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Assessment of the Potential of Groundwater Quality Indicators by Geostatistical Methods in Semi-arid Regions

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ABSTRACT Conducting groundwater quality studies is a practical necessity for obtaining quality information from water resources. Corrosion and sedimentation are important characteristics and quality indicators of groundwater. The purpose of this study is to analyze the geostatistical potential of corrosion and sedimentation of groundwater as important indicators of aquifer quality in semi-arid regions such as Birjand plain. For this purpose, 27 wells were sampled and geostatistical analyzes were performed by kriging geostatistical method. The results showed that all qualitative components follow the spherical variogram model. The range of effect of the measured indices was from 3220 m (RSI) to 10300 m (TH). The range of effect of LSI and RSI is smaller than the range of effect of their components and looks similar. Due to the inverse relationship between the Rayznr index and the Langelier index, in the western and southwestern parts of the aquifer where the value of the Langelier index and corrosion potential are minimal, in this part of the aquifer the indices are maximum. Also, in the southeast and east of the aquifer, the pH and in the southwest of the aquifer alkalinity is higher than other parts of the aquifer. Due to the direct relationship between the Langelier index and pH, TDS, alkalinity and hardness, the spatial distribution of the LSI index is similar to the distribution of these components and follows a similar trend. In other words, it can be said that the average Langelier index for Birjand plain indicates its corrosion.
Key Words: Langelier index, corrosion, sedimentation, Birjand plain.

Introduction

Water scarcity crisis is one of the long-standing problems of arid regions and dealing with it is a vital issue. In Iran, where most of the regions are located in arid and semi-arid climates, groundwater is one of the important sources of water supply for agriculture, industry and drinking water. With the growth and expansion of industry and agriculture, groundwater abstraction is increasing day by day, while groundwater is gradually becoming more polluted due to the discharge and leakage of industrial and agricultural floodwaters (Akbarpour et al., 2012). Water quality assessment is one of the most important aspects of water studies (Eyankware, 2019). Conducting qualitative studies of groundwater resources is a basic and practical move to obtain quality information from water resources. Water used for general purposes, irrigation and industry each have their own quality, and low quality water is not desirable for any of these uses.

Water can cause corrosion of transmission and distribution lines, and also cause the formation of thick layers of sediment on the surfaces of facilities and water pipes (Kalyani et al., 2017). Corrosion is a physicochemical reaction between water and its environment. This process has adverse health, economic, technical and aesthetic effects (Zare Abyaneh et al., 2010). Sedimentation is also one of the chemical reactions of water with its environment, as a result of which water precipitates its salts as a layer on the surfaces and transmission channels (Rafferty, 2000).

Many solutions have been proposed to prevent corrosion and sedimentation in facilities. However, the use of predictive methods, combined with the use of control methods, can more favorably reduce the effects and damage caused by these two phenomena in the water treatment, transmission and delivery industry (Mokhtari et al., 2010). Mokhtari et al. (2010) in a study evaluated the corrosion and sedimentation status of the drinking water distribution network in Ardabil using Langelier and Rayznr indices. In this descriptive cross-sectional study, which was conducted in the fall of 2009, the city was divided into 12 blocks in two time periods, the second half of September and the second half of December. The parameters of alkalinity, calcium hardness, electrical conductivity, temperature and pH were analyzed. The results of experiments and calculations showed that the mean LSI index in the first and second stages were -0.23 and -0.56, respectively, and the mean of the Rayznr index in the first and second stages were 7.98 and 8.37, respectively. According to the LSI index, the water in the distribution network was prone to corrosion in the first stage in 9 stations and in the second stage in all stations; According to the RSI index, in the first stage, 6

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items tended to be corrosive and the rest were balanced, and in the second stage, 10 stations tended to be corrosive and the rest had a relative equilibrium state. According to the results and findings, drinking water in the water supply network of Ardabil is somewhat prone to corrosion.

