Assessment of the quality and quantity of groundwater in Bahadoran plain using neural network methods, geostatistical and multivariate statistical analysis

Mohammad Sadegh Talebi, Mehran Fatemi

Department of Geography, Faculty of Humanities, Meybod University, Meybod, Iran.

Graphical Abstract

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ABSTRACT

Growing water demand in various sectors including agriculture, industry, drinking water and eventually increasing production and risk of pollution have imposed mounting pressure on water resources. The relative stability of renewable water resources makes it necessary to pay special attention to the conservation and optimal use of these resources, especially in desert areas such as Iran, and this requires careful and principle planning for the optimal use of existing water resources. In this research, a descriptive-analytical method was adopted. The data were collected from fifteen wells during an 8-year period (2010-2017). The Kolmogorov-Smirnov method was recruited to assess the normality of data distribution. Also, since the classical data (water quality data) did not take into account the spatial distribution of groundwater quality parameters, we used the geostatistics for this purpose. The results suggested that the dominant groundwater type in the Bahadoran region was sodium chloride (NaCl), which is highly volatile. This volatility can be attributed to cationic and anionic exchanges as well as the dissolution of salt and gypsum in the neogene formation of the region. On the other hand, overexploitation and increasing drainage of agricultural, residential and even industrial wastewaters in the plain water resources have drastically influenced the groundwater quality. In the second period of the studied period (2012-2013), the level of maximum classes of most parameters has increased compared to the first period, and these changes have increased with a greater slope in the third period. According to the studies, the most important formations in terms of reservoir rock, feed source of alluvial plains and groundwater quality are lower cretaceous calcareous sediments of Bahadoran.

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1. Introduction

Today, it is a common practice to supply the drinking water of urban areas and cities through groundwater extraction. There is a body of studies on the quality of groundwater and the prevention of groundwater pollution in most countries. Since Iran is classified as a dry region, the optimum use of groundwater resources due to the growth of industry and agriculture in the country and the reliance of these industries on water resources call for a detailed and systematic planning aimed at appropriate exploitation of water resources available. Today, as far as

*Corresponding author Email: talebi@meybod.ac.ir

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the sustainable development is concerned, special attention should be paid to the utilization of these resources. With increasing population and growing demand for water in various sectors including agriculture, drinking water, health and eventually rising production and income, water resources have come under mounting pressure. Since the renewable water resources in each climate zone are relatively fixed, systematic policies and methods should be adopted to preserve and optimize the utilization of these resources (Sedaghat, 2006). In addition, more than one billion people in the world do not have access to clean water, and 80% of the diseases in developing countries originate from unclean water sources. Today, the problems associated with water shortage and pollution are getting more attention. In recent years, there have been debates on how to respond to the problems of both climate change and extreme weather events, with many national managers and planners and regional and global summits putting this issue top on their agenda.

With the current trend, it is expected that by 2025, two out of every three people will live in the areas stricken with water crisis. Food and Agriculture Organization of the United Nations (FAO) studies in 93 countries is indicative of water instability in these countries (Malakukhan, 2004) (The Food and Agriculture Organization of the United Nations (FAO) is an international organization established in 1945 by 44 United Nations member states to work in the field of agricultural development). Even though the problem of fresh water and its sustainability and unsustainability have affected a wide spectrum of countries around the world, the climatic and geographical features of some countries in arid and semi-arid regions have exacerbated this problem so that the lack of water and reliable access to water resources during certain seasons and days is a major threat to the sustainability of life in the region. With about 95% of its land located in an arid and semi-arid region, Iran is one of the countries struggling with severe water shortage. Specific climatic and geographical features of Iran, precipitation regime influenced by the Mediterranean system, topographical conditions and variable terrain features have provided a vast stretch of lands for water penetration into the ground. As series of these factors, which spurred the use of Qanat technology in Iran, has given long-standing importance to the exploitation of underground water (Talebi et al., 2016).

The first method of ground water withdrawal was probably digging a well. The oldest water wells that is still extant is located in the valley of the Sind River, which dates back to 6,000 years ago. The Iranians were the inventor of the Qanats, and this technology began to spread to other parts of the world in about 3,000 years ago. Water is accumulated in the pores and empty spaces of rocks and soils below the ground (Sedaghat. 2008).

