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Evaluation of Groundwater Suitability for Drinking, Irrigation, and Industrial Purposes (Case Study: Yazd-Ardakan Aquifer, Yazd Province, Iran)

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ABSTRACT

Aims Water quality is an important factor in determining groundwater uses. An effort has been made to determine the groundwater quality of the Yazd-Ardakan aquifer. This research was conducted to fill the research gap in aquifer quality in the study area and make a comprehensive evaluation of the study aquifer using different water quality indices. The results can be used for decision-makers better to understand the water quality situation in the area.

Materials & Methods In order to carry out this study, the Ryznar Stability Index (RSI), Langelier saturation index (LSI), Larson–Skold index (LS), and Puckorius scaling index (PSI) were considered to determine groundwater quality for industrial use. Also, the drinking water quality index (WQI) and FAO water quality index (FWQI); and irrigation water quality index (IWQI) were employed to categorize water suitability for drinking and irrigation uses. Finally, the spatial distribution of water quality parameters was assessed.

Findings This study showed that the study aquifer is less corrosive based on PSI, significant, and heavy corrosive, according to LI. Also, results of the aquifer classification based on WQI indicated that about 45% of the aquifer is categorized as poor, very poor, and undesirable for drinking purposes. Finally, IWQI showed that %2.8 of the aquifer is categorized as "non-restriction" class and %4.1 as a "severe restriction" class for irrigation.

Conclusion Therefore, it could be concluded that Yazd-Ardakan aquifer water quality is exacerbating. Consequently, the water quality and water treatments should be taken into account to mitigate the exacerbating trend of the Yazd-Ardakan aquifer.

Keywords Agriculture; Aquifer; Geographic Information System (GIS); Water Quality

CITATION LINKS

[1] Evaluation of groundwater quality ... [2] Four billion people are facing ... [3] OECD environmental outlook to ... [4] 21st century runoff sensitivities of major global river ... [5] Human impact on freshwater ecosystem ... [6] eemj.icpm.tuiasi ... [7] Occurrence and health implication of fluoride in groundwater of loess aquifer in the Chinese ... [8] Ground water and climate ... [9] Measuring global water security towards ... [10] Water balance of global aquifers revealed by groundwater ... [11] Valuation of hidden water ecosystem services: The replacement cost of the aquifer ... [12] Mechanism of fluoride enrichment in groundwater of hard rock aquifers ... [13] Geochemical characteristics and controlling factors of chemical composition of ... [14] Geochemistry and quality of groundwater of the Yarmouk ... [15] Evaluating the main sources of groundwater pollution in ... [16] Evaluation of groundwater quality for drinking and irrigation purposes ... [17] Groundwater quality evaluation using water ... [18] Evaluation of groundwater contamination for fluoride ... [19] Fragmented local governance and water resource ... [20] Construction of a novel water quality index and quality indicator for reservoir water ... [21] Water quality for ... [22] A new proposal of the classification of ... [23] evaluation of groundwater quality using ... [24] Heavy metal contamination and health risk assessment in ... [25] Evaluation of spatial variations in groundwater quality ... [26] use of the water quality index and dissolved oxygen deficit ... [27] Use of water quality index for river classification ... [28] Application of water quality index for quality ... [29] Assessment of water quality index of industrial ... [30] GIS-based evaluation of groundwater quality and ... [31] The analytical control of anti-corrosion water ... [32] A new index for determining amount ... [33] Survey of corrosion and scaling potential produced ... [34] Laboratory studies relating mineral ... [35] Evaluation of corrosion and scaling potential ... [36] Conjunctive water resources management with ... [37] A water quality index- do we ... [38] Drinking-water quality ... [39] Soil and plant testing ... [40] Guidelines for drinking-water ...

Introduction

Water is critical for sustainable development, and water resource constraints in many arid and semi-arid regions of the world are a serious threat to sustainable regional development [1]. Studies show that nearly two-thirds of the world's population (four billion people) is experiencing water shortage at least a month [2]. Given the world's population growth of 9 billion in 2050 and an increase of 55 percent in water per capita in 2050 compared to 2000, the water resources problem seems to be more serious in the future [3]. Surface water resources are under tension because of land use, changing urbanization, deforestation, pollution, and groundwater over-exploitation [4-7] essentially. Factors such as population growth, industrial and agricultural development, welfare levels, and climate changes have resulted in a rising water crisis in recent decades. This situation affects water resources capacity to meet the needs of the future population of the world [8, 9]. Today, nearly 1.7 billion of the world's population live in the areas where groundwater is the only or the main water resource [10]. Given the critical state of the water resources and the management of this crisis, preserving existing water resources and supplying the water needed by communities is one of the main challenges [11]. Among the main challenges facing water resource managers, the contamination of these resources through the agricultural and industrial developments and urbanization is an important issue. This issue has affected groundwater resources and resulted in groundwater quality [1, 12, 13]. Many studies have been conducted in different parts of the world to investigate groundwater quality. Based on the results of a study conducted on groundwater quality and geochemical properties in northern Jordan, extensive agricultural activities, inappropriate drainage, and a high volume of wastewater were the main causes of groundwater contamination in it [14]. Studying the quality of groundwater resources in south Tehran showed that the main pollutants of the groundwater aquifer in the study area are silicate weathering of the surface soil, extensive agricultural activities, human wastewater, and industrial development [15]. The study of aquifer quality in the northwest of Libya reflected the impact of human activities and climatic factors, especially evaporation, on the quality of groundwater resources in the area [16].

