piper diagram: I) NaCl type, II) CaHCO3 type, III) $NaCaHCO_3$ type, IV) CaMgCl type, V) CaCl type, and VI) $NaHCO_3$ type. The studied wells plotted in the $NaCaHCO_3$ type of water, this result agreement with Salah and Fawzi (2022) (Fig. 6). Based on Schoeller diagram (Fig. 7). The groundwater's dominant cation order of ion contents is K >Na >Mg > Ca and anion order in HCO_3> Cl > SO_4.The Stiff diagram's form analysis indicates the dominance of Na+K – HCO_3 +CO_3. According to the Gibbs (1970) diagram, the relationship between Cl/Cl+HCO_3 and TDS indicates the ions of the studied ground water originated from rock predominance (Fig. 8). Han and Liu (2004) used the differences in the water's composition (Mg/Ca vs. Na/Ca) to differentiate the ions' origins in limestone, dolomite, and silicate rocks. The studied samples plot in silicate rocks (Fig. 9).

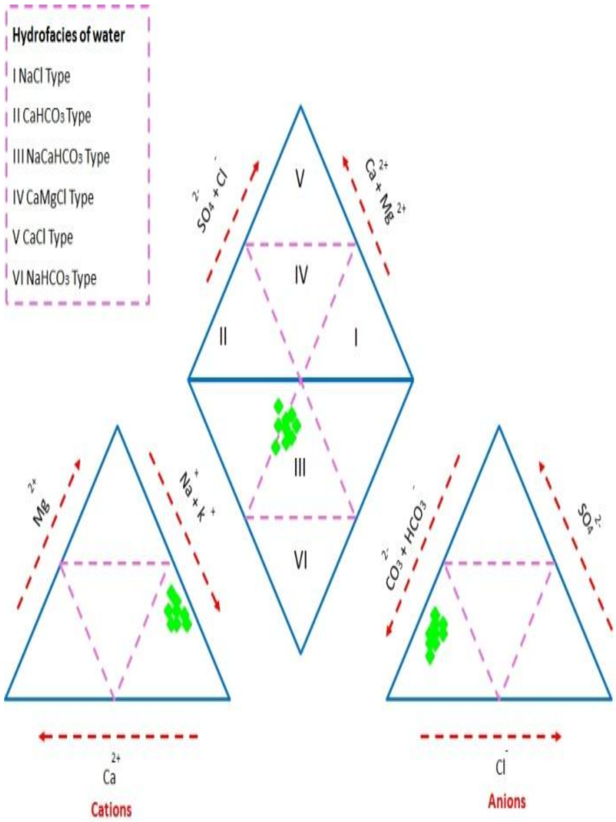

Fig. 6: Piper diagram revealing the hydrofacies of the water (modified from Tweed et al. 2005).

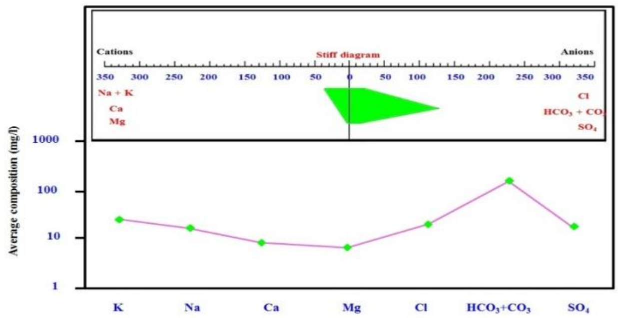

Fig. 7: Schoeller diagram revealing the average composition in mg/l of the studied water samples. Stiff diagram is shown in inset.

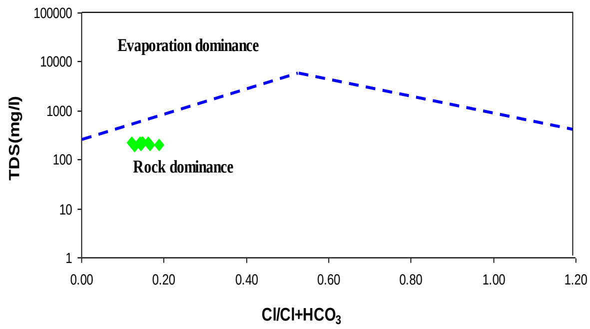

Fig. 8: Dominance of rock on Cl/Cl+HCO3 vs. TDS of

the **focus** area (modified from Gibbs 1970).