Groundwater quality plays a key role in the health and safety of people. In 1989, the first groundwater quality study was conducted in the United States, which assessed the quality of ground water in more than 1,000 wells in 25 states. This study was followed by several other studies in different countries, including Iran. Underground water quality relies on its path through the rocks, and its changes depend on many factors such as minerals, temperature, duration of contact with minerals, water soluble carbon dioxide, etc. Therefore, any change and transformation of water when it penetrates the ground is inevitable as it constitutes one of the stages of groundwater measurement (Mokhtari, 2011). The quality and quantity, and quality parameters related to the chemical, physical and biological properties exhibit its suitability for drinking. Ryan et al. (2006) reported in their study that spatial and temporal variations coupled with salinity and temperature of underground water during the tide vary in different latitudes and seasons. Dhar et al. (2008) in their study of Bangladesh demonstrated that temporal variations influenced the groundwater quality in deep and shallow aquifers. Khloqi (2009) also compared the three methods of geostatistics, artificial neural network and fuzzy-neural inference system in the calculating the transfer coefficient. The results showed that the fuzzy-neural system was more accurate than other methods. Rizi and Dugretti (2011) presented a method called Neura-Kriging by integrating artificial neural network and Kriging method to determine the hydrodynamic characteristics of the aquifer in different areas. Nazarzadeh et al. (2006) argued that the quality of groundwater has changed over spatial and temporal scales on a wide range of scales. Generally, the pollution levels vary over different time periods and places. Water quality is relative, reflecting the characteristics of water that affect its use for a particular purpose. Quality is defined based on the physicochemical and physiological characteristics. Noshaid et al. (2009) compared the geostatistics and artificial neural network (ANN) methods based on the quality and correlation of the main ions in the dry and wet seasons. According to their study, in the dry season, the most important ions for water classification are sulfate, magnesium and calcium ions. In the wet season, the absolute concentration of sulfate increases in most of the water sources especially due to the infiltration of surface water into the groundwater. The chemical composition of different sources is gyspum and calcareous groundwater is of higher quality.

Salajegheh (2010) investigated land use changes and its effects on water quality in five sub-basins of Karkheh River in northern Iran in 1988 and 2002 using TM and ETM sensors of the Landsat satellite. (The TM sensor is one of the Earth observation sensors that was first activated on the Landsat 4 satellite (until 2001) and then on the Landsat 5, which was active until 2012.Thiem sensors include image data in seven spectral bands, three of which are in the visible wavelength range and four of which are in the infrared wavelength range, and the resolution of most bands is 30 meters. Landsat 7 has an improved version of the TThm sensor, known as the Enhanced Subject Mapper Plus (ETM) and then studied the process of water quality changes in the river. The results showed that land use changes in the Karkheh watershed have contributed to the expansion of rangelands, forests, gardens and agricultural lands and the expansion of dry land. Also, the analysis of land use changes in each of the existing sub-basins illustrates the stretching of urban areas into most sub-basins. On top of that, the water quality analysis in Karkheh river indicates the decline of water quality.

In investigating the process of changes in water resource, the hydraulic characteristics of the aquifer and the effect of the relevant natural and artificial factors are considered. Using groundwater monitoring, information such as geological and hydrogeological features of the aquifer, the distribution of hydraulic load in different times and places, the direction of groundwater flow, water quality, the extent of contaminants and characteristics of pollutant sources is achieved (Safari, 2002). In this research, an attempt has been made to analyze the results of chemical analysis of samples taken from piezometers and deep wells in the region and according to the pollution sources during the years, geographical and temporal factors, using hydrochemical software, which is superior to previous studies. Today, geostatistics methods and artificial neural networks are used to explore the spatial variables such as groundwater quality parameters.

2. Materials and methods

2.1. Study area

Bahadoran village is located in the city of Mehriz in Yazdi province, 85 km from Yazd on the road from Yazd to Kerman. It has an arid and dry climate with a precipitation of less than 150 mm. Bahadoran village has a population of over 5,000. The main product of this region is pistachio and it represents one of the most important export centers for pistachio in Yazdi province and the second largest pistachio hub of the country after Rafsanjan. Still, other products such as wheat, barley and oats are grown in this area. The average rainfall in this area is about 70 mm. Bahadoran, at a distance of 70 km from the Shirkouh, enjoys a relatively mild climate (Detailed Plan of Watershed Studies, 2009). Bahadoran plain is a small plain along the Yazd-Ardakan large plain with a relatively fertile soil, which is currently one of the major agricultural pistachio cultivation areas in Yazdi province. A distance of 15 km from Bahadoran (2006) showed Mount Bahadori, which is conical, and Mount Bafq forms the eastern boundary of the city, separating the two cities of Mehriz and Bafghs. Bahadoran Plain is part of the massive central plateau of Iran that is home to one of the oldest (Percambrian) and youngest (Holocene) geological formations.