Dehshibi and Fadaei (2011) studied the sedimentation and corrosion status of water resources in the villages of Zahedan during the years 2008-2009. For this purpose, in summer and winter, a total of 52 samples were prepared from 26 water supply wells, which were mostly covered by the Rural Water and Sewerage Company of Sistan and Baluchestan Province. Then temperature, pH, TA, calcium hardness, TDS and ECwere measured. Langelier and Rayznr indices were used to determine the deposition and corrosion potential. The results showed that based on the Langelier index, 3.6% of the total samples taken were sedimentary and 76% were corrosive. These sedimentary and corrosive waters cause problems in water supply systems in the long run. Dehghani et al. (2010) used Langelier index to evaluate the corrosion and sedimentation potential of Shiraz water supply network. They sampled 118 wells and surface water sources in the summer and fall of 2007. The mean results of Langelier index were 0.417 which showed low to medium sedimentation potential (in 92.4% of samples) and low corrosion potential (in 1.3% of samples). Khaledian and Salehpour (2020) investigate the quality of groundwater of Qazvin plain with regard to both sedimentation and corrosion indices by Langelier (LSI), Ryznar (RSI), and Puckorius (PSI) indices. According to the results of the LSI index, most of the area of the Qazvin plain is in the range of 0 to 2 indicating low, moderate, and in some of the years, high groundwater deposition. Also, according to the results of the RSI index, most of the plain is in the range of 6 to 7, indicating low corrosiveness of the groundwater. Hussien et al (2020) proposed new method to predict corrosion and encrustation from groundwater chemistry of the aquifers. The chemical properties of the groundwater within the aquifers of eight hydrogeologic districts in the western portion of Iraq were used in the calculation of Ryznar Stability and Langelier saturation indices supported by Phreeqe software. The results show that the groundwater of all aquifers has a potential of incrustation with a majority percent of 95.4, while 4.2% of the groundwater is continued to corrosion ability. Eyankware et al (2020), evaluated the corrosion and scaling potential of groundwater at Warri, Niger Delta region of Nigeria from 15 sample points. The corrosion and scaling tendency of groundwater was determined using chloride-sulfate mass ratio (CSMR), Revelle index (RI) and Larson-Skold index (LSI). Their findings revealed that CSMR ranges from 0.00 to 2.84, RI ranges from 0.8 to 3.28 and LSI ranges from 0.81 to 3.28. Finally, CSMR, RI and LSI showed that effect of corrosion potential of groundwater within the study area is low to insubstantial. Table 1 shows the different degrees of corrosion and sedimentation based on El-Shishtawy et al (2013) studies.

According to the information of Birjand meteorological station, Birjand plain (with an altitude of 1491 meters above sea level) in the statistical period 1957 to 2011, has an average annual rainfall of 153 mm (average 55 years) and an average temperature of 16.5 degrees Celsius. According to the Embereger climatic classification, it is cold-dry and in the De Martonne climate classification it is dry. The average evapotranspiration potential in Birjand synoptic station is 2621 mm per year. Due to the lack of rainfall, it can be said that the most important source of water for various uses such as agriculture, industry and drinking is groundwater resources. Therefore, it will be necessary to evaluate the groundwater quality of this plain with the existing water quality standards and zoning and preparation of qualitative maps of this aquifer to apply proper management and planning for different uses.

Due to mentioned conditions of Birjand aquifer, this research purposes to analyze the geostatistical potential of corrosion and sedimentation of groundwater as important indicators of aquifer quality to evaluate the Birjand aquifer status.

Table 1 Different degrees of corrosion and sedimentation based on El-Shishtawy et al (2013) studies

Water behavior	RSI value	Water behavior	LSI value
Poor sedimentation	5-6	Low sedimentation	0-0.5
Slight sedimentation and corrosion	6-7	Medium sedimentation	0.5-1
Moderate corrosion	7-7.5	Severe deposition	1-2
Excessive corrosion	>7.5		

2. Materials and methods

1. Study area

Birjand plain is one of the study areas of Lut desert watershed where its geographical coordinates located between longitudes of 58 degrees and 41 minutes to 59 degrees and 46 minutes east and latitudes of 32 degrees and 35 minutes to 33 degrees and 8 minutes north. The total area of the study area is 3406.72 square kilometers, of which the share of plains and altitudes is 900.63 and 2506.09 square kilometers, respectively. In this study area, based on the distribution of observatory and exploitatory wells and considering the areas that have geophysical studies, two alluvial aquifers have been identified. Birjand plain aquifer is the largest catchment area in the province with an average rainfall of 170 mm per year (Eftekhari et al. 2019) which is a low precipitation value and due to this problem in the recent years this plain has been as one of the plains with critical conditions for water abstraction (Figure 1).

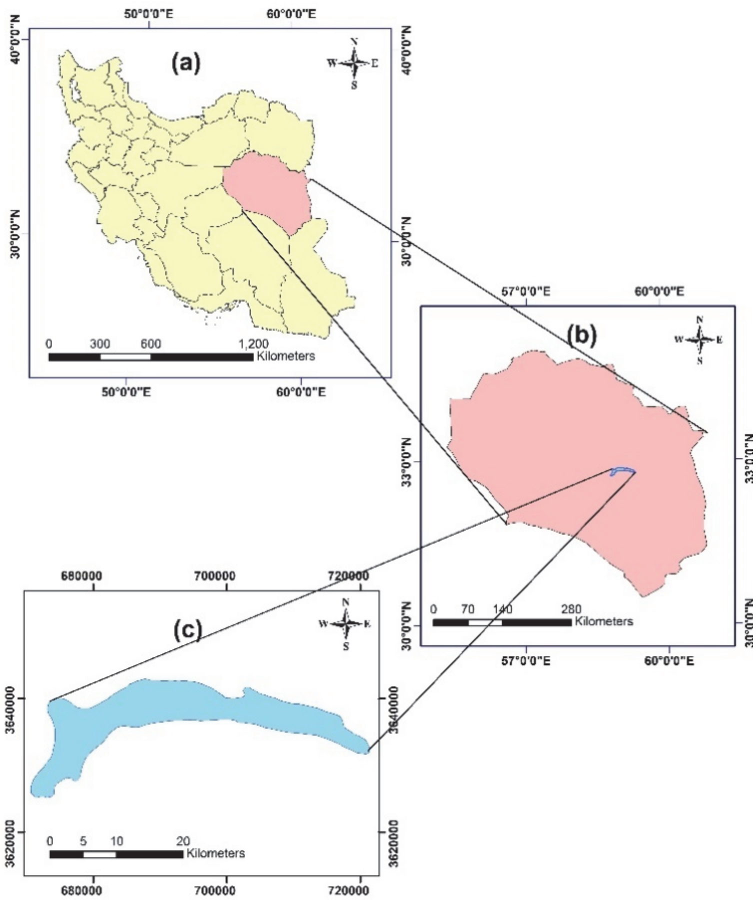

Fig.1 General location of Birjand plain

2. Sampling

To evaluate the quality of groundwater resources in Birjand plain, 27 agricultural wells were sampled and the geographical coordinates of the wells were recorded by GPS. Samples were collected in a 250 ml bottle and transferred to the laboratory. Temperature was recorded at the sampling site. After adding a few drops of toluene, the samples were stored in an ice-filled refrigerator to prevent biological reactions and transported to the laboratory immediately. The collected samples were analyzed according to APHA (1998) standards. In addition to sampling from wells, multi-year data from the Regional Water Organization of South Khorasan Province were used to evaluate temporal changes in water quality and quantitative spatial changes in water levels.

3. Laboratory decomposition

Water temperature at the sampling site was measured with a thermometer. EC and pH of the samples were measured with istek device, TDS of the samples were measured by evaporation of 100 mL and residual weighting. Chloride anion (Cl^-) in the samples was measured immediately after transfer to the laboratory by titration with silver nitrate. Sodium (Na^+) and potassium (K^+) were measured by flameometric method, calcium (Ca_2^+) and magnesium (Mg_2^+) were measured by titration method with EDTA, bicarbonate (CHO_3^-) and carbonate (CO_3^{2-}) were measured by titration method with sulfuric acid and sulfate were measured by spectrophotometry. Iron (Fe_2^+) and manganese (Mn_2^+) were measured by atomic absorption spectrometry. Na^+, K^+, CHO_3^-, CO_3^{2-}, Ca_2^+ and Mg_2^+ ions were used to calculate the ratio of sodium adsorption (SAR), residual sodium carbonate (RSC), total hardness (TH), total alkalinity (TA), penetration index (PI) and Langelier index (LI).

4. Calculation of hardness and alkalinity

Total water hardness based on equivalent calcium carbonate and total water alkalinity were obtained from Equations 1 and 2, respectively (Shi et al., 2007). Since the carbonate concentration of the samples was zero, the alkalinity was equal to the bicarbonate concentration and was expressed on the basis of calcium carbonate in.

$$TH\ (mg\ of\ CaCO_3) = (Ca_2^+ + Mg_2^+) \times 50 \tag{1}$$

$$TA\ (mg\ of\ CaCO_3) = (CHO_3^-) \times 50 \tag{2}$$

In these equations, TH: total hardness in *mg/L*, Ca_2^+ and Mg_2^+ : calcium and magnesium cations in *mg/L*, TA: total water alkalinity in mg/L, CHO_3^- : water bicarbonate in *mg/L* IS.

5. Calculation of Langelier (LI) and Rayznr (RI) indices

To calculate LI and RI, first the reaction of water in the state of saturation of calcium carbonate (pHs) was calculated (Mokhtari et al. 2010):

$$pHs = \left[(9.3 + A + B) - (C + D)\right] \tag{3}$$

Where in:

$$A = \left(Log\left[TDS\right]-1\right)/10 \quad (4)$$

$$B = -3.12 \times Log\left(℃ + 273\right) + 34.55 \quad (5)$$

$$C = Log\left[TH\right] - 0.4 \quad (6)$$

$$D = Log\left[TA\right] \quad (7)$$

In these relationships, TDS: total soluble solids in mg / L, °C: temperature in degrees Celsius, TH and TA were defined by Equations 1 and 2, respectively. Finally, the values of Langelier (LI) and Rayznr (RI) indices were calculated from the following equations:

$$LI = pH - pHs \quad (8)$$

$$RI = 2pHs - pH \quad (9)$$

In which pH is the actual reaction of water and pHs have already been defined.

Geostatistical analysis

1. Kriging method

This method relies on the weighted moving average and is the best estimator which, in addition to the estimated values, also determines the amount of estimation error at each point. Despite all the advantages of this method, smoothing the changes during estimation causes the variance of the estimated samples to be less variable than the actual points. This means that the amount of changes in model prediction is less than reality (Cambardella et al., 1994). Overall, the success of this method in interpolating variables is completely dependent on the accuracy of data selection with experimental semi-variogram. First, the experimental semi-variogram $\gamma(h)$ was calculated:

$$\gamma^{\circ}(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[Z(x_i) - Z(x_i - h)\right]^2 \quad (10)$$

Where N: the number of pairs of observations, $Z(x_i)$ and $Z(x_i - h)$ are the amount of observations of the variables at the points x_i and $x_i + h$ respectively. Then the spherical, exponential and Gaussian semi-variogram theory models were fitted and the best model was selected.

2. Evaluation of variogram model accuracy

Validation of the model was performed using the following evaluation criteria:

$$ME = \sum_{j=i}^{n} \frac{X(p)_j - X(m)_j}{n} \quad (11)$$

$$RMSE = \sqrt{\sum_{j=1}^{n} \frac{X(p)_j - X(m)_j}{n}} \quad (12)$$

$$\%RMSE = (RMSE/\mu) \times 100 \quad (13)$$

In which, ME: mean error, $RMSE$: root mean square error and $\%RMSE$, $X(p)$: estimated values of each water quality component, $X(m)$: measured values of each water quality component, n: number of samples and μ: the average of each measured component.

ME statistics indicate the presence of bias. Its positive values indicate an estimate higher than the actual value and its negative values indicate an estimate less than the actual value. As the ME value gets smaller, the prediction of the interpolation method will be less skewed. The $RMSE$ value is zero in the optimal state or in the state where the estimated and measured values are equal. As the $RMSE$ value gets smaller, the prediction of the interpolation method will be more accurate. The $RMSE$ criterion is sensitive to outdated data, so $\%RMSE$ can be used. The smaller size of this criterion is a reason for the higher accuracy of the estimates or the small difference between the actual values and the estimated values.

$RMSE$ and ME indices were used to compare kriging method and inverse distance weighting method. The normality of the data, which is one of the conditions for using the variogram, was assessed using the Kolmogorov-Smirnov test. Statistical analyzes were performed using STATISTICA 8.0 (Jascaniene et al., 2013). The variogram models were determined with Variowin 2.21 (Zelenika et al., 2010). The zoning method and the preparation of spatial distribution maps of the components were performed in ArcMap 10.8 (Eftekhari and Akbari, 2020).

Results and discussion

Table 2 shows a statistical summary of corrosion and sedimentation potentials (LSI and RSI) and their dependent variables. The average temperature of 17 °C was used to calculate the LSI and RSI indices.

The pH value in the aquifer of Birjand region is always base and varies from a minimum of 7.32 to a maximum of 7.36 (Table 2). Alkalinity in Birjand groundwater aquifers varies from moderate to very high (Boyd, 2000), but according to the average of 270 mg / L in the aquifer, the alkalinity of the water is high. Alkalinity and pH of the water are usually closely related to each other, and waters with a pH between 7.32 and 7.36 are usually moderately to highly alkaline. Due to the minimum hardness of all water, Birjand groundwater is considered as hard water and sometimes very hard (Boyd, 2000). In Birjand plain aquifer, LSI value in all samples is negative, which according to Langelier index shows that groundwater of Birjand plain tends to corrode (Table 2). In Birjand plain aquifer in 100% of water samples, LSI index was less than -1, which indicates the tendency to weak to moderate corrosion potential (Table 2).

In Birjand aquifer, the average value of Rayznr stability index is 10.6, which shows the high corrosion potential of water in this aquifer (Table 2). In Birjand plain aquifer, the value of Rayznr index in 100% of samples is more than 10. This RSI value indicates the high corrosion potential of Birjand groundwater.

In Birjand plain aquifer, the coefficient of variation of factors affecting LSI and RSI stability indices is generally less than

30%, which indicates their relative uniformity at the aquifer level. The coefficient of variation of LSI is greater than the coefficient of variation of RSI and is greater than the coefficient of variation of the factors affecting these two.

Table 3 shows the Spearman correlation coefficient of pH, TDS, TH, alkalinity, LSI and RSI indices of Birjand plain aquifer. In this aquifer, there is a significant and relatively strong positive correlation between pH and total hardness and total alkalinity which the correlation of pH with alkalinity is stronger than its correlation with total hardness (Table 3) (p<0.05). Also, TDS and water hardness and hardness and alkalinity are related (p<0.05). In particular, p-value (p) indicates the probability of error in accepting the validity of the observed results. For example, a p-value of 0.05 indicates that there is a 5% probability that the relationship we observed in the sample is “Random”.

The similarity of significant and relatively strong positive correlation of total hardness with pH and TDS is probably due to the fact that Ca_2^+ and Mg_2^+ ions are the main constituents of hardness and solids dissolved in groundwater of Birjand region. These two ions also maintain the pH of the water in base with an average of about 7.35 (Table 2). On the other hand, total alkalinity is correlated with water hardness and pH.

In Birjand aquifer, LSI and RSI stability indices show positive correlation and negative correlation with the indices based on which they have been calculated (pH, TDS; TH and TA), respectively. Meanwhile, the correlation between these two indicators and TDS was low (p>0.05) and on the contrary with total alkalinity is very strong (p<0.05). Therefore, it seems that LSI and RSI indices are changing with changes in total alkalinity, although LSI changes are directly related to water alkalinity and RSI changes are inversely related to water alkalinity (Figure 2). Alkalinity is more correlated with the RSI index than the LSI index.