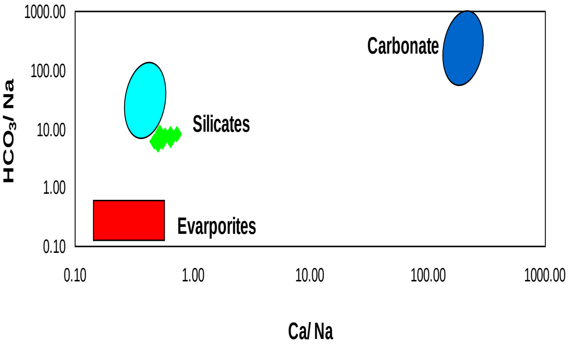

Fig. 9: Plot of Ca/Na vs. Mg/Na revealing the water origin (from Gaillardet et al. 1999).

Drinking water quality

In the current work, the values of pH, EC, T, K, Na, Ca, T, Alk, TH, HCO_3, CO_3, Cl and SO_4 are in the safe limit while Fe and Mn are above the permissible limit. It is necessary to treat the water before it is pumped into the GMRP pipe systems. To determine the level pollution of Fe and Mn it was used Caerio et al. (2005) index. MI is computed as follows: MI = C / MAC where MAC (mg/l) is the maximum permitted concentration and C is the metal content (mg/l) in the water sample (WHO 2018).

The MI value of Mn is greater than 1 is classified as class III (slightly affected) while the value of Fe is greater than 6 is classified as class VI (seriously affected). Based on the Total Dissolved Solids (TDS) the samples of water are appropriate for fresh water (Table 7). TH vs. TDS (Fig. 10) supports this interpretation. The investigated groundwater has an acidity level of 6.03 to 6.3 and is primarily categorized as slightly corrosive (Table 8). The bivariate plot of pH vs. Al kalinity confirms the previously mentioned conclusion; the samples are categorized as corrosive water (Fig.11).

Table 7: Total Dissolved Solids (TDS)-based water classification (from Fetter 1994).

Class	TDS (mg/l)
Fresh	0 - 1000
Barkish	1000 - 10000
Saline	10000 - 100000
Brine	> 100000

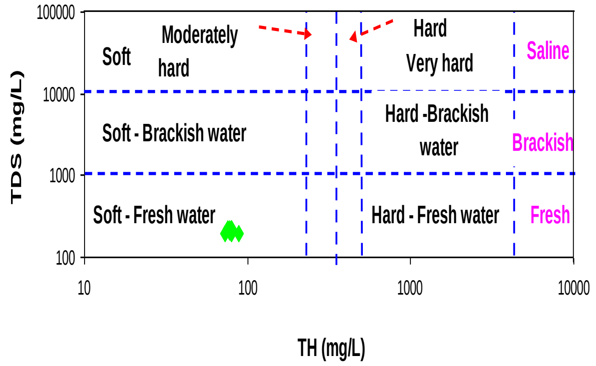

Fig. 10: Total dissolved solids (TDS) and total hardness (TH) of the water samples in relation to each other (modified from Todd 1989).

Table 8: Classification of pH according to corrosive water (from Swistock et al. 2001).

pH	Corrosive water
6.00	Highly corrosive
6.0 - 6.9	Somewhat corrosive
7.0 - 7.5	Not corrosive

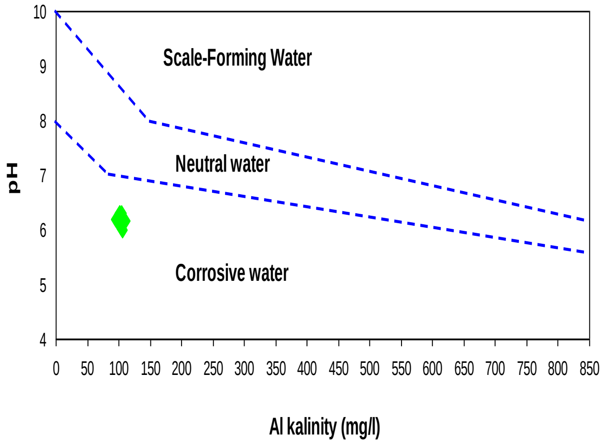

Fig. 11: Plot the relationship between the water samples under study's pH, alkalinity, and water stability standard (modified from Singh and Hussian 2016).

CONCLUSIONS

This study's summary is as follows:

- The irrigation parameters show the ground water samples are good and suitable for irrigation purpose.
- The main ions are arranged in the following order: K >Na >Mg > Ca and HCO_3> Cl > SO_4.
- The dominated hydrochemical facies of groundwater is $NaCaHCO_3$ type of water.

- All the analysis of the studied samples are in the safe limit excluding (Fe and Mn) are above the safe limit should be treated before pumping to the pipe line.
- The main source of the major ions were derived from silicate rocks.
- The ground water samples of the studied wells is corrosive water.
- The relationship between pH and alkalinity revealed the ground water samples are as corrosive water.

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