2.2. Data collection

The data used in this study is divided into two categories: quantitative (depth of water in wells with piezometers) and qualitative data (qualitative parameters of wells in the study area). The water level measurement data and quality parameters related to the study area were obtained from the regional water company of Yazdi province and subjected to the initial organization. In the first stage, 35 wells were identified, but considering their incomplete statistics, a total number of 15 wells with relatively complete data were extracted during the period (2010-2017). Table 1 shows the coordinates and specifications of these studied wells. X and Y are the longitude and latitude locations of the wells in the Universal Transverse Mercator (UTM) system.

Before any statistical analysis, the normal distribution of data should be determined. For this purpose, in terms of comprehensiveness of the geological and hydrogeological tests, first by Klomogorov non-parametric method (for non-classical data) and because classical data (water quality data) are able to consider the spatial distribution of water quality parameters. Not underground, geostatistics was used as a technique for this purpose. Therefore, due to the abnormal distribution of the data, they were converted into a normal log, and the normality was confirmed by the Kolmogorov Smirnov test. Given the breadth of the study period, to evaluate the time trend (in each period) and the

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normality of data, the mean values of the years 2010, 2011 and 2012 were examined as the first period, the mean values of the years 2012, 2013 and 2014 as the second period and the mean values of the years of 2014, 2015, 2016, and 2017 as the third period. In the next step, in order to find the dominant geomorphic type of wells, their distribution was analyzed on the land use map of the studied area and the percentage of well density in each type was determined. In Fig. 1, the distribution map of wells is presented on the enhanced thematic mapping (ETM) satellite image to identify the location of wells on various uses in the study area.

**Table 1. Characteristics of wells in the study area.**

<table>
<thead>
<tr>
<th>Number</th>
<th>Well</th>
<th>X</th>
<th>Y</th>
<th>Type of well</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Baharestan</td>
<td>296337</td>
<td>3483849</td>
<td>Semi-deep</td>
</tr>
<tr>
<td>2</td>
<td>Islamabad</td>
<td>296736</td>
<td>3481395</td>
<td>Deep</td>
</tr>
<tr>
<td>3</td>
<td>Khoramabad</td>
<td>299110</td>
<td>3480331</td>
<td>Deep</td>
</tr>
<tr>
<td>4</td>
<td>Majidabad Delbar</td>
<td>297731</td>
<td>3477517</td>
<td>Deep</td>
</tr>
<tr>
<td>5</td>
<td>Alabad Fayaz</td>
<td>301491</td>
<td>3477156</td>
<td>Deep</td>
</tr>
<tr>
<td>6</td>
<td>Hamidabad Islami</td>
<td>299399</td>
<td>3774785</td>
<td>Semi-deep</td>
</tr>
<tr>
<td>7</td>
<td>Rezaabad Naghdi</td>
<td>300586</td>
<td>3472934</td>
<td>Semi-deep</td>
</tr>
<tr>
<td>8</td>
<td>Ghazizabad</td>
<td>299319</td>
<td>3471229</td>
<td>Semi-deep</td>
</tr>
<tr>
<td>9</td>
<td>Hamidieh (Goldasht Sadeghia)</td>
<td>302286</td>
<td>3471382</td>
<td>Semi-deep</td>
</tr>
<tr>
<td>10</td>
<td>Amirabad Zamari</td>
<td>302630</td>
<td>3469907</td>
<td>Semi-deep</td>
</tr>
<tr>
<td>11</td>
<td>Aburizadeh</td>
<td>300705</td>
<td>3466395</td>
<td>Deep</td>
</tr>
<tr>
<td>12</td>
<td>Industrial Estate</td>
<td>301377</td>
<td>3465924</td>
<td>Deep</td>
</tr>
<tr>
<td>13</td>
<td>Karimabad (Farah Abad)</td>
<td>303542</td>
<td>3465679</td>
<td>Deep</td>
</tr>
<tr>
<td>14</td>
<td>Askarabad</td>
<td>307266</td>
<td>3466395</td>
<td>Deep</td>
</tr>
<tr>
<td>15</td>
<td>Khoramabad Naghdi</td>
<td>305923</td>
<td>3463536</td>
<td>Deep</td>
</tr>
</tbody>
</table>

**Fig. 1. Distribution map of wells on ETM satellite image.**

**2.2.1. Determining the boundary of the study area**

Considering the vastness of the Bahadoran area in Yazd province and the special distribution of wells in this area, along with the necessity of using interpolation techniques that requires the generalization of small areas to large areas (Hasani Pak. 1998), the boundary of the area is limited to the distribution of wells under study to bolster the reliability of results. Therefore, at this stage, by specifying the distribution of wells in the region, which is part of the Bahadoran aquifer in Yazd province, the boundary of the study areas was enclosed. Fig. 2 shows the location of the studied area on the map of Iran and Yazd province.

