ISSN: 2538-2152; ECOPERSIA 2022;10(4):257-266.

Groundwater suitability in Tashk-Bakhtegan and Maharloo basin, Iran

ARTICLEINFO

Article Type
Original Research

Author
Pouyan Dehghan Rahimabadi, *Ph.D.*[1]
Reyhaneh Masoudi, *Ph.D.*[2*]
Mahsa Abdolshahnejad, *Ph.D.*[1]
Esmaeil Hojjati Marvast, *M.Sc.*[3]

How to cite this article
Dehghan Rahimabadi P., Masoudi R., Abdolshahnejad M., Hojjati Marvast E. Groundwater suitability in Tashk-Bakhtegan and Maharloo basin, Iran. ECOPERSIA 2022;10(4): 257-266

DOR:
20.1001.1.23222700.2022.10.4.1.0

[1] Ph.D. in Combat Desertification, Faculty of Natural Resources, University of Tehran, Tehran, Iran
[2] Ph.D. in Combat Desertification, Faculty of Natural Resources, University of Tehran, Tehran, Iran
[3] M.Sc. Watershed Management, Faculty of Natural Resources & Desert Studies, Yazd University, Yazd, Iran

***Correspondence**
Address: Department of Reclamation of Arid and Mountainous Regions, Faculty of Natural Resources, University of Tehran, Karaj, Alborz, Iran
Tel: +982632227765
Fax: +982632222045
Email: r.masoudi@ut.ac.ir

Article History
Received: May 19, 2022
Accepted: October 21, 2022
Published: November 15,2022

ABSTRACT

Aims: The main goal of the present study is the investigation of the suitability of groundwater for drinking and irrigation consumption in the Tashk-Bakhtegan and Maharloo basin based on the data from 420 observation wells.

Materials & Methods: Hydrogeochemical parameters including Potassium (K^+), Sodium (Na^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Chloride (Cl^-), Bicarbonate (HCO_3), Sulfate (SO_4^{2-}), Electrical Conductivity (EC) and total soluble solids (TDS) for 420 monitoring wells in November 2017 (as a dry month) and May 2018 (as a wet month) were used to estimate Drinking Water Quality Index (DWQI) and Irrigation Water Quality Index (IWQI) for determining the suitability of groundwater.

Findings: The results indicated that groundwater quality for drinking consumption varied widely across the basin and the mean value of DWQI increased from 238.83 in November 2017 to 249.79 in May 2018. IWQI results indicated that in most areas, especially on the north and south side of the basin, groundwater has moderate, high, and severe limitations for agricultural activities in both months. The average value of IWQI increased from 47.67 in November 2017, to 49.67 in May 2018, reflecting a slight increase in groundwater quality for agricultural uses.

Conclusion: According to the obtained results, it can be said that necessary precautions should be taken for groundwater before using it for different purposes, and the results can be utilized in the management and organization of groundwater resources.

Keywords: Drinking; Groundwater; Irrigation; Hydrogeochemical.

CITATION LINKS

[1] Dehghan Rahimabadi P., Azarnivand H., Malekian A. Hydrogeological... [2] Sakizadeh M. Performance of Classification Methods to Evaluate... [3] Bahar Gogani M., Douzbakhshan M., Shayesteh K., Ildoromi A.R. New formulation... [4] Ghazavi R., Ebrahimi H. Estimation of Artificial Groundwater... [5] Ravikumar P., Somashekar R.K. Principal... [6] Su Z., Wu J., He X., Elumalai V. Temporal changes of groundwater quality... [7] Priyanka M., Venkata M., Ratnakar D. Groundwater Quality... [8] Abdalazem, A.H., Gamee M.A., Hamdan A., Awad A.A.M., Mohamed A.G. Groundwater Quality... [9] Ravikumar P., Somashekar R., Angami M. Hydrochemistry and evaluation of groundwater suitability for irrigation and... [10] Elsayed, S., Hussein H., Moghanm F.S., Khedher K.M., Eid E.M., Gad M. Application of Irrigation Water Quality Indices and... [11] Taheri M., Gharaie M.H.M., Mehrzad J., Afshari R., Datta S. Hydrogeochemical and isotopic evaluation of arsenic... [12] Banda, T.D., Kumarasamy M. Application of multivariate... [13] Horton R.K. An index number system for... [14] Ram A., Tiwari S., Pandey H., Chaurasia A.K., Singh S., Singh Y. Groundwater quality assessment... [15] Khalaf R.M., Hassan W.H. Evaluation of irrigation water quality index IWQI for Al-Dammam confined... [16] Tarawneh M.S.M., Janardhana M.R., Ahmed M.M. Hydrochemical processes and... [17] Abbasnia A., Yousefi N., Mahvi A.H., Nabizadeh R., Radfard M., Yousefi M., Alimohammadi M. Evaluation of groundwater quality... [18] Jehan S., Ullah I., Khan S., Muhammad S., Khattak S.A., Khan T. Evaluation of... [19] Subba Rao N., Srihari C., Deepthi Spandana B., Sravanthi M., Kamalesh T., Abraham Jayadeep V. Comprehensive understanding of... [20] Ramachandran Muthulakshmi Y. Geo-spatial analysis... [21] Yıldız S., Karakuş C.B. Estimation of... [22] Sadat-Noori S., Ebrahimi K., Liaghat A. Groundwater quality assessment... [23] Soleimani H., Nasri O., Ojaghi B., Pasalari H., Hosseini M., Hashemzadeh B., Kavosi A., Masoumi S., Radfard M., Adibzadeh A. Data on... [24] Hojjati, M.H., Boustani F. An assessment of... [25] Nafarzadegan A., Zadeh M.R., Kherad M., Ahani H., Gharehkhani A., Karampoor M., Kousari M. Drought... [26] Choubin B., Malekian A., Golshan M. Application of several data-driven techniques to... [27] Brown R.M., McClelland N.I., Deininger R.A., Tozer R.G. Water... [28] Ayers R.S., Westcot D.W. Water quality for agriculture: Food... [29] Meireles, A.C.M., Andrade E.M.D., Chaves L.C.G., Frischkorn H., Crisostomo L.A. A new...

Introduction

Groundwater resources are considered crucial needs in agricultural water in arid and semi-arid areas, due to the lack of surface water [1]. Most regions of Iran in arid and semi-arid lands, thus, groundwater may be used as the main water source in these areas [2, 3]. As a result, groundwater is the main freshwater source for drinking and agricultural activities [4]. Hence the evaluation of groundwater quality in modern life should be done for different purposes [5].

Groundwater quality is often a complex phenomenon, in which many elements are involved and are directly or indirectly affected by the leaching of hazardous chemicals from soil [6] and results in the interaction of water and rock during the water infiltration process and hydrological cycle and carried organic matter from soil to water [7]. Therefore, excessive amounts of ions and groundwater-soluble elements used for irrigation can affect plants and soils in agricultural lands, reducing crop productivity [8,9].

The physical and chemical properties and different groundwater criteria provide basic information about various geochemical processes, and water properties for various uses [10] and reflect sources of key components, environmental conditions, and suitability [11]. In recent decades, various techniques have been adopted to accurately determine groundwater quality. Water Quality Index (WQI), which is fixed important hydrogeochemical parameters, is simple and can act as a groundwater quality index, as well [12], and provide useful and important information for users. WQI, which is based on the calculations and assigning a weight of various elements, was initially presented by Horton (1965) based on the calculations and assigning a weight of various elements [14]. This index ranges from 0 to 100 values, which converts complex information from several elements into a single dimensionless number reflecting the overall water quality in a specific place and time [15]. In recent years, the Drinking Water Quality Index (DWQI) [16,19] and Irrigation Water Quality Index (IWQI) [17,20,21] have been created to evaluate the suitability of water for drinking and irrigation purposes, respectively.

Much research has been carried on for assessing groundwater suitability in Iran. Sadat-Noori *et al.* [22] studied groundwater suitability in Qorveh and Dehgolan, Kurdistan, using a sampling of 50 observation wells. Their results showed that WQI results showed that 36% of wells have groundwater with "Excellent" quality and 64% of them have "Good" quality. Also, the calculated index for irrigation groundwater suitability indicated that groundwater quality in all collected samples is in the "Excellent" and "Good" categories. Soleimani *et al.* [23] assessed the quality of groundwater in Saveh plain, using 58 observation wells data. WQI results showed groundwater in more than 65% of wells have "Poor", "Very weak" or "Unsuitable" quality, which indicated that groundwater was mostly unsuitable for drinking in this plain. Abbasnia *et al.* [17] investigated groundwater suitability for using in both domestic and agricultural uses in Sistan and Baluchestan Province using the information from 654 wells and reported that just 1.2% of total samples have "Excellent" quality, 52.1% of samples have "Good" quality, 39% of them have "Poor" quality, 6% were classified in "Very poor" and 1.7% in "Unsuitable" for drinking. The IWQI also indicated that 19.9% of samples are in the "Excellent" class and 80.1% of them are categorized into the "Good" class.

The Tashk-Bakhtegan and Maharloo basin is located in an arid and semi-arid region. Life is dependent on groundwater in this basin because of the shortage of surface water and agricultural activities, which are the main occupation of local people. Hence, this study aims to evaluate groundwater suitability for drinking and agricultural purposes in both wet

[DOR: 20.1001.1.23222700.2022.10.4.1.0]

and dry seasons using the hydrogeochemical parameters to plan and adopt appropriate groundwater management strategies. The results of this study can help decision-makers with important information on groundwater suitability for drinking and agricultural purposes.

Materials & Methods

Study area

Tashk-Bakhtegan and Maharloo basin, which includes northern and central parts of Fars Province, Iran, is the study area. Most regions of this basin have arid or semi-arid climates [24] and are on the Zagros mountain ranges. The latest droughts and the absence of other surface water resources have caused excessive groundwater exploitation for irrigated agriculture activities and led to the depletion of groundwater levels in the [25]. Table 1 and Figure 1 show the properties and location of the basin with the monitoring wells, respectively.

Table 1) Properties of Tashk-Bakhtegan and Maharloo basin.

Properties	Range
Longitude	51° 42’ - 54° 37 N
Latitude	29° 01’ - 31° 11’ E
Elevation Range (m)	1987 -3922
Annual Average Rainfall (mm)	270* (26)
Area (ha)	3145840

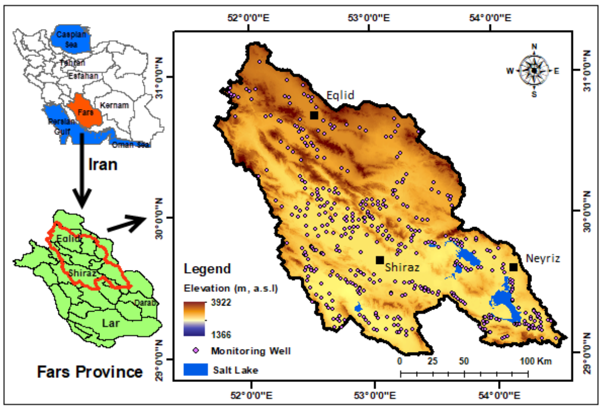

Figure 1) Location of Tashk-Bakhtegan and Maharloo basin and monitoring wells in Iran (*Generated by authors*).

Land Use Land Cover

Land Use Land Cover (LU/LC) map was generated for the study area using MODIS Land Cover (MCD12Q1) images for the year 2019 (https://search.earthdata.nasa.gov) and classified based on supervised classifications of MODIS Terra and Aqua reflectance data. The spatial LU/LC derived 7 classes including water body, open shrubland, grassland, permanent wetland, cropland, urban and non-vegetation areas (Figure 2), and most of the studied basin covered by shrublands. Agricultural lands are mostly located in the center of the basin and southern and northwestern parts are covered by non-vegetation areas.

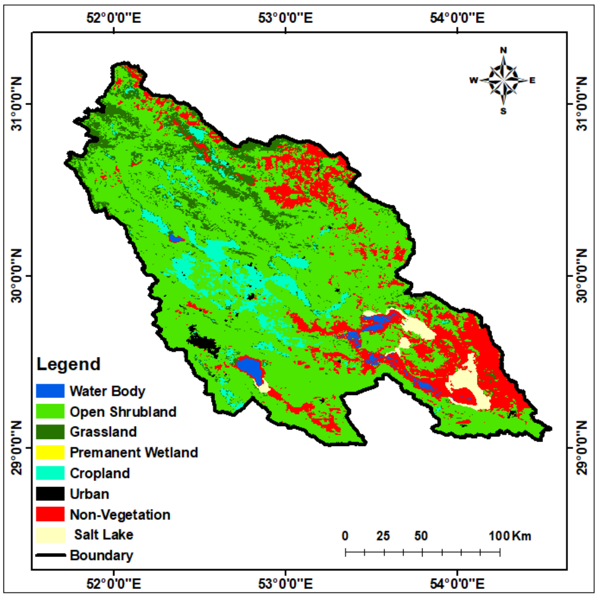

Figure 2) LULC map of Tashk-Bakhtegan and Maharloo basin in 2018 (*Generated by authors*).

Data Collection

To assess the groundwater suitability, the hydrogeochemical parameters of groundwater including Potassium (K^+), Sodium (Na^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Chloride (Cl^-), Bicarbonate (HCO_3^-), Sulfate (SO_4^{2-}), Electrical Conductivity (EC) and Total Soluble Solids (TDS) for 420 observation wells in November 2017 (dry season) and May 2018 (wet season) from Iran Water Resources Management Company (https://www.wrm.ir/) were prepared and used.

Table 2) Relative weight of hydrogeochemical parameters and their standard values based on WHO (2011).

Parameters	Units	WHO standard (S_i)	WQI weight (W_i)	Relative weight (rw_i)
K^+	(mg.L^{-1})	12	2	0.077
Na^+	(mg.L^{-1})	200	2	0.077
Mg^{2+}	(mg.L^{-1})	50	1	0.038
Ca^{2+}	(mg.L^{-1})	75	2	0.077
SO_4^-	(mg.L^{-1})	250	4	0.154
Cl^-	(mg.L^{-1})	250	3	0.115
HCO_3^-	(mg.L^{-1})	120	3	0.115
pH	-	6.5–8.5	4	0.154
TDS	(mg.L^{-1})	500	5	0.193
Sum	-	-	26	1

Methodology

DWQI computing involves assigning a weight to each parameter and normalizing weights, normalizing parameters based on standards from World Health Organization (WHO), computing individual DWQI for each observed point, and finally aggregating and zoning the scores.

The relative weight for each hydrogeochemical parameter is computed using equation 1:

$$rw_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad \text{Eq. (1)}$$

Where rw_i is the relative weight of the i^{th} parameter (Table 2), w_i is the weight of the i^{th} parameter and n is the number of parameters.

The observed data are normalized according to standards using equation 2:

$$q_i = \left(\frac{C_i}{S_i}\right) \times 100 \quad \text{Eq. (2)}$$

Where; qi is the quality rating, Ci is the concentration of each hydrogeochemical parameter in each well (mg.L^{-1}) Si is the WHO standard for each hydrogeochemical parameter in milligrams per liter according to the guidelines of WHO (mg.L^{-1}). Then the subindex of each parameter (S_I) is computed by multiplying the quality rating of each parameter by its normalized weight using equation 3, and finally, the sum of all subindices gives the DWQI value for each sampling point as equation 4.

$$SI_i = rw_i \times q_i \quad \text{Eq. (3)}$$

$$DWQI = \sum_{i=1}^{n} SI_i \quad \text{Eq. (4)}$$

After calculating the DWQI value for each sampling point, groundwater quality can be categorized into different classes according to Table 3.

Table 3) Classification of the water quality according to the WQI [27].

Range	Type of Groundwater
< 50	Excellent
50 – 100	Good
100 – 200	Poor
200 – 300	Very Poor
300	Unsuitable for Drinking

Irrigation Water Quality Index (IWQI)

IWQI is computed using five hydrogeochemical parameters including Na^+, Cl^-, HCO_3^-, EC, and SAR, which play main roles in groundwater sustainability for irrigation. In this case, SAR is calculated as equation 5:

[DOR: 20.1001.1.23222700.2022.10.4.1.0]

$$\mathrm{SAR} = \frac{(Na^{+})}{\left(\frac{(Ca^{2+}+Mg^{2+})}{2}\right)^{\frac{1}{2}}} \qquad \text{Eq. (5)}$$

Afterward, the weighting of the hydrogeochemical parameters is determined. This weight includes hydrogeochemical parameter values of the groundwater sample and relative weight for each parameter and finally the criteria proposed by Ayers and Westcot (1985). The lower values indicate poorer groundwater quality. The value of q_i is computed using equation 6:

$$q_i = q_{max} - \left(\frac{[(x_{ij} - x_{inf}) \times q_{iamp}]}{x_{amp}}\right) \qquad \text{Eq. (6)}$$

Where; q_{imax} is the maximum value of q_i for the class, x_{ij} is the observed value for the parameter, x_{inf} is a value corresponding to the lower limit of the class, to which the parameter belongs, q_{iamp} is class amplitude, and x_{amp} is class amplitude to which the parameter belongs.

The upper limit value was regarded as the highest value determined during the analysis of the groundwater sample and w_i values were eventually normalized according to equation

$$w_i = \sum_{j=i}^{k} F_j\, A_{ij} \Big/ \sum_{j=1}^{k} \sum_{i=1}^{n} F_j A_{ij} \qquad \text{Eq. (7)}$$

Where; w_i is the weight of the parameter for the IWQI, F is a constant value of component 1, A_{ij} is the explainability of parameter i by factor j, and i is the number of hydrogeochemical parameters selected by the model, ranging from 1 to n and j is the number of factors selected in the model, varying from 1 to k.

The values of q_i were computed based on acceptable limits of groundwater quality parameters (Table 4). It is estimated by the University of California Advisory Committee (UCCC) [17].

Eventually, the value of IWQI can be computed using equation 8:

$$IWQI = \sum_{i=1}^{n} q_i \times w_i \qquad \text{Eq. (8)}$$

IWQI values are dimensionless and varied between 0 and 100 which constrains the use of irrigation and are classified according to Table 5.

Table 5) Irrigation Water Quality Index Characteristics [30].

IWQI	Water Use Restrictions
85 ≤ 100	No Restriction (NR)
70 ≤ 85	Low Restriction (LR)
55 ≤ 70	Moderate Restriction (MR)
40 ≤ 55	High Restriction (HR)
0 ≤ 40	Severe Restriction (SR)

Findings

Groundwater Hydrochemical Analysis

Statistical analysis of the relationship between parameters and ion concentrations in groundwater samples can explain the interaction between them. According to the

Table 4) Parameter limiting values for quality measurement (q_i) calculation and weights for the IWQI parameters [30].

q_i	EC ($S.cm^{-1}$)	SAR	Na^+ ($meq.L^{-1}$)	Cl^- ($meq.L^{-1}$)	HCO_3^- ($meq.L^{-1}$)
85-100	0.20 EC < 0.75	2 ≤ SAR < 3	2 ≤ Na^+ < 3	1 ≤ Cl^- < 4	1 ≤ HCO_3^- < 1.5
60-85	0.75 ≤ EC < 1.5	3 ≤ SAR < 6	3 ≤ Na^+ < 6	4 ≤ Cl^- < 7	1.5 ≤ HCO_3^- < 4.5
35-60	1.50 ≤ EC < 3.00	6 ≤ SAR <12	6 ≤ Na^+ < 9	7 ≤ Cl^- <10	4.5 ≤ HCO_3^- <8.5
0-35	EC < 0.20 or EC 3.00	SAR < 2 or SAR 12	Na^+ < 2 or Na^+ 9	Cl^- < 1 or Cl^- 10	HCO_3^- < 1 or HCO_3^- 8.5
	0.211	0.189	0.204	0.194	0.202

[DOR: 20.1001.1.23222700.2022.10.4.1.0]

Table 6) Correlation matrix of hydrogeochemical parameters.

Parameter	K^+	Na^+	Mg^{2+}	Ca^{2+}	SO_4^{-2}	Cl^-	HCO_3^-	pH	TDS	EC	SAR
K^+	1										
Na^+	0.90**	1									
Mg^{2+}	0.85**	0.67**	1								
Ca^{2+}	0.80**	0.64**	0.79**	1							
SO_4^{-2}	0.73**	0.75**	0.65**	0.64**	1						
Cl^-	0.96**	0.91**	0.87**	0.86**	0.70**	1					
HCO_3^-	-0.13*	-0.08*	-0.10**	-0.20**	-0.10**	-0.16**	1				
pH	-0.15*	-0.17**	-0.11*	-0.16**	-0.11*	-0.17**	-0.12*	1			
TDS	0.95**	0.91**	0.85**	0.83**	0.77**	0.97**	-0.11**	-0.17**	1		
EC	0.95**	0.91**	0.86**	0.83**	0.77**	0.97**	-0.13**	-0.18**	0.98**	1	
SAR	0.74**	0.93**	0.46**	0.43**	0.68**	0.75**	0.01	-0.15**	0.76**	0.77**	1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

correlation coefficient (*R*) of hydrogeochemical parameters, TDS has a highly significant correlation with the concentration of all cations and anions, except for HCO_3^-. As well, there is a highly significant correlation between TDS and EC (*r=0.98*), which can be due to water-rock interaction and mineral dissolution in groundwater. A high significant correlation (*r=0.91*) of Na^+ with Cl^- indicates the high salinity of groundwater. These two ions are concentrated as a result of natural activities and the movement of groundwater from different terrestrial facies or as a result of human activities. The weak relationship between HCO_3^- with Mg^{2+} and Ca^{2+} shows calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), which control the concentration of these ions, do not dissolve in groundwater. The low correlation coefficient of Ca^{2+} and SO_4^{2-} (*r=0.64*) indicating gypsum is not the source of these two ions. The correlation matrix of hydrogeochemical parameters of groundwater based on elements in groundwater samples is presented in Table 6.

Drinking Water Quality Index (DWQI)

According to DWQI, the maximum and minimum values of DWQI are 31.56 and 1155.28, respectively, in November 2017. 42 (10%) of collected samples are categorized into the "Excellent" class, 161 (38.5%) samples into the "Good" class, 75 (18%) samples into the "Poor" class, 22 (5%) samples into "Very poor" class 120 (28.5%) samples were classified as "Unsuitable". While the value of DWQI in May 2018 is in the range of 41.17 to 1528.44. 40 (9.5%) samples are categorized into the "Excellent" class, 162 (38.5%) samples into the "Good" class, 70 (16.5%) samples into the "Poor" class, 19 (4.5%) samples into "Very poor" class and 129 (31%) samples into "Unsuitable" class. Based on spatial distribution maps of DWQI, the value of DWQI is generally increasing from north to south, so there is spatial variation in groundwater quality having high quality on the northern side and poor quality on the southern parts of the basin (Figure 3).

[DOR: 20.1001.1.23222700.2022.10.4.1.0]

DWQI maps show groundwater quality is classified into different classes and the DWQI value is higher in the north of the basin than in other parts. In November 2017, "Excellent" quality includes 13.69% of the basin, "Good" quality includes 39.33%, "Poor" quality includes 11.80%, "Very poor" quality includes 6.73%, and "Unsuitable" quality includes 28.45% and in May 2018, "Excellent" quality includes 11.15% of the basin, "Good" quality includes 41.09%, "Poor" quality includes 11.91%, "Very poor" quality includes 7.22% and "Unsuitable" quality includes 28.63%.

Irrigation Water Quality Index (IWQI)

According to IWQI, in November 2017, the maximum and minimum values of IWQI are 22.85 and 89.33, respectively. One (0.24%) of the collected sample is classified into the "No Restriction" class, 44 (10.48%) samples into the "Low Restriction" class, 73 (17.38%) samples into the "Moderate Restriction" class, 157 (37.38%) samples into the "High Restriction" class and 145 (34.52%) samples into the "Severe Restriction" class. While the value of DWQI in May 2018 is in the range of 20.48 to 89.67. 5 (1.19%) samples are categorized into the "No Restriction" class, 67 (15.95%) samples in the "Low Restriction" class, 60 (14.29%) samples into the "Moderate Restriction" class, 162 (38.57%) samples into "High Restriction" class and 126 (30%) samples into "Severe Restriction" class. According to IWQI spatial distribution maps, the value of this index is more in the central parts of the basin than in the northern and southern parts in both months, indicating the groundwater in the central parts has more suitability than the northern and southern parts for agricultural purposes (Figure 4). IWQI maps show that groundwater quality is classified into different classes, its value is lower in the north and south sides than in the

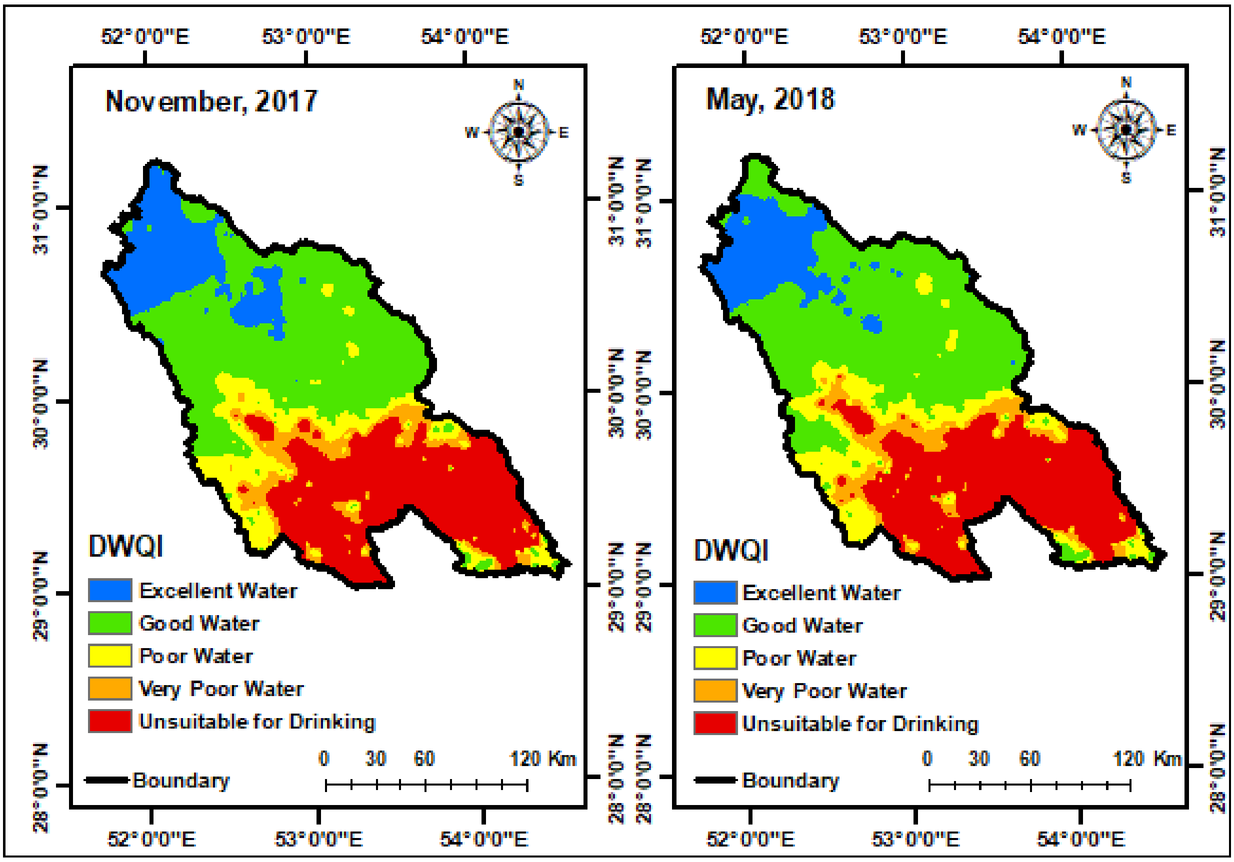

Figure 3) Classified maps of DWQI.

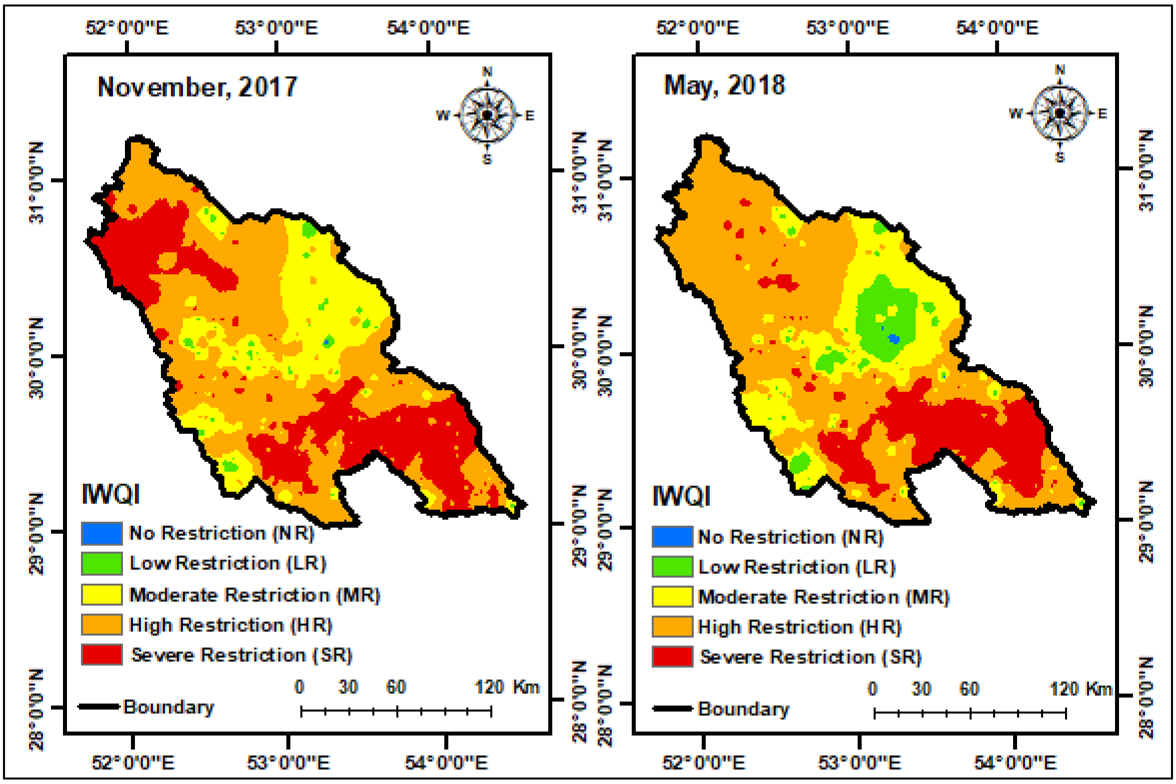

Figure 4) Classified maps of IWQI.

central parts of the study area. In November 2017, 0.01% of the basin has groundwater in the "No Restriction" quality class, 1.27% in the "Low Restriction" class, 22.12% in the "Moderate Restriction" class, 48.39% in the "High Restriction" class and 28.21% in "Severe Restriction" class. While, in May 2018, 0.11% of the basin has groundwater with a "No Restriction" class, 6.67% with a "Low Restriction" class, 20.46% "Moderate Restriction" class, 54.98% "High Restriction" class and 17.78% with "Severe Restriction" class.

Discussion

The suitability of groundwater in the Tashk-Bakhtegan and Maharloo basin was determined using DWQI and IWQI through the Geographic Information System (GIS). Using these indices along with GIS can provide an efficient summary of groundwater quality status.

Groundwater hydrochemical analysis showed that TDS has a highly significant correlation with Cations and Anions. Element leaching from rocks to groundwater can be caused high TDS and electrical conductivity [17]. Also, there is a strong positive relationship between Na^+ and Cl^- indicating high salinity of groundwater. A high concentration of Na^+ and its exchange in groundwater can reduce soil permeability and drainage.

DWQI results showed that there were all 5 classes of groundwater quality, which indicated that the quality of groundwater was completely variable throughout the basin. The average value of DWQI increased from 238.83 in November 2017 to 249.79 in May 2018. This reduction in quality was greater in the central parts, where more urban areas are located. Generally, DWQI status was moderate in urban areas compared to other parts.

Also, IWQI results revealed groundwater in most areas of the basin, especially in the northern and southern parts, had a high limitation. The average value of IWQI increased from 47.67 to 49.67 during the

[DOR: 20.1001.1.23222700.2022.10.4.1.0]

studied period. In the southern parts, groundwater was almost unsuitable for irrigation. For this reason, there are barren lands in these areas without vegetation. In the central areas, groundwater had a higher quality than other parts. This better quality has caused agricultural lands to be located in these areas.

Conclusion

According to the results obtained in this study, groundwater resources are qualitatively more suitable for drinking in the northern parts of the Tashk-Bakhtegan and Maharloo basin than in the southern parts in both dry and wet seasons. Based on DWQI, groundwater in the northern parts have "Excellent" and "Good" quality; while it has "Very Poor" and "Unusable" quality in the southern parts. IWQI showed the groundwater quality is poor in most areas of the basin in both dry and wet seasons, due to the high salinity, which has placed many restrictions on irrigation. Lands in the central parts of the study area have the best groundwater quality, and most agricultural lands are located in these areas. In general, the quality of groundwater for drinking consumption has decreased slightly in the basin in both wet and dry seasons, but it has increased slightly for agricultural use.

Finally, it can be suggested that according to the climatic and environmental conditions of the Tashk-Bakhtegan and Maharloo basin, groundwater resources should be properly planned and managed and also taken necessary precautions before using it for drinking and agricultural purposes.

Conflict of Interest

The author states that there are no conflicts of interest regarding the publication of this manuscript.

Ethical Permissions

Not declared by the authors.

Funding/Support

This study received no specific grant from any funding agency.

References

1. Ehghan Rahimabadi P., Azarnivand H., Malekian A. Hydrogeological Drought and Groundwater Quality Changes Using GRI and GQI in Semnan and Damghan Plains, Iran. ECOPERSIA 2022; 10(2): 95-108.
2. Sakizadeh M. Performance of Classification Methods to Evaluate Groundwater (Case Study: Shoosh Aquifer). ECOPERSIA 2014; 2(2): 597-612.
3. Bahar Gogani M., Douzbakhshan M., Shayesteh K., Ildoromi A.R. New formulation of fuzzy comprehensive evaluation model in groundwater resources carrying capacity analysis. ECOPERSIA 2018; 6(2): 79-89.
4. Ghazavi R., Ebrahimi H. Estimation of Artificial Groundwater Recharge by Flood Water Spreading System in an Arid Region Using Inverse Modeling and SCS Method; A case Study of Mosian Plain. ECOPERSIA 2018; 6(3): 187-194.
5. Ravikumar P., Somashekar R.K. Principal component analysis and hydrochemical facies characterization to evaluate groundwater quality in Varahi river basin, Karnataka state, India. Appl. Water Sci. 2017; 7(2): 745-755.
6. Su Z., Wu J., He X., Elumalai V. Temporal changes of groundwater quality within the groundwater depression cone and prediction of confined groundwater salinity using Grey Markov model in Yinchuan area of northwest China. Expo. Health. 2020; 12(1): 447–468.
7. Priyanka M., Venkata M., Ratnakar D. Groundwater Quality Appraisal and Its Hydrochemical Characterization in and around Iron Ore Mine, Chitradurga, Karnataka. Int. j. hydrol. 2017; 1(5): 151-161.
8. Abdalazem, A.H., Gamee M.A., Hamdan A., Awad A.A.M., Mohamed A.G. Groundwater Quality Assessment for Irrigation in West Edfu Region, Aswan, Egypt. Assiut. J. Agric. Sci. 2020. 51(1): 125–149.
9. Ravikumar P., Somashekar R., Angami M. Hydrochemistry and evaluation of groundwater suitability for irrigation and drinking purposes in the Markandeya River basin, Belgaum District, Karnataka State, India. Environ. Monit. Assess. 2011; 173(1): 459-487.
10. Elsayed, S., Hussein H., Moghanm F.S., Khedher K.M., Eid E.M., Gad M. Application of Irrigation Water Quality Indices and Multivariate Statistical Techniques for Surface Water Quality Assessments in the Northern Nile Delta, Egypt. Water. 2020; 12(1): e3300.
11. Taheri M., Gharaie M.H.M., Mehrzad J., Afshari R., Datta S. Hydrogeochemical and isotopic evaluation of arsenic contaminated waters in an

argillic alteration zone. J. Geochem. Explor. 2017; 175(1): 1-10.

12. Band, T.D., Kumarasamy M. Application of multivariate statistical analysis in the development of a surrogate water quality index (WQI) for South African watersheds. Water. 2020; 12(6): e1584.
13. Horton R.K. An index number system for rating water quality. J. Water. Pollut. Control. Fed. 1965; 37(3): 300-306
14. Ram A., Tiwari S., Pandey H., Chaurasia A.K., Singh S., Singh Y. Groundwater quality assessment using water quality index (WQI) under GIS framework. Appl. Water. Sci. 2021; 11(2): 1-20.
15. Khalaf R.M., Hassan W.H. Evaluation of irrigation water quality index IWQI for Al-Dammam confined aquifer in the west and southwest of Karbala city, Iraq. Int. J. Civ. Eng. 2013; 2(3): 21-34.
16. Tarawneh M.S.M., Janardhana M.R., Ahmed M.M. Hydrochemical processes and groundwater quality assessment in North eastern region of Jordan valley, Jordan. HydroResearch. 2019; 2(1): 129-145.
17. Abbasnia A., Yousefi N., Mahvi A.H., Nabizadeh R., Radfard M., Yousefi M., Alimohammadi M. Evaluation of groundwater quality using water quality index and its suitability for assessing water for drinking and irrigation purposes: Case study of Sistan and Baluchistan Province (Iran). Hum. Ecol. Risk. Assess. 2019; 25(4): 988-1005.
18. Jehan S., Ullah I., Khan S., Muhammad S., Khattak S.A., Khan T. Evaluation of the Swat River, Northern Pakistan, water quality using multivariate statistical techniques and water quality index (WQI) model. Environ. Sci. Pollut. Res. Research. 2020; 27(31): 38545-38558
19. Subba Rao N., Srihari C., Deepthi Spandana B., Sravanthi M., Kamalesh T., Abraham Jayadeep V. Comprehensive understanding of groundwater quality and hydrogeochemistry for the sustainable development of suburban area of Visakhapatnam, Andhra Pradesh, India. Hum Ecol. Risk. Assess. 2019; 25(1-2): 52-80.
20. Ramachandran Muthulakshmi Y. Geo-spatial analysis of irrigation water quality of Pudukkottai district. Appl. Water Sci. 2020; 10(3): 1-14.
21. Yıldız S., Karakuş C.B. Estimation of irrigation water quality index with development of an optimum model: a case study. Environ. Dev. Sustain. 2020; 22(5): 4771-4786.
22. Sadat-Noori S., Ebrahimi K., Liaghat A. Groundwater quality assessment using the Water Quality Index and GIS in Saveh-Nobaran aquifer, Iran. Environ. Earth. Sci. 2014; 71(9): 3827-3843.
23. Soleimani H., Nasri O., Ojaghi B., Pasalari H., Hosseini M., Hashemzadeh B., Kavosi A., Masoumi S., Radfard M., Adibzadeh A. Data on drinking water quality using water quality index (WQI) and assessment of groundwater quality for irrigation purposes in Qorveh & Dehgolan, Kurdistan, Iran. Data Brief 2018; 20(1): 375-386.
24. Hojjati, M.H., Boustani F. An assessment of groundwater crisis in Iran, case study: Fars Province. World. Acad. Eng. Tech. 2010; 4(10): 2066-2070.
25. Nafarzadegan A., Zadeh M.R., Kherad M., Ahani H., Gharehkhani A., Karampoor M., Kousari M. Drought area monitoring during the past three decades in Fars Province, Iran. Quat. Int. 2012; 250(1): 27-36.
26. Choubin B., Malekian A., Golshan M. Application of several data-driven techniques to predict a standardized precipitation index. Atmósfera. 2016; 29(2): 121-128.
27. Brown R.M., McClelland N.I., Deininger R.A., Tozer R.G. Water quality index-Do we dare?. Water. Sew. Works. 1970; 117(10): 339-43.
28. Ayers R.S., Westcot D.W. Water quality for agriculture: Food and Agriculture Organization of the United Nations Rome. 1985; 29(1): 1-174
29. Meireles, A.C.M., Andrade E.M.D., Chaves L.C.G., Frischkorn H., Crisostomo L.A. A new proposal of the classification of irrigation water. Rev. Cienc. Agron. 2010; 41(3): 349-357.

[DOR: 20.1001.1.23222700.2022.10.4.1.0]