Figure 3 shows the experimental variograms and the theoretical model fitted to the groundwater quality indicators of Birjand plain. For pH, TA, TDS, TH, LSI and RSI, the spherical model had the best fit. The variograms of LSI and RSI indices were very similar to each other, which shows the close relationship between these two indices.

Table 4 shows the results of geostatistical analysis of LSI and RSI indices and their components in the Birjand plain aquifer, where C_0 is nugget effect, C is sill of a semi-variogram, C_0 +C represents Sill of impact threshold and $\frac{C_0}{C_0+C}$ shows spatial correlation.

The range of effect of the measured indices was from 3220 m (RSI) to 10300 m (TH). The range of effect of LSI and RSI is smaller than the range of effect of their components and looks similar. The value of the nugget effect to effect threshold ratio for all variables was less than 0.25, indicating a strong spatial correlation (El-Shishtawy et al., 2013). The ratio of nugget effect to effect threshold was similar and low for both LSI and RSI indices and the spatial dependence class of both indices was strong.

1. Zoning of LSI and RSI indices and their components

Based on the optimal variogram models and kriging interpolation method, zoning maps of LSI and RSI indices as well as their components were drawn. These maps are shown in Figure 3. PH and alkalinity maps do not follow the same trend despite being related to each other (Fig.4). In the northeastern part of the aquifer, the pH and in the southern part of the aquifer, the alkalinity is higher than other parts of the aquifer, and in the central part, the pH is lower and the alkalinity of the water is the highest (Figure 4). High pH affects the dissolution of minerals in formations and thus has a direct effect on the Langelier index.

Table 2 Statistical summary of LSI and RSI indices, and the factors affecting them in Birjand plain aquifer

Indicator	unit	average	median	minimum	maximum	Standard deviation	Coefficient of variation (%)
pH	—	7.35	7.34	7.32	7.36	0.08	1.13
TH	*mg/L*	308	300	212	395	67	21
TDS	*mg/L*	454	444	299	726	108	23
TA*	*mg/L*	270	267	216	358	34	12
LSI	—	-49.01	-1.49	-1.73	-1.2	0.11	7.6
RSI	—	10.6	10.7	10.25	0.11	0.2	2

Table 3 Spearman correlation coefficients of pH, TDS, TH, alkalinity, LSI and RSI in Birjand aquifer

indicator	TA	TDS	TH	pH	LSI	RSI
TA	1.00					
TDS	1.50	1.00				
TH	0.49	0.98	1.00			
pH	-0.40	-0.42	0.73	1.00		
LSI	0.54	0.61	0.66	0.31	1.00	
RSI	-0.73	-0.81	-0.84	0.08	0.92	1.00

Table 4　Results of geostatistical analysis of LSI and RSI indices and their components in Birjand plain aquifer

indicator	model	Impact range (meters)	Impact threshold (C_0+C)	nugget effect (C_0)	$\frac{C_0}{C_0+C}$	Spatial correlation class
pH	spherical	5412	0.042	0.007	0.16	strong
TDS	spherical	8489	242000	2225	0.09	strong
TH	spherical	10300	1.649	1008	0.09	strong
TA	spherical	7758	5180	0	0	strong
LSI	spherical	3604	0.562	0.032	0.06	strong
RSI	spherical	3220	1.769	0.109	0.7	strong

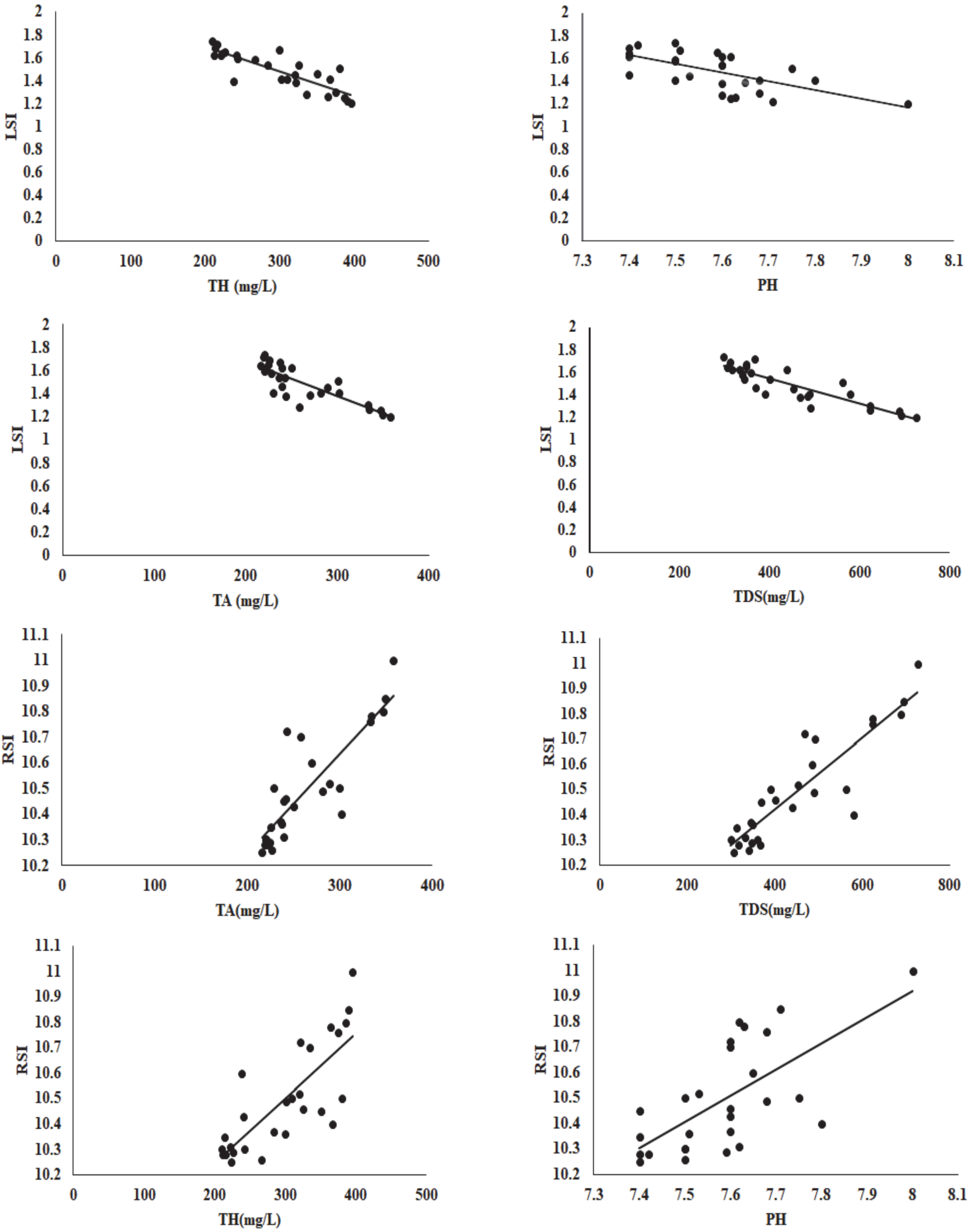

Fig.2　Relationship between LSI, RSI index with pH, TH and TA in groundwater of Birjand plain

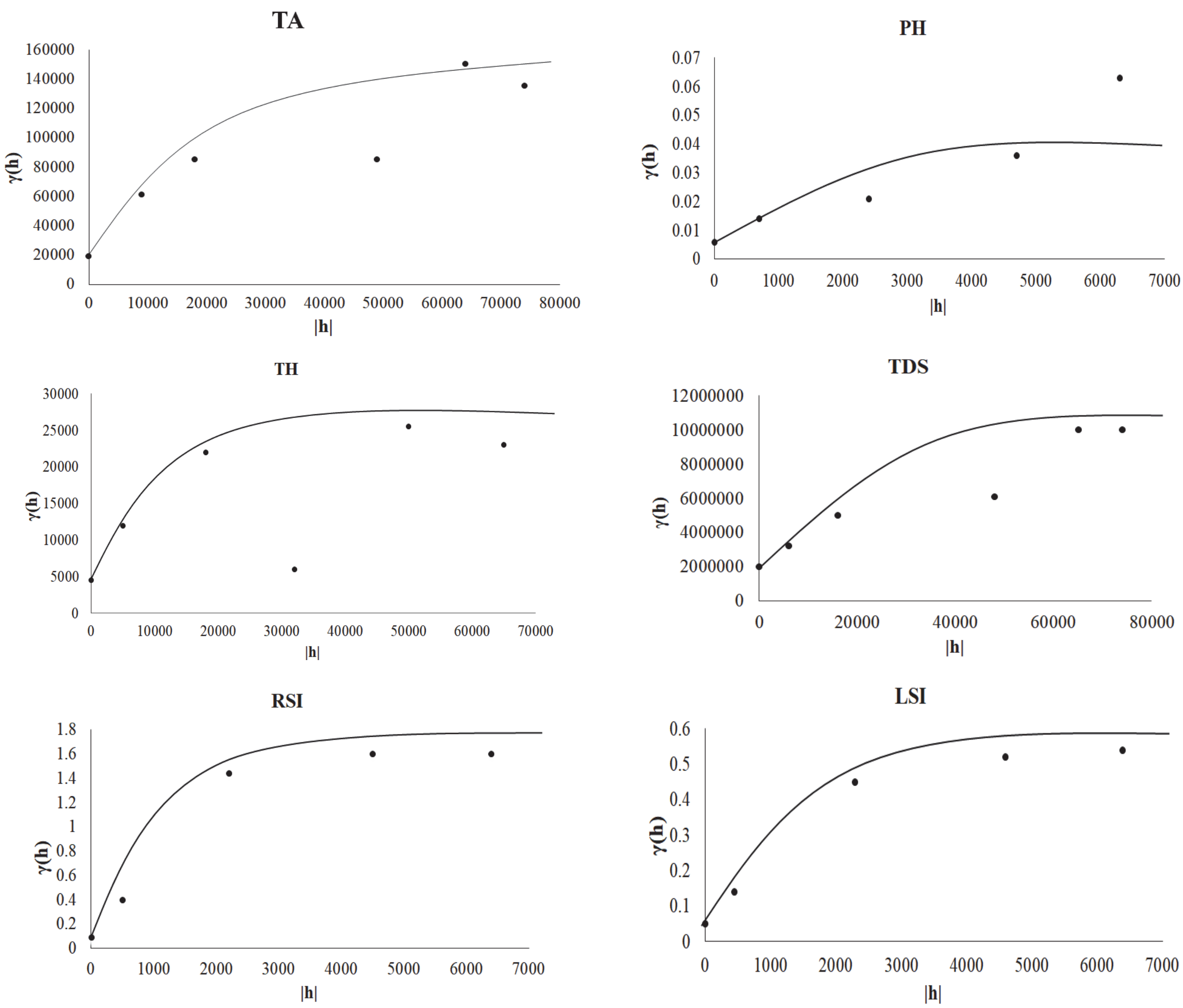

Fig.3 Experimental variograms and theoretical model fitted to groundwater quality indicators of Birjand plain

The spatial distribution of TDS and TH in the aquifer of Birjand plain is almost similar to each other (Fig.4). The lowest amount of TDS and TH is observed in the center and east of the plain and the highest amount of TDS and TH is observed in the west and southwest of Birjand plain. TDS and TH decrease from the center of the plain toward the north and east of the plain. In the southwest, salinity and high TDS aquifers can be seen, which include gray, cream, red and green colored marls with gypsum. Part of the water entering the Birjand plain passes through the rocks of this formation. Due to the presence of gypsum salts in this formation, the water that passes through these rocks in its path, due to the dissolution of gypsum and other salts, water quality is greatly reduced. Due to the presence of gypsum salts in this formation, as water passes through these rocks, due to the dissolution of gypsum and other salts, water quality is reduced significantly. The presence of gypsum salts in the form of veins can also reduce the quality of water that passes through this formation and enters the Birjand plain. Due to the direct relationship between the Langelier index and pH, TDS, alkalinity and total hardness, the spatial distribution of the LSI index is similar to the distribution of these components and follows a similar trend (Figure 4).

According to the obtained results, kriging method is a suitable method to evaluate the quality of groundwater and in particular its corrosion and sedimentation potential. One of the effective factors in calculating the Langelier and Rayznr index is temperature. In this paper, these indicators are calculated and presented in the average temperature of plain water. Therefore, the current calculated indicators are to show the sedimentation and corrosion potential under natural water temperature conditions. All qualitative components follow the spherical variogram model. Similar studies on Birjand plain in various fields such as aquifer vulnerability, well location, groundwater quality assessment, etc. also confirm these results. Keshavarz et al. (2014) in a study entitled "Suitable location of drinking water extraction using fuzzy hierarchical analysis in the Birjand plain aquifer", have prepared a classification map of drinking water extraction potential in the Birjand aquifer that has 5 classes from poor to very good (Keshavarz et al., 2014). According to the results, the western and southwestern regions of the aquifer have a poor class and the eastern regions of the aquifer have a very good class which Compared to the zoning of LSI and RSI indices, it can be inferred that these areas are not suitable in terms of drinking potential and corrosion potential. Eftekhari and Akbari (2020) evaluated the qualitative vulnerability of Birjand plain aquifer by SINTACS-LU method. According to the results and zoning of the study area, it was found that the western and southwestern parts of the aquifer in the vulnerability map have more potential to contaminate the aquifer which indicates the relationship between LSI and RSI indices with groundwater quality indicators in the region (Eftekhari et al., 2019). Eftekhari et al. (2020) also achieved similar results in another study entitled "Development of DRASTIC method considering land use to analyze the potential of aquifer pollution in semi-arid regions", so that the western and southwestern regions of the aquifer have moderate to high vulnerability and the central regions of the aquifer have moderate and low vulnerability, which confirms the results of this study. In the present study, according to the methodology used and the results obtained from it and the zonation, similar results were obtained regarding corrosion and sedimentation of Birjand aquifer plain. The range of effect of the measured indices was from 3220 m (RSI) to 10300 m (TH). The range of effect of LSI and RSI is smaller than the range of effect of their components and looks similar. Due to the direct relationship between the Langelier index and pH, TDS, alkalinity and total stiffness, the spatial distribution of the LSI index is similar to the distribution of these components and follows a similar trend. In better words, it can be said that the average Langelier index for Birjand plain indicates its corrosion. According to zoning maps, pH and alkalinity are higher in the western and southwestern part of the aquifer than in other parts of the aquifer, and pH is lower in the central part and water alkalinity is the lowest. The central part of Birjand plain aquifer has suitable indicators for various activities such as agriculture and even drinking. On the other hand, the eastern regions of the plain have milder conditions than the western and southwestern regions, where the indicators are very high. Based on the results, there is no limit in terms of corrosion and sedimentation for irrigation in the central part of the plain (Langelier index), but according to the results of other indicators, due to corrosion potential and sedimentation in some areas, especially in the northeast, it is better to take necessary measures for drinking.

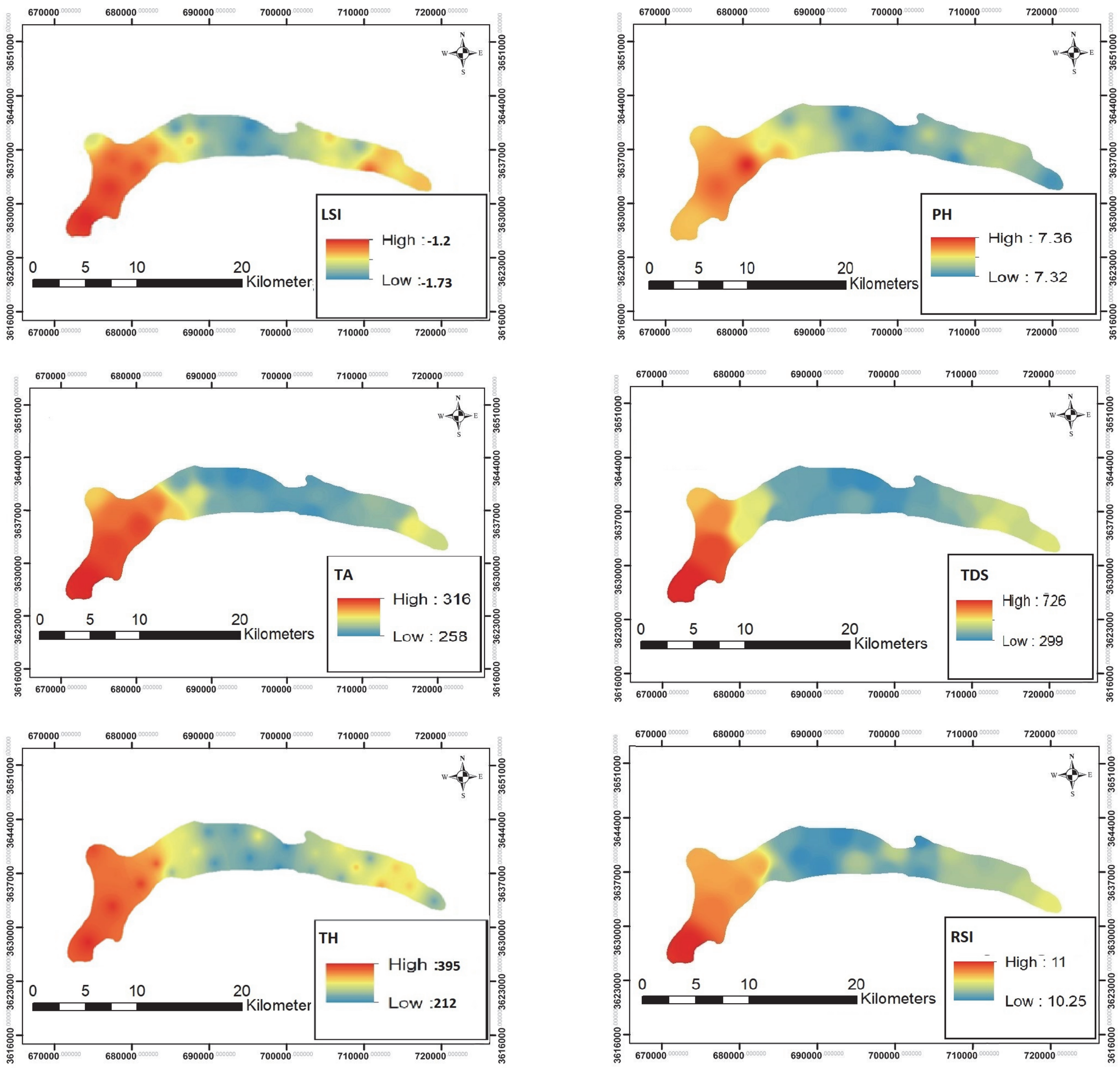

Fig.4 Zoning maps of LSI and RSI indices and their components in Birjand groundwater

Conclusion

Optimal management of water resources and maintaining and improving their quality requires data of the location, amount and distribution of the chemical components in the water in a designated geographical area. The purpose of this study is spatial analysis of sedimentation potential and corrosion potential of Birjand plain groundwater. Considering that Birjand plain is one of the important plains of South Khorasan province, this plain was selected for study. By using Rayznr and Langelier index in a geostatistical analysis platform, corrosion and sedimentation evaluated for the Birjand plain groundwater. The spatial changes of Langelier index show that in the northern, central and eastern parts of the Birjand plain aquifer, there is a minimum corrosion potential and in the southwestern and western parts of this aquifer there is a maximum corrosion potential. Due to the inverse relationship between the Rayznr index and the Langelier index, in the western and southwestern parts of the aquifer where the value of the Langelier index and corrosion potential are minimal, in this part of the aquifer the indices are maximum. Therefore, controlling and reducing the corrosion process in Birjand water resources, especially in the western regions, is essential. In order to reduce its corrosion, corrosion inhibitors can be used and injected into areas with high indices or reduce pH and alkalinity.

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