**Fig. 2. Location of the study area on the map of Iran and Bahadoran.**

**2.2.2. Underground water quality parameters trend test**

When the time series of hydrological data follows an even ascending or descending trend, the data is said to have a trend. This can be determined by conducting static testing or test of randomness for data. In this research, Kendall test was used to examine the data trend. The Kendall test was first developed by Mann (1945) and then developed by Kendall (1948). This test has been recommended by the World Meteorological Organization (Michelle et al. 1996).

**2.3. Introduction of software used in the study**

**2.3.1. Neuro Solution software**

One of the software used in the artificial neural network is Neuro Solution software. The data used in this software was retrieved from the Nodpad. By introducing the type of network, input data, output data, train, test and validation data, the number of middle and output layers, the type of functions used in the middle and output layers, the learning rule, dynamic elements of the network and the number of epochs or rotations required to learn the design of the network structure are designed and the system is run. After the train step, the network is verified with test data. Then, the results are transferred from the software to the Microsoft Excel, and by comparison with the observational data, the error rate is determined graphically and accuracy of the mode results are evaluated by calculating the error parameters (RMSE and R²). In the next step, by testing different methods based on RMSE and R² statistics, the best method, network, number of rotations and number of hidden layers are determined. In the end, the results of the neural network are compared with those of statistical interpolations and the best method is identified.

**2.3.2. AQQA software**

This software allows determining the chemical properties of water such as water type, salinity, sodium absorption risk, magnesium risk, saturation index and water hardness. To do so, first based on the acceptable format of the software, the data are organized and then in accordance with the three time periods (first, second and third periods), a comparison is drawn between the process of qualitative changes. In each period, the dominant types of water are determined and their specifications are listed (Hajian Nejad and Rahsepar. 2009).

**2.3.3. Geo statistical Analysis Extension**

In the ARC GIS9.3 software, there is a tab called Geo Statistical Analysis, which allows performing all of interpolation and statistical calculations in this software. The software input requires special data, which must be tagged with latitude and longitude. One advantage of this software is that it normalizes data before each step. It also has the ability to display semivariogram cloud based on variance and distance points.

**3. Results and discussion**

In the wake of growing population and increasing water demand in various agriculture, drinking, sanitation and industry sectors, as well as mounting production and pollution risk, water resources have come under escalating pressure. Since the renewable sources of water in...
each climate are relatively fixed, special attention should be allocated to policies and methods adopted to preserve and optimize the use of these resources (Ebrahimi, 2001).

3.1. Evaluation of normality test

The first step in the use of geostatistical methods is to investigate spatial structures of data using Semivariogram analysis. One way to evaluate the normality of data is to use skewness coefficient. For coefficient values below 0.5, there is no need for data conversion, but for values between 0.5 and 1 or greater than 1, the root and logarithm should be used to normalize data, respectively (Robinson and Metternicht, 2006). The Kolmogorov-Smirnov test was used to evaluate normal distribution of data. According to results of the normality test, since Cl, TDS, TH, EC, NA, K, MA and CA data are not normally distributed, they need to be normalized. Therefore, the data were normalized by the logarithm. On the other hand, HCO$_3$, SO$_4$, pH and SAR parameters have normal distribution.

In Fig. 3, the values of some qualitative water statistics and their normal distribution are presented.

![Fig. 3. Histogram and normal curves of (a) K, (b) Cl, (c) EC, (d) pH, (e) HCO$_3$, (f) Mg.](image-url)
3.2. Artificial neural network

Various models were tested for prediction and simulation. By introducing parameters of water depth and water quality to software, the desired parameters were predicted. Then, the coefficient of efficiency and root mean square error for each network were calculated. Although in all cases the coefficient of efficiency was relatively low at this stage, the results of RBF and MLP networks were more accurate than that of other networks, and therefore more suitable for prediction of time series. MLP networks are not very efficient when there are high fluctuations and changes. In all networks, different functions were in the middle and output layers and a comparison of the results was drawn. The results showed that among all the networks used in this study, the hyperbolic tangent function in both the middle and output layer yielded the best results, whereas the sigmoid function and linear functions had relatively poor performance in these two layers. The number of epochs in all networks was 6000. The “root of efficiency coefficient” (R) between the results of the model and the actual values in the RBF networks was around 0.6 and the root mean square error was estimated at 0.051. In the MLP networks, these two values were about 0.5 and 0.41, respectively. As can be seen, RBF networks have more desirable performance, suggesting that the results of simulation are satisfactory especially when there are fewer inputs. In this research, the input layer consisted of other qualitative parameters in the specified date, latitude and longitude, and the output function included quantitative and qualitative parameters. Tables 2-7 show the efficiency of different types of networks for the water quality parameters in the Bahadoran plain.

3.3. Geostatistics

Given that geostatistical methods are based on the spatial variable, the coordinates of the points in which the desired variable have been measured, as well as the value of variables in those points should be considered as input information. Using the existing data and ARCGIS9.3 software, the semivariogram of each parameter can be obtained in the first step. Then the appropriate semivariogram can be extracted based on the error sum of squares. However, it should be noted that the best model with the lowest error and the highest compliance with the resulting points must be fitted on the coordinate points. In the next step, we can obtain the cross validation curve based on semivariogram data using Kriging equations. Table 7 compares various exponential, spherical, Gaussian and circular semivariogram of the underground water qualitative parameters in Bahadoran plain based on the coefficient of determination. As can be seen, in most cases exponential and spherical models are suitable. The information of various semivariogram methods for each parameter is presented in Table 8 and Figs. 4a-h, respectively.

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3.4. Interpolation analysis

3.4.1. Results of in-depth analysis of underground water depths

Following the interpolation of piezometric parameters of the underground water depth by geostatistics and artificial neural network in Bahadoran plain of Yazd province over different years, to compare the interpolation results of these methods with actual statistics, RMSE and R² statistics were adopted. Thus, a percentage of the data obtained from interpolation and actual values were compared to each other. The results indicate that the geostatistical method of interpolation compared to the multivariable regression methods (artificial neural network) can offer a more accurate estimate the groundwater depth. This has been demonstrated for RMSE and R² values. The results also suggest the higher accuracy of the Kriging method compared to other geostatistical methods. Also, the exponential method of Kriging is more reliable than other methods. Table 9 shows the accuracy of methods based on RMSE and R² statistics for the depth of underground water in Bahadoran plain over three statistical periods. After determining the best groundwater depth interpolation method, namely the simple Kriging method, this method was employed to interpolate groundwater depth in the studied area. Then, the resultant maps were used to analyze the spatial variations of this parameter. As Table 10 shows, the minimum, maximum, and median depths of years 2014 and 2017 are greater than that of 2010. Fig.5 shows the distribution of different water levels in the three periods studied. As can be seen, the class of 40-35 m in each period has the highest percentage of groundwater polygonal area. Also, the percentage of polygon areas in depth below 14 m fell gradually. For depths of 21-14 m, which were the highest in 2010, it dropped in 2017. In depths exceeding 45 m, there has been an incremental slope from the beginning to the end of the studied period.

3.4.2. Spatial variation of underground water depths

Interpolation of groundwater level at the surface of the cut-off area in the Bahadoran plain as well as the zoning and spatial and temporal trend analysis of groundwater depth exhibited that the southern and northeastern parts of the study area witnessed the highest drop in groundwater level (more than 0.5 m) during the study period (2010-2017). This could be attributed to the special use of this area, which is primarily agricultural and residential in certain parts, which has led to the overexploitation of aquifers and drastic decline of groundwater in these areas. The results also illustrated that the water decline was lower in the western and northwestern parts. This could be due to the geological features of this area, which is mostly composed of neogene saline sediments that curb the exploitation of water resources and therefore diminish the water level.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean depth, m</th>
<th>Minimum depth, m</th>
<th>Maximum depth, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>32.66</td>
<td>13.19</td>
<td>48.67</td>
</tr>
<tr>
<td>2014</td>
<td>36.18</td>
<td>15.78</td>
<td>53.98</td>
</tr>
<tr>
<td>2017</td>
<td>39.26</td>
<td>17.75</td>
<td>58.08</td>
</tr>
</tbody>
</table>

3.4.3. General water type determination

- Clustering and determining homogeneous regions

Given the inappropriate distribution of wells in the study area, the areas that were homogeneous in terms of water quality were detected by clustering the existing wells. For this purpose, the Minitab software package was utilized. To do so, the qualitative parameters of each well
are given to the software, and clusters are connected using ward method and the eclipse distance technique to extract homogeneous regions. Accordingly, the wells of Islamabad-Khormabad, Hamidabad Islami-Ghaziabad and Karimabad- Industrial Estate are the most homogeneous. After determining the qualitative homogeneous regions by the AQQA software, the dominant water type and the process of water quality changes were determined using diagrams such as Stiff, Piper, Durov and Radial. In Figs. 5a-f, the groundwater quality diagrams of homogeneous clusters are presented in three periods.

- **Analysis of the groundwater hydrodynamic diagram**

The hydrochemical origin of homogeneous zones of Bahadoran plain is the effects of groundwater currents and surface evaporate. According to the Stiff, Durov, radial and piper diagrams, the dominant water type of the first homogeneous zone (including wells of Islamabad, Khormabad, Baharestan and Mohammadabad Delbar) is a Na-Cl, though in some places (Mohammadabad Delbar) the Na-So4 type is also present. This water type is the results of neogene saline formations. The dominant water type of the second homogeneous zone (including wells of Ghaziabad, Hamidabad Islami, Alabad Fayaz) is the Na-Cl, which is strongly inclined toward the Mg-Cl type. The quality of this water type is determined based on the location of the zone and its vicinity to or distance from saline formations. This zone has a lower exploitation limit than the first zone. The third zone is located in the vicinity of the neogene saline formations. The dominant water type of this zone, similar to the other two zones, in Na-Cl, but on the account of its high salinity (7385 micromos per cm) it faces greater limitations. This zone is commonly used for constructing brick kiln and other industrial purposes. The quality of underground water in Piper over the years exhibits that the ionic composition of water is controlled by chlorine, sulfate and sodium. The study of temporal trends indicates that the dominant water type is sodium chloride and sources that are located in the salty zone near the neogene formation have undergone greater qualitative changes over time. Basically, underground waters have low bicarbonate content at the outset of their movement cycle (water feeding zones) and over the course of their path, they accumulate various mineral, resulting in the emergence of sulphate and chloride water types at the end of the course. However, factors such as industrial and municipal wastewater, pollutant, etc. can accelerate or exacerbate this gradual evolutionary phenomenon.

- **Analysis of time trend of quality parameters of Bahadoran plain**

The analysis of mean water quality parameters of Bahadoran Plain in the years 2010-2017 exhibits that except for the PH parameter, which has a slightly decreasing trend, other quality parameters of this plain show follows an ascending trend.

![Fig. 5. Stiff diagram of Islamabad well during (a) 2010-12 period; (b) 2012-14 period; (c) 2014-17 period; (d) 2010-12 period; (e) 2012-14 period; (f) 2014-17 period.](image)

4. **Conclusions**

Given that the Bahadoran plain is one of the most complex aquifers in the Yazd province, the necessity of using systems that demonstrate the quantitative and qualitative changes of groundwater in this plain is strongly felt. The hydromechanical diagram of the plain indicates the qualitative changes over time in this plain. The dominant water type in Bahadoran plain is sodium chloride, which is a highly variable. These variations can be attributed to cationic and anionic exchange, as well as the dissolution of NaCl and gypsum developed in the Neogene
formations in the region. On the other hand, overexploitation and increasing drainage of agricultural, residential and even industrial wastewater into plain water resources have spurred changes in groundwater quality. In the second period (2012-14), the maximum class level of most parameters followed an ascending trend compared to the first period, and these changes became more drastic in the third period. According to the results of this research, the most important formations in terms of reservoir rock, water source of alluvial plains and the quality of groundwater are cretaceous calcareous sediments in Bahadoran plain. The limestone and dolomite formations of Oghda and Soltanieh structures in the north of the study area are qualitatively and quantitatively moderate in terms of rigidity and inadequate feeding. It should be stressed that the decline of groundwater levels, in addition to reducing the quantity and changing of the water quality, leads to land consolidation and settlement in fine-grained and silty formations. On the other hand, the quantity of water reservoirs and the increasing salinity of water threaten groundwater aquifers, thereby compromising the current investments and engendering a myriad of social and political problems. The above points clearly show that the only effective and systematic solution is the proper and regulated used of water resources and the prevention of groundwater overexploitation.

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