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Qualitative monitoring of Saveh plain's Groundwater based on water quality index (WQI)

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Abstract

In this study, the quality of groundwater resources of Saveh plain was investigated based on water quality index (WQI). WQI index is based on use of magnesium (Mg), sodium (Na), potassium (K), sulfate (SO4), chloride (Cl), Total solids (TDS), bicarbonate (HCO3), calcium (Ca) and pH which determines the class of water quality. The required qualitative data were collected from12 wells at Saveh plain and WQI index was calculated. Based on WQI index from the needed 12 wells, 2 wells were at High class, 5 wells were at the appropriate class, 4 wells in weak class and 1well in very weak class. Based on WQI, the more we move from West ,the groundwater quality reduces, in the way that the quality of ground water in western areas of plain are in High class and in the eastern areas of the plains are in the weak class.

Keywords: Saveh plain, water quality, the WQI, ground water resources

Introduction

Population growth and increased demand for food and limited water resources in many parts of the country caused water crisis. On the other hand, regardless of the available water quantity, its quality also has many constraints. Thus, maintaining the quality of water resources shows its importance. Contamination of water will actually cause it to become unusable. Thus, water pollution, in addition to damaging human health, also paralyzes socio-economic development (Mylvonik, 2007). Awareness of water quality in each area could be helpful to maximize management programs in order to make optimal allocation of water.

Evaluation of water quality is done in different ways. In general, these methods can be classified into two groups; the first group, known as the traditional methods are methods that examine the water quality based on a qualitative parameter such as nitrate. In these methods, the desired quality is compared with standards of water quality and we will comment on the quality of water. The second group includes methods that based on multi-parameters of water quality will result in an indicator of water quality. This index which is based on the number it provides determines the quality of the water. Use of the indexes is more comprehensive and convenient than traditional methods since it includes several parameters.

Numerous researches in water quality were conducted using different methods. Qamishion et al. (2012) paid attention to the zone-classification of groundwater quality of Semnan-Sorkheh. They used three methods of inverse distance, kriging and co-kriging for zone-classification of qualitative parameters. They analyzed the changes of five parameters of hydraulic conductivity, chloride, concentration of soluble salts, sodium and sulfate in aqueous years from 1999-2000 to 2009-2010; the results show that co-kriging method is more accurate than other methods.

Mohammadi and Associates (2011) paid attention to spatial and temporal changes in groundwater quality in Qazvin plain. They studied water quality in the wells of Qazvin plain in 50 wells during 2003-2007. The results showed that 10 percent of the region's groundwater is suitable for drinking, agriculture and 6 percent is not appropriate for these purposes. Furthermore, only 4.0 percent of total groundwater is desirable for agriculture and 83/6 % have average quality. Salajegheh and colleagues (2003) examined the spatial distribution of groundwater quality in the city of Karaj. For this purpose, we used data from 43 wells. The results showed that groundwater quality is on the rise from the Southern and Central regions to the north and the western half.

Badiei Nejad and colleagues (2014) examined the quality of drinking water resources of Shiraz Plain. In their study, 110 water samples from 55 wells in two seasons of high rainfall and low rainfall were used. They investigated pH parameters, total dissolved solids, chloride, sulfate, sodium, hardness and nitrate. The results showed that the optimum pH value of the whole area's water is desirable. Sulfate concentration in most wells is desirable. Also, with regard to hardness, all the points are classified in the very hard category. The concentration of nitrates is observed in the center and south-east part. According to the general conclusion, 4.6 percent of groundwater of areas under study has desirable quality, 9.7 percent has good quality, 27.7 percent has average to low quality and 11.3 percent which are located in the south-eastern parts has a very low quality. Saheb Delan et al. (2013) examined the spatial and temporal variation of the four parameters of quality including chlorine, salt and sodium absorption ratio for bahadoran plain of Mehriz. The results showed that the salinity of 48% of the area under study is highly limited and 52% had low to moderate limitations.

Connell et al (2008) examined the spatial-temporal variations of water quality parameters in an area of Nepal. The results showed that water quality in urban areas is lower than rural areas. Also, by examining the phosphorus concentrations in rural surface and underground areas, they found that phosphorus concentration in groundwater area is more than surface water. Beckman et al. (1998) have developed a qualitative index for evaluating ground water pollution and applied it to the areas in Finland and Slovakia. Rezvan and Gordip (2010), using a water quality index WQI and qualitative data of 24 sampling points in regions of India, studied the spatial-temporal water quality in the area. Sadat Nouri et al. (2013) assessed water quality of Saveh-Nobaran plain using the WQI index. Results showed that 65% of samples had poor quality and were not suitable for drinking. By plain zoning based on WQI, they stated that the water quality in the central and north-east parts of the Plain is inappropriate.

As previous studies have indicated, evaluation of water quality in each area is highly important. Also, the use of water quality parameters compared to the individual study of each parameter provides a better view of the water quality. The aim of this study was to evaluate the groundwater quality of Saveh plain based on WQI. Also, we tried to characterize the areas with good water quality and to identify wells with low water quality.

Materials and Methods

Case Study

In this research, the Saveh plain was considered as a case study. This area is located in Markazi Province and geographically it is located in coordinates '45: ˚34 to '03: ˚35 north latitude and '08: ˚50 to '50: ˚50 east longitude. The average rainfall in this area is about 200 mm and the average temperature is 18 degrees Celsius. The nine qualitative parameters include magnesium (Mg), sodium (Na), potassium (K), sulfate (SO4), chlorine (Cl), all solids (TDS), calcium(Ca) and carbonate (HCO3), and pH were used to determine the groundwater quality of this plain.

These nine qualitative parameters for both 2003 and 2004 years were collected in 12 wells with a suitable distribution in the plain. Figure 1 shows the distribution of wells studied in Saveh plain. Geographical location of wells is listed in Table 1.

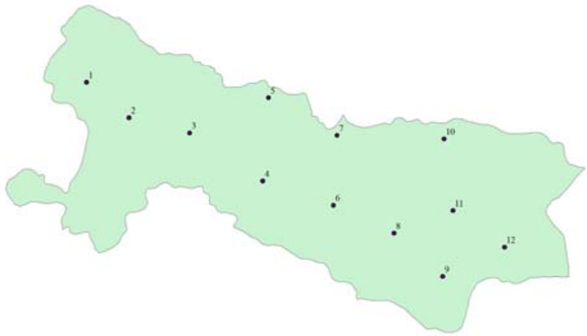

Figure 1. **Wells' location tested in Saveh**

Table 1: Geographical location of the wells studied in Saveh

UTMx	UTMy		UTMx	UTMy	
419000	3891400	7	360300	3903950	1
432355	3868471	8	370250	3895600	2
443760	3858350	9	384450	3892000	3
444042	3890582	10	401590	3880713	4
446141	3873780	11	402950	3900300	5
458206	3865220	12	418150	3875050	6

Water Quality Index (WQI)

Water quality indexes, by combining several parameters of the qualitative parameters is used for judging water quality in a region. Since these parameters do not discuss the water quality based on one parameter, it is superior over the traditional methods. Water quality indicators applied in this study uses nine qualitative parameters of Mg, Na, K, SO4, Cl, TDS, HCO3, Ca and pH to evaluate water quality. In order to calculate this indicator, first, each parameter must be weighted, the weights are presented in Table 2 below based on the standard World Health Organization (WHO, 2014). Then, using equation (1), relