Journal of Geotechnical Geology

Journal homepage: geotech.iauzah.ac.ir

Zahedan Branch,
Islamic Azad University

USSL based Bonab's groundwater quality experimental diagram for agricultural aims

Dariush Ahadi Ravoshti*[1], Ahmad Baybordi[2], Leila Farjam Haji Agha[3]

[1]*Department of Agriculture, University of Mohaghegh Ardabili, Ardabil, Iran*
[2]*Department of Agriculture, University of Tabriz, Tabriz, Iran*
[3]*Department of Agriculture, University of Maragheh, Maragheh, Iran*

ARTICLE INFORMATION

Received 14 Mar 2019
Revised 07 June 2019
Accepted 25 June 2019

KEYWORDS
USSL classification; Groundwater quality; Sodium adsorption ration; Electrical Conductivity; Bonab.

ABSTRACT

This study is present the comprehensive work on groundwater quality estimation for Bonab Plain located in East-Azerbaijan, northwest of Iran. In this regard, experimental procedure concluded electrical conductivity (EC), sodium adsorption ratio (SAR) and united states salinity laboratory diagram (USSL) to provide the empirical classification of groundwater quality in the Bonab region. In experimental stage, the 25 sample of the Bonab Plain groundwater was taken and conducted the laboratory tests to preparing USSL requirements then in classification stage, used the USSL diagram to preparing the irrigation waters classes as well as qualities. As results it has been determined that the water samples of Bonab plain is in located on C2S1 and C3S1 classes based on USSL classification which is indicated the low to moderate salinity.

1. Introduction

According to the scholars, groundwater supports about two-thirds of the world's population by supplying freshwater for drinking and other house need applications (Adimalla, 2018) which increasing population and industrial countries have led to rapid decline in groundwater, aquifers and water lens due to over-exploitation and also resulted in quality deterioration (Sharma et al., 2017) which the groundwater quality and quantities has become crucial especially in arid and semi-arid regions where rainfall is irregular and major water supplies to drinking and irrigation are met by groundwater (Ramesh and Elango, 2012; Roy et al., 2018). In arid and semi-arid regions like Iran were faced with different aspect of shortcomings and mismanagements, demand for freshwater resource has been an incredible increases which it is worrying in its place.

Bonab Plain is one of the largest plains of Lake Urmia, which covers more than 5 major cities of the East-Azerbaijan province (except Tabriz city) includes the Bonab, Maragheh, Ajabshir, Malekan cities and neighboring villages were that contain over one million people in the region. The studied area is located in northwest of Iran and Fig. 1 is present the location of the Bonab city and Bonab plain. In term of geology, the Bonab plain mainly covered by Quaternary alluvial despites related to the Urmia Lake sedimentary fans (Azarafza and Mokhtari, 2013; Azarafza and Ghazifard, 2016). But some rocky outcrop of the limestone, sandstone and dolomolimestones relate the maragheh formations are shows in north part of the studied area which related to Sahand Mountains. Sahand is a massive, heavily eroded stratovolcano in East-Azerbaijan province and by 3,707 m, it is the highest mountain in the province (also, considered as is one of the highest mountains in Iranian). Sahand being an important dormant volcano in the country which are directly located in north part of Bonab plain, the highest peak of which is Kamal at an

*** Corresponding author.**
E-mail address: dariushahadi@gmail.com
M.Sc., Research Assistant.

elevation of 3,707 m. Approximately 17 peaks can be accounted for as being over 3,000 m in height. Due to the variety of flora and fauna presence, the Sahand mountains are known as the bride of mountains in Iran which is made chiefly of dacite and associated felsic rocks. As absolute dating of Sahand rocks is indicates that this volcano has been sporadically active from 12 million years ago up to almost 0.14 million years ago (Aghanabati, 2007). The region in term of the meteorological condition is mainly moderate and alpine climate which aren't many changes throughout the year, but the semi-arid climatological index is present of the region. The city has very low seismic activity and is generally inactive. Therefore, this factor is not included in the analysis of landslides in the Bonab region.