Water quality studies play an important role in clarifying and providing managers with appropriate decision-making tools [17]. In many countries, monitoring water quality is one of the major programs of water resource management organizations [18] Most of these countries have developed plans and guidelines for monitoring their water resources [19]. In these guidelines, indicators for studying the water resources quality are defined. Some of the most common indices in this regard are as the following: Water Quality Index (WQI) [20], FAO water quality index [21], Irrigation Water Quality Index (IWQI) [22], Industrial Water Quality Indices (PSI, RSI, LSI, LI) [23, 24]

Among the preferred indicators for water quality monitoring, the WQI index is one of the most effective means of transferring water quality data to citizens, government officials, and policymakers [25]. The indicator is a simple way to summarize much water quality data as an indicator and water quality zoning [26]. The WQI index is used to integrate multiple water quality data and create an effective and understandable number to display water resource quality [27]. Different researchers have employed the WQI index to investigate the quality of surface water and groundwater resources worldwide.

The WQI index was used to verify the water quality of the Karaj River between 2007 and 2009. The results showed that the water quality of the Karaj River in 2008 was more favorable than in 2009 and 2007, and the use of drinking water is necessary for river water treatment [28]. The WQI index was applied to study the surface water quality in the Bhilai steel plant in India. The results showed that only the parameters of alkalinity and magnesium are beyond the standard limits and other variables are in a favorable state [29]. The quality of drinking water and human health risks in southern India were examined using the WQI index. The results of this study showed that 86% of samples taken from underground water sources in the study area do not have a proper grade for drinking, and the amount of nitrate in 61% of samples is higher than the standards of the World Health Organization (WHO) [17].

Some studies used the IWQI index to evaluate water quality for irrigation uses [22, 25]. IWQI was introduced by Meireles *et al.* in 2010 [22] and then employed in different studies to classify irrigation water quality. Bessre *et al.* used IWQI to categorize irrigation water quality in Tunesia [30]. IWQI also was used to classify groundwater quality in Sistan and Baluchestan province, Iran, in terms of irrigation use [23]. Industrial water quality indices were also applied to investigate water quality in corrosion and its effects on industrial equipment and pipes. Langelier Saturation Index (LSI) defines the difference between pH and calcium carbonate saturation's pH. This index is widely used as a scale prediction tool [31]. LSI has been considered a worthwhile network monitoring parameter, especially when $CaCO_3$ is used as a protective layer. Ryznar developed a similar index by modification of the Langelier index formula [32]. The maximum quantity of sediments formed in the equilibrium, based on buffer capacity, is predicted by the Puckorius Scaling index (PSI) [33]. Larson-Skold index (LS) also evaluates the tendency of water to corrosion of the cast-iron and steel pipes [34]. PSI, RSI, LSI, and LI indices are the most important indices to evaluate industrial water quality. Corrosion and scaling potential of water was evaluated using PSI, RSI, LSI, and LI indices in rural water supply distribution networks of Tabas city in Iran [35]. Industrial water quality indices (PSI, RSI, LSI, LI) were also used to classify groundwater quality in Sistan and Baluchestan province in Iran [23, 24]

Despite studies on the quality of water resources around the world, due to the undeniable effects of water on human life components such as health, industry, agriculture and the like, as well as reducing the precipitations and high volume of groundwater extraction, identifying the qualitative characteristics of water and compliance rates, it is of great importance to managers for various uses. This problem, along with severe and prolonged drought, has created a critical situation in the country and has caused most of the regions to face serious challenges in terms of quantity and quality of groundwater. Yazd-Ardakan plain is one of these areas.

All conducted researches show that without conducting qualitative water quality studies, it is not possible to plan the water resources allocation for various uses. Due to population growth and the need for development, suitable and standard water is a critical issue. The majority of the recent studies have emphasized on the drinking or agricultural water quality. Only a few works in the literature demonstrated a comprehensive evaluation of water quality from different drinking, agricultural, and industrial aspects. Besides, despite accelerated development in the study area and the vital role of water as an important resource, no efforts have been made to specify a comprehensive assessment of groundwater quality in the study region. This research was conducted to fill this gap and evaluate water quality in the Yazd-Ardakan aquifer in terms of physicochemical parameters from different perspectives using several water quality indices.

Materials and Methods

Study area

Yazd-Ardakan aquifer is located between 31°15′N to 32°30′N latitude and 53°30′E to 55°E longitude in central Iran. It covers an area of about 12473km^2. There are 945 wells in the Yazd-Ardakan basin, 821 of which with annual extraction of 275Mm^3 are located in Yazd - Ardakan aquifer, and others are located in secondary and small mountainous aquifers. Moreover, there are 22 deep wells with an annual extraction of 15Mm^3 to supply drinking water. Also, 52Mm^3 of groundwater of the Yazd-Ardakan basin are drained through Qanats, but only 7Mm^3 of this extraction is related to the main aquifer [36]. There are 64 piezometric wells in the region (Figure 1). This area is divided into four cities, including Yazd, Ashkezar, Meybod, and Ardakan. The area has a hot and dry climate. Because of these climatic factors, groundwater plays an essential role in human survival and development. In recent decades, the population and industrial growth of the region have led to an increasing trend in groundwater exploitation and inter-basin water transportation from Isfahan. It seems there is a need for water quality assessments of the Yazd-Ardakan aquifer.

Water samples were collected from piezometric wells located in the region from the 2017-2018 period. The samples were examined based on the water and wastewater examination standards. Important water quality affecting factors were analyzed, including electrical conductivity (EC), the concentration of hydrogen ion (pH), total dissolved solids (TDS), sodium (Na^+), potassium (K^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), bicarbonate (Hco_3^-), carbonate (Co_3^-), sulfate (So_4^-) and chloride (Cl^-). It should be noticed that all parameters, except pH, are expressed as milliequivalent per liter.

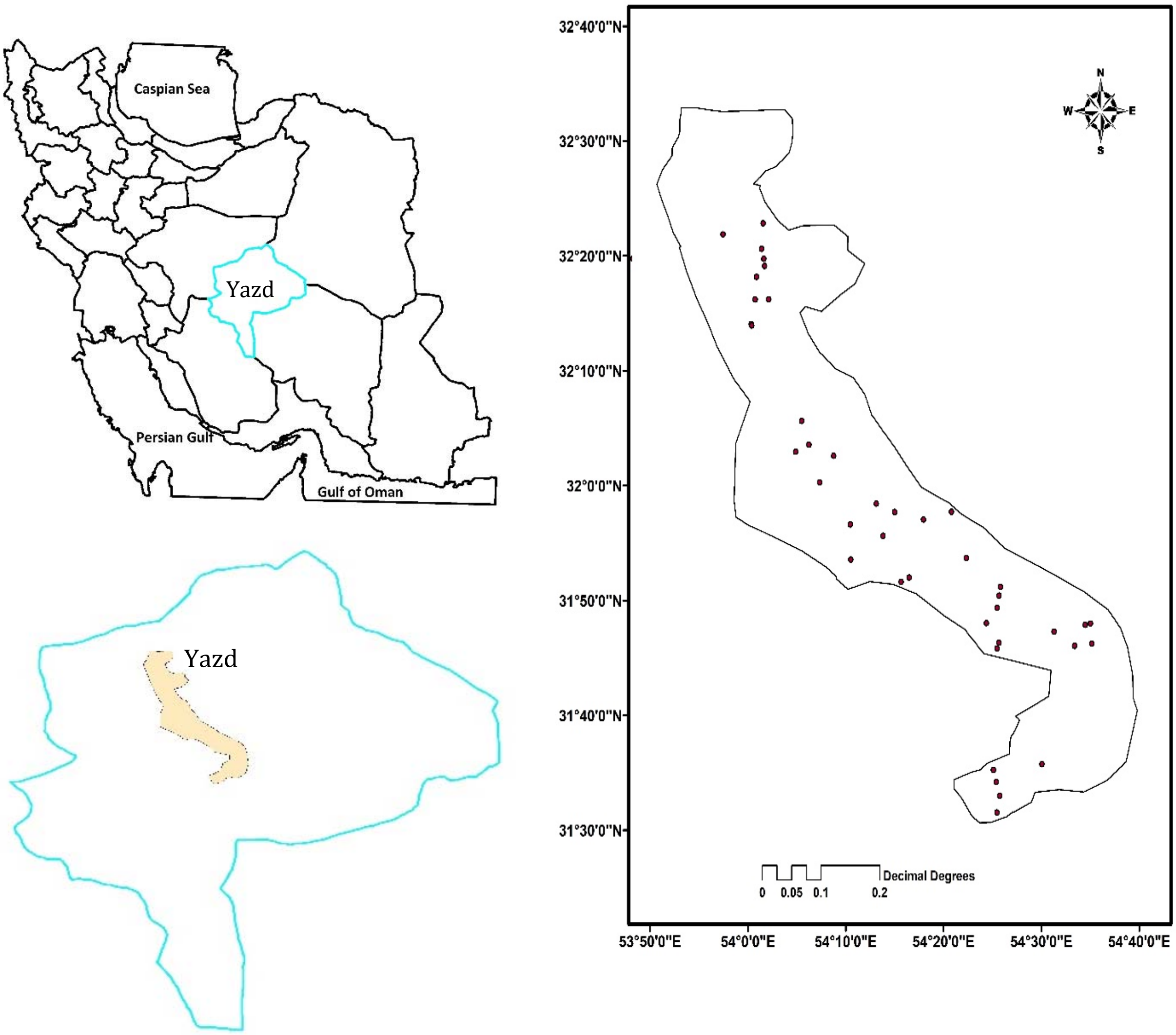

Figure 1) Location of Yazd-Ardakan aquifer and piezometric wells

Drinking-Water Quality Determination Using Water Quality Index (WQI)

Water quality evaluation was performed using WQI, which is widely used for drinking water quality assessment. The WQI is also specified for groundwater quality evaluation. WQI index was initially introduced by Brown *et al.* [37] and then developed by Backman *et al.* [38]. Based on the world health organization (WHO) report in 2004, WQI is a composite index quantifying water quality [39]. The value of each qualitative parameter is evaluated based on the standard and related to other parameters. The value of physicochemical parameters and their relative importance in the overall quality of drinking water is applied to calculate the WQI index. The relative weight is calculated based on Equation 1.

$$W_i = \sum \frac{w_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

where W_i is weighting factor ($\sum W_i = 1$) and n is the number of parameters. The relative weight assigned to parameters is presented in Table 1. By comparing the observed value of each parameter to a benchmark (water quality standard), the quality rating scale was calculated [35]. The results of the analysis were multiplied by 100, as presented in Equation 2.

$$q_i = \left(C_i / S_i\right) \times 100 \quad (2)$$

in which q_i is the quality rating value of parameter I, C_i represents the concentration of each parameter in the water sample, and S_i is the standard for each parameter according to

WHO's gridline [40].

Finally, the SI_i was calculated based on Equation 3, and then a weighted sum aggregation function was applied to measure WQI (Equation 4).

$$SI_i = w_i \times q_i \tag{3}$$

$$WQI = \sum SI_i \tag{4}$$

Where SI_i represents the sub-index of parameter i, q_i The rating according to the concentration of its parameter and n refers to the number of the parameters. Table 1 also represents food and agricultural organization (FAO) standard limits for water quality parameters. The same procedure was done for calculating the FAO water quality index (FWQI). Based on the WHO community standard, water quality observations are categorized into five classes (Table 2).

Table 1) Chemical parameters, weight (wi) and relative weight (Wi) of each parameter based on WHO and FAO standard values

Chemical parameter	WHO standards (mg/l)	FAO standards (mg/l)	Weight (w_i)	Relative Weight (W_i)
K	12	2	2	0.056
Na^+	200	919	4	0.111
Mg^{2+}	50	60	3	0.083
Ca^{2+}	75	400	3	0.083
Hco_3^-	120	610	1	0.028
So_4^-	250	1063	5	0.139
Cl^-	250	960	5	0.139
pH	8.5	8.5	3	0.083
TDS	500	2000	5	0.139
NO_3^-	11	10	5	0.139
$\sum$	-	-	-	1

Table 2) The WQI and FWQI classification and type of water

Type of water	WQI range
Excellent	<50
Good	50 to 100
Poor	100 to 200
Very poor	200 to 300
Not suitable for drinking water	>300

Irrigation water quality evaluation using (IWQI)

IWQI was introduced as a specified method for water quality evaluation in agricultural assessments [22]. In this method, important parameters that affect water quality for agricultural purposes were analyzed through water samples, including (Na^+, EC, SAR, and HCO_3^-). Same as WQI and FAO methods, water quality parameter (q_i) and relative weight of each parameter (w_i) were determined. The value of the q_i parameter is calculated using Equation 5, and the tolerance limits are represented in Table 3.

$$q_i = q_{max} - \left(\left[\left(x_{ij} - x_{inf} \right) \times q_{imap} \right] / x_{map} \right) \tag{5}$$

Table 3) Tolerance limit of quality parameter calculations [20].

q_i	E.C.0 (µs/m)	SAR ((mmol/l)$^{0.5}$)	Na^+ (meq/l)	Cl^- (meq/l)	HCO_3^- (meq/l)
85-100	[200,750)	[2,3)	[2,3)	[1,4)	[1,1.5)
60-85	[750,1500)	[3,6)	[3,6)	[4,7)	[1.5,4.5)
35-60	[1500,3000)	[6,12)	[6,9)	[7,10)	[4.5,8.5)
0-35	EC<200 or EC>=3000	SAR<2 or SAR>=12	Na<2 or Na>=9	Cl<1 or Cl>=10	HCO_3<1.5 or HCO_3>=8.5

where q_{max} represents the maximum value of q_i for the class (i), x_{ij} is the observed value of each chemical parameter, x_{inf} refers to the lower bound of the class to which the parameter belongs, q_{imap} is the class amplitude and x_{map} is the class amplitude to which the parameter belongs. To compute the x_{map} of the last class of each parameter, the upper bound was considered the highest value determined in the water sample analysis. Each parameter weight (w_i) used in the IWQI was obtained by Meireles *et al.* [22], represented in Table 4.

Table 4) Relative weight for the IWQI parameters [20]

Parameters	wi
EC	0.211
Na^+	0.204
HCO_3^-	0.202
Cl^-	0.194
SAR	0.189
Total	1

IWQI was calculated using Equation 6.

$$IWQI = \sum_{i=1}^{n} (q_i \times w_i \quad IWQI = \sum_{i=1}^{n} (q_i \times w_i) \tag{6}$$

Where IWQI is a dimensionless parameter ranging from 0 to 100, q_i refers to the quality of the i^{th} parameter; w_i is the normalized weight of the i^{th} parameter an is related to its relative importance to groundwater quality. Water use classes and their restrictions are shown in Table 5.

Groundwater suitability for industrial use

Low quality of water often provides requirements for the corrosion process. The process leads to different problems, such as reducing the equipment longevity, pipe clogging, and economic and health problems caused by dissolved materials in the water [23, 24]. Different studies introduced useful indices for industrial water quality evaluation. Among them, the Ryznar Stability Index (RSI), Langelier saturation index (LSI), Puckorius scaling index (PSI), and Larson-Skold index (LS) are considered as the most efficient indices for determining water suitability for industrial uses. The indices, their equations, and some definitions are presented in Table 6 [23, 24]. The water quality indices calculations were imported to ArcGIS software to produce the spatial distribution maps of the water quality indices using the IDW method.

Table 5) Definition and classification of IWQI [20]

IWQI	Exploitation restrictions	Recommendation	
		Soil	Plant
[85,100]	No restriction (NR)	Water can be used for almost all types of soil. Soil is exposed to lower risks of salinity/ sodicity problems	No toxicity risk for most plants.
[70,85]	Low restriction (LR)	Irrigated soils with a light texture or moderate permeability can be adopted to this range. To avoid soil sodicity in heavy texture, soil leaching is recommended.	Elevated risks for salt-sensitive plants.
[55,70]	Moderate restriction (MR)	The water in this range would be better used for soils with moderate to high permeability values. Moderate leaching of salts is highly recommended to avoid soil degradation.	Plants with moderate tolerance to salts maybe grow
[40,55]	High restriction (HR)	This range of water can be used in soils with high permeability without compact layers-high-frequency irrigation schedule.	Suitable for irrigation of plants with moderate to high tolerance to salt with special salinity control particles, except water with low Na, Cl, and HCO_3 values
[0,40]	Sever restriction (SR)	Using this range of water for irrigation under normal conditions should be avoided.	Only plants with high salt tolerance, except for waters with extremely low values of Na, Cl, and HCO_3

Table 6) Corrosion and saturation indexes, criteria, and equations for industrial water quality classification

Index	Equation	Index value	Water condition
Langelier saturation index	LSI=pH-pHs pHs=A+B-log (Ca^{2+}) -Log (Alk)pH<=9.3 pHs=(9.3+A+B)-(C+D) (3) pH>9. 3	LSI>1	Supersaturated, tend to precipitate $CaCO_3$
		LSI=0	saturated, $CaCO_3$ is an equilibrium
		LSI<0	Undersaturated, tend to dissolve solid $CaCO_3$
Rynzar stability index (RSI)	RSI=2pHs-pH	RSI<6	Supersaturated, tend to precipitate $CaCO_3$
		6<RSI<7	Saturated, $CaCO_3$ is an equilibrium
		RSI>7	Undersaturated, tend to dissolve solid $CaCO_3$
Puckorius scaling index (PSI)	PSI=2 (pHeq)-pHs pH=1.465+log(T.ALK)+4.54 pHeq=1.465×log(T.ALK)+4.54	PSI<6 PSI>7	Scaling is unlikely to interfere with the formation of protecting film
Larson-skold index (LS)	Ls=(Cl- +SO_4^{-2})/(HCO_3+CO_3^{-2})	LS<0.8	Chloride and sulfate are unlikely to interfere with the formation of the protecting film
		0.8<LS<1.2	Corrosion rates may be higher than expected
		LS>1.2	Hight rates of localized corrosion may be excepted

Findings and Discussion

Physicochemical characteristics

The statistical explanation (maximum, minimum, average, and standard deviation) of various physiochemical parameters of 64 groundwater samples were presented in Table 6. Also, the tolerable limits of each parameter for drinking water based on the WHO standard are shown in Table 7. Using this explanation, evaluation of the main physicochemical aspects of the study aquifer was done.

Groundwater quality for drinking purposes

The concentration of hydrogen ion (pH) as an important factor shows water conditions in acidic or alkaline strength. The pH of groundwater in the study area is in the range of 7.1 to 8.11, with an average value of 7.77. Compared with the limits of the pH values for drinking water (6.5-8.5), results revealed that pH in the study aquifer is in the standard range for drinking purposes. Electrical conductivity (EC) shows the ionic concentration presented in the water samples. Besides, there is a straight correlation between EC, total dissolved solids, and salinity. EC concentration varies from 358 to 18670 µS/cm, with a mean of 3363 µS/cm in the study area. A higher value of EC is a result of the geological condition and anthropogenic activities. Total dissolved solids (TDS) in the study region are in the range of 230-12020mg/l with an average of 2409mg/l. compare this range with the WHO standard in the TDS term (Table 7) shows that some water samples consider in the unpalatable condition for drinking purposes.

Table 7) statistical summary of chemical parameters of groundwater samples in Yazd-Ardakan aquifer.

Parameters	Unites	Min	Max	Mean	WHO (2008)
pH	-	7.1	8.11	7.75	6.5-8.5
EC	µS/cm	358	18670	3363	/
TDS	mg/l	230	12020	2409	500-1500
TH	mg/l	163	3870.4	696.46	100-500
Ca^{+2}	mg/l	104	2016	351.16	75-200
Mg^{+2}	mg/l	59	1855	345	50-150
Na^{+}	mg/l	10.2	620	105.9	200
K^{+}	mg/l	1.02	5.18	3.2	12
Cl	mg/l	80	560	207	200-600
SO_4^-	mg/l	4.6	1164.66	159.532	200-400
HCO_3^-	mg/l	80	560	207.5	-

Water hardness is derived from a variety of dissolved ions, mainly magnesium and calcium [40]. In the study aquifer, TH values varied from 163 to 3870.4mg/l, with an average of 696.46mg/l (Table 7). Considering the standard limits of WHO for TH, the Yazd-Ardakan aquifer is categorized as very hard in terms of water hardness criteria.

Major cations and anions are arranged in the order of Ca>Mg>Na>K and SO_4> HCO_3>Cl, respectively. The maximum allowable limit of calcium for drinking water is 200mg/l based on WHO standard, while the calcium concentration in the study area is in the range of 104 to 2016mg/l with a mean of 351.16mg/l. The magnesium concentration was found in the range of 59 to 1855mg/l, with an average of 345mg/l compared to the maximum standard limit of 150mg/l for drinking water. Sodium concentration is also exceeding the allowable range for drinking water. At the same time, potassium concentration is located within the acceptable range of drinking standard. Sulfate concentration is ranging from 4.76 to 1164.66mg/l within a mean of 159.539mg/l. The permissible upper limit of the WHO standard for sulfate in drinking water is 600mg/l.

The results of the groundwater analysis revealed that in some areas of aquifer, sulfate concentration exceeds standard limits. Chloride is known as an indication of water pollution. Also, chloride is derived from industrial and domestic waste [17].

In the present study, chloride concentration of groundwater samples varies from 12.8 to 670mg/l with an average of 12.8mg/l compared with a desirable range of chloride, i.e., 200 to 600mg/l in WHO standard. Bicarbonate concentration is located in the range of 80 to 560mg/l with a mean of 207.5mg/l.

Analysis of physicochemical parameters showed that 26%, 14%, and 5% of total aquifer area are classified as poor, very poor, and undesirable for drinking purposes, respectively as shown in the Figure 2.

Results of using FWQI for quality evaluation of the study aquifer for drinking uses are presented in Figure 3. Results of the FWQI and WQI are similar.

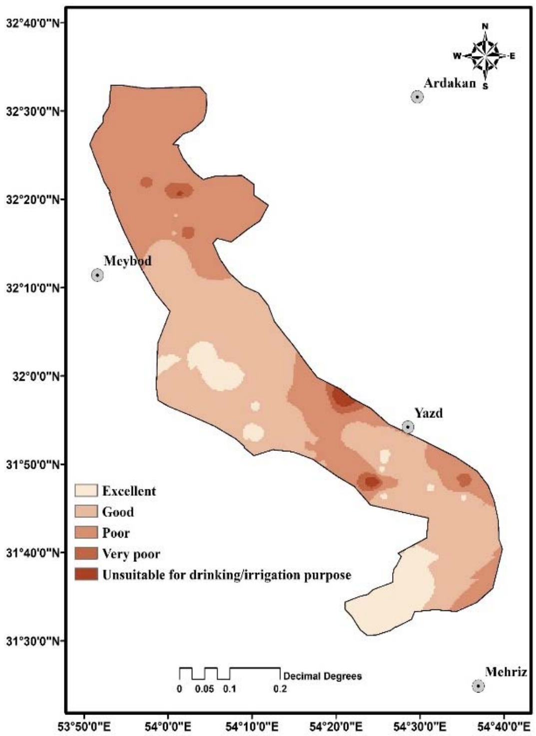

Figure 2) Average values of groundwater quality index for drinking consumption.

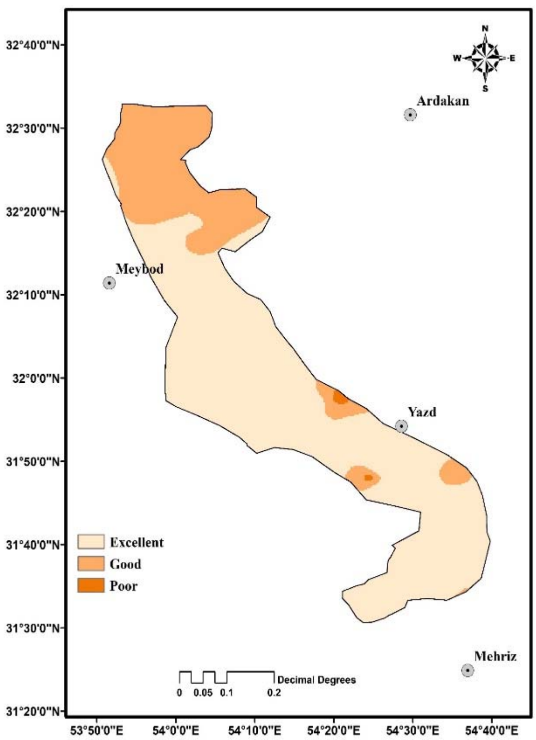

Figure 3) Average values of groundwater quality index for drinking consumption based on WHO standard

Groundwater quality for irrigation purposes

Irrigation water quality index (IWQI) was employed to evaluate groundwater quality for irrigation purposes in the study region. Results showed that IWQI is ranged between 31.1 and 90.53. The results of aquifer classification based on IWQI are presented in Figure 4. Based on the interpolated results of the IWQI method, 2.8% of the aquifer is categorized as a non-restriction class, 15.6% as low restriction class, 63% as moderate restriction class, 14.5% as high restriction class, and 4.1% as sever restriction class for irrigation purposes.

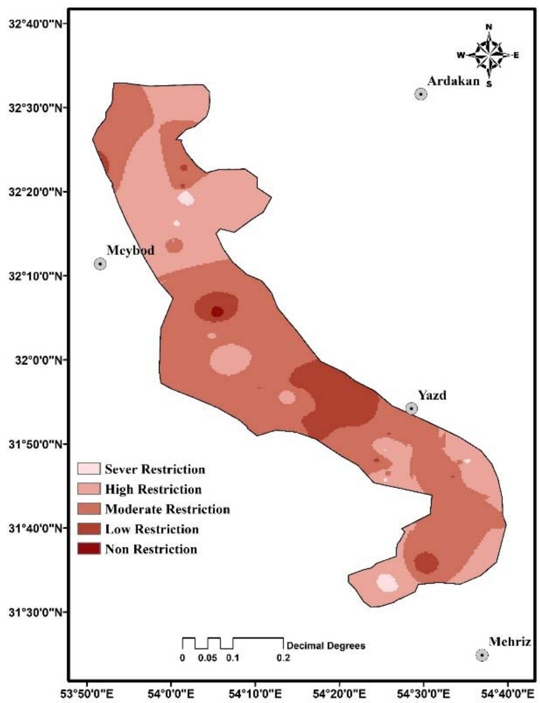

Figure 4) Average values of groundwater quality index for agricultural consumption based on FAO standards.

Groundwater quality for industrial purposes

To estimate industrial water quality, Langelier, Rayner, Puckorius, and Larson-Skold indices were evaluated for groundwater samples. The results of these calculations are depicted in Figure 5. The results indicated that the study aquifer is less corrosive based on the PSI index. Also, according to the Langelier index, the aquifer is categorized as insignificant and heavy corrosion classes. RSI and LSI evaluations indicated that the groundwater in the study region was very corrosive.

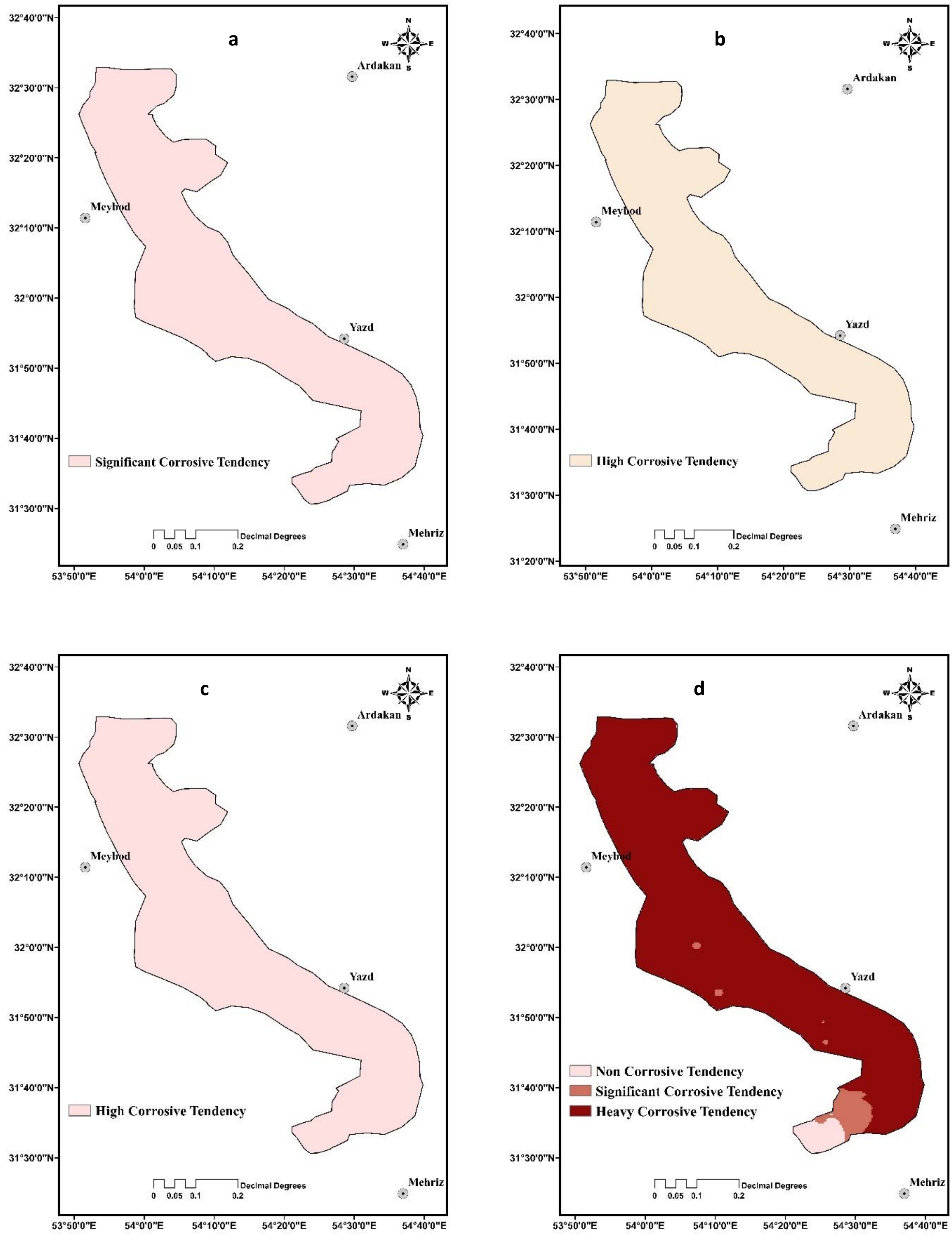

Figure 5) Average values of groundwater quality index for industrial consumption. (Spatial distribution of a: Puckorius, b: Ryznar, c: Langelier, and d: Larson-Skold indices).

Conclusion

This paper has evaluated groundwater quality for industrial, agricultural, and drinking use in the Yazd-Ardakan aquifer using water quality indices. The results advocated that some areas in the study region, especially northern and eastern, are classified as poor, very poor, and undesirable for drinking use. In the central and western margins of the aquifer, groundwater quality is evaluated as excellent and good.

Comparing the location of the main drinking wells of the Yazd-Ardakan plain, it could be concluded that drinking water of the area is extracted from suitable zones (western margins of the aquifer). Based on the results of the groundwater classification for irrigation purposes, almost 20% of the aquifer is categorized as high and severe restrictions for irrigation. Results of the aquifer quality evaluation using industrial indices advocated that the aquifer is located in the corrosive class. Besides, the future development of the study area is based on industrial growth. Considering the results of the present study revealed that aquifer is classified as high corrosive for industrial use, the water quality and aquifer potential for water supplying should be considered in defining the future perspective of the region. Also, since the aquifer quality is affected by industrial and domestic wastewater, so it is essential to pay more attention to manage wastewaters.

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