Figure 1. Location of studied area

2. Material and Methods

In order to groundwater quality estimation for Bonab Plain gathered the 25 samples were collected from 25 hand pumps bores related to agricultural farms during September to December, 2018 which are used for cities drinking and agricultural irrigation purposes. The samples were performed according to APHA (2005) guidelines which are prepared with 1 liter polyethylene bottles were rinsed with distilled water followed by deionized water were collected after pumping out water for about 10 min to remove stagnant water from the well and then transferred and stored at 4 °C. The water contents moved to the water laboratory in Department of Agriculture, University of Mohaghegh Ardabili to analyze based on standard instructions. In this regard, groundwater samples were analyzed for various hydrochemical parameters, such as pH, electrical conductivity (EC), $CaCO_3$ cations (e.g., calcium, magnesium, sodium and potassium), and anions (e.g., chloride, bicarbonate, sulfate, nitrate, and fluoride). Table 1 is present the statistical summary of physicochemical parameters form taken samples from Bonab Plain. For the identification of water characteristics and quality evaluations used the sodium adsorption ratio (SAR) and United States Salinity Laboratory diagram (USSL) procedures. The SAR is an irrigation water quality parameter used in the management of sodium-affected soils. It is an indicator of the suitability of water for use in agricultural irrigation, as determined from the concentrations of the main alkaline and earth alkaline cations present in the water. It is also a standard diagnostic parameter for the sodicity hazard of a soil, as determined from analysis of pore water extracted from the soil. The formula for calculating the SAR is (Reeve et al., 1954):

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

where [Na] is sodium, [Ca] is calcium, and [Mg] magnesium concentrations are expressed in meq/lt.

SAR allows assessment of the state of flocculation or of dispersion of clay aggregates in a soil. Sodium and potassium ions facilitate the dispersion of clay particles while calcium and magnesium promote their flocculation. The behavior of clay aggregates influences the soil structure and affects the permeability of the soil which directly depends on the water infiltration rate. It is important to accurately know the nature and the concentrations of cations at which the flocculation occurs: critical flocculation concentration (CFC). The SAR parameter is also used to determine the stability of colloids in suspension in water. Although SAR is only one factor in determining the suitability of water for irrigation, in general, the higher the sodium adsorption ratio, the less suitable the water is for irrigation. Irrigation using water with high sodium adsorption ratio may require soil amendments to prevent long-term damage to the soil. If irrigation water with a high SAR is applied to a soil for years, the sodium in the water can displace the calcium and magnesium in the soil. This will cause a decrease in the ability of the soil to form stable aggregates and a loss of soil structure. This will also lead to a decrease in infiltration and permeability of the soil to water, leading to problems with crop production. Sandy soils will have fewer problems, but fine-textured soils will have severe problems if SAR is greater than 9. When SAR is less than 3, there will not be a problem. The Fig. 2 is presents the SAR classification (Rashidi, 2012).

Sodium Hazard Class	SAR (meq/L)	Remark
C1	0-10	Excellent (Little or no Hazard)
C2	10-18	Good (Appreciable hazard but can be used with appropriate management)
C3	18-26	Doubtful (Unsatisfactory for most of the crops)
C4	>26	Unsuitable (Unsatisfactory for all the crops)

Figure 2. SAR classification system (Rashidi, 2012)

The U.S. salinity laboratory is a national laboratory for research on salt-affected soil-plant-water systems which it resorts under the agricultural research service (ARS) of the United States Department of Agriculture (USDA) and is located in Riverside, California. The USSL diagram presented by ARS commonly used for investigates the irrigation waters quality based on SAR and EC values (Twomey, 2019). Figure 3 is presented the USSL classification diagram. In this study, this diagram used for

prepare the classification of groundwater conditions in Bonab Plain.

Table 1 SAR classification system (Rashidi, 2012)

Parameter	Unit	Max	Min	Mean	S.D.
pH	-	7.2	8.3	7.75	0.77
EC	µS/cm	544	766	655	156.7
Calcium	mg/l	1.9	578.3	290.1	407.5
Magnesium	mg/l	0.85	1277	638.92	902.3
Sodium	mg/l	89.17	4155	2122	2874
Potassium	mg/l	1.66	35.50	18.58	23.92
Bicarbonate	mg/l	65.44	1950.2	1007.8	1332
Chloride	mg/l	17.4	7880.3	3948.8	5559
Sulphate	mg/l	15.10	1258	636.5	878.8
Nitrate	mg/l	0.3	5.4	2.85	3.606

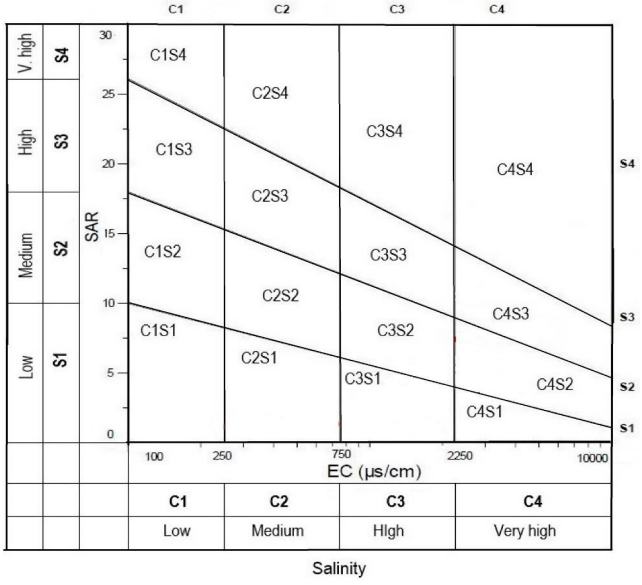

Figure 3. USSL classification chart (Twomey, 2019)

3. Results and Discussions

The groundwater mainly used for domestic or agricultural purposes such as drinking, cooking, irrigation, etc. which should be limited from toxic chemicals and pathogens (Twomey, 2019). Thus, the percentage of cations/anions must be estimated to lead the proper tasks. In this regard, the 25 sample were taken from the Bonab plain. Mainly irrigation groundwater n this study area was assessed using sodium percentage, SAR, USDA and USSL classifications. Tables 2 and 3 are presented the results of the experimental evaluations of water properties. In the meantime, USSL chart is used for water quality description of the area. The Malaza (2017) instructions were used to perform experiments.

Table 2 Bonab groundwater classification based on TDS

TDS (mg/l)	Water type	Samples number	Percentage
<1000	Fresh	7	28
1000 – 10000	Brackish	10	40
10000 – 100000	Saline	5	20
>100000	Brine	3	12

Table 3 Bonab water irrigation suitability by USDA

EC (µS/cm)	Salinity class	Samples percentage	Quality remark
<250	C1	30	Low
250 – 750	C2	40	Medium
750 – 2250	C3	20	High
2250 – 5000	C4	10	Very high

Irrigation waters classification with respect to SAR is based primarily on the sodium exchangeable effect on the soil physical condition. Thus, sodium-sensitive plants may suffer injury as a sodium accumulation result in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the soil physical condition. USSL diagram is applied the SAR vs. EC values which produce the salinity chart were classified in four categories included (Twomey, 2019):

- *S1*: Low sodium content water (It can be used in each type soil);
- *S2* and *S3*: Medium and high sodium content water, respectively (It may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as adding gypsum and organic matters to soil);
- *S4*: Very high sodium content water (It is generally unsuitable for irrigation).

Table 4 is presented the results of the quality estimation for Bonab groundwater for suitability in domestic or agricultural activities.

Table 4 Results of the USSL classification for Bonab water

Sample	EC	SAR	USSL
1	650	1.20	C2S1
2	630	1.77	C2S1
3	590	2.09	C2S1
4	588	1.85	C2S1
5	557	1.77	C2S1
6	630	1.39	C2S1
7	601	1.63	C2S1
8	544	1.25	C2S1
9	557	2.11	C2S1
10	588	1.20	C2S1
11	630	1.60	C2S1
12	644	1.55	C2S1
13	760	1.85	C3S1
14	549	1.20	C2S1
15	630	1.39	C2S1
16	614	1.83	C2S1
17	633	2.16	C2S1
18	595	1.45	C2S1
19	611	1.77	C2S1
20	766	1.25	C3S1
21	740	1.49	C3S1
22	750	1.37	C3S1
23	579	0.59	C2S1
24	690	1.25	C2S1
25	739	0.66	C3S1

As results it has been determined that the water samples of Bonab plain is in located on C2S1 and C3S1 classes based on USSL classification which is indicated the low to moderate salinity.

4. Conclusion

Groundwater quality diagrams classify the water quality in separated classes which is commonly use for categorize the aim of water utilization like domestic or agricultural purposes. These classes are responsible for the cations/anions concentration such as sodium, calcium, potassium, and magnesium as well as carbonate and bicarbonate concentrations in the groundwater. Thus, knowledge of concentration rate these elements can be used for quality classifications. The presented study has relied on this issue and tried to apply a laboratory study for groundwater quality in Bonab Plain located in East-Azerbaijan, northwest of Iran. In this regard, the experimental procedure concluded electrical conductivity (EC), sodium adsorption ratio (SAR) and U.S. salinity laboratory diagram (USSL) was conducted. The 25 samples of Bonab groundwater was taken and utilized the empirical test under standard methods. As results of this study, it has been determined that the water samples of Bonab plain is in located on C2S1 and C3S1 classes based on USSL classification which is indicated the low to moderate salinity.

Acknowledgements

The authors wish to thank the Department of Agriculture for giving the permission and laboratory for this study.

References

Adimalla N., 2018. Groundwater Quality for Drinking and Irrigation Purposes and Potential Health Risks Assessment: A Case Study from Semi‐Arid Region of South India. *Exposure and Health*, 11: 109-123.

Aghanabati A., 2007. *Geology of Iran*. Geological Survey of Iran press, Tehran, Iran. [In Persian]

APHA, 2005. *Standard method for examination of water and wastewater* (21th edition). APHA, AWWA, WPCF, Washington DC.

Azarafza M., Ghazifard A., 2016. Urban geology of Tabriz City: Environmental and geological constraints. *Advances in Environmental Research (AER): An International Journal*, 5(2): 95-108.

Azarafza M., Mokhtari M.H., 2013. Evaluation drought effect on the Urmia lake salinity change by using remote sensing techniques. *Arid Biome Scientific and Research Journal*, 3(2): 1-14. [In Persian]

Malaza N., 2017. Hydrogeochemical assessment of groundwater quality in the Soutpansberg Basin around Tshikondeni, Limpopo Province, South Africa. *Geochemistry: Exploration, Environment, Analysis*, 17: 35-41.

Ramesh K., Elango L., 2012. Groundwater quality and its suitability for domestic and agricultural use in Tondiar river basin, Tamil Nadu, India. *Environmental Monitoring and Assessment*, 184(6): 3887-3899.

Rashidi M., 2012. *Pedotransfer Functions: Cation Exchange Capacity-Sodium Adsorption Ratio-Exchangeable Sodium Percentage-Total Nitrogen-Available Phosphorous*. LAP LAMBERT Academic Publishing, 180 p.

Reeve R.C., Bower C.A., Brooks R.H., Gschwend F.B., 1954. A comparison of the effects of exchangeable sodium and potassium upon the physical condition of soils. *Soil Science Society of America Journal*, 18(2): 130.

Roy A., Keesari T., Mohokar H., Sinha U.K., Bitra S., 2018. Assessment of groundwater quality in hard rock aquifer of central Telangana state for drinking and agriculture purposes. *Applied Water Science*, 8: 124.

Sharma D.A., Rishi M.S., Keesari T., 2017. Evaluation of groundwater quality and suitability for irrigation and drinking purposes in southwest Punjab, India using hydrochemical approach. *Applied Water Science*, 7(6): 3137-3150.

Twomey D., 2019. *Principles and Practices of Irrigation Water Management*. Callisto Reference, 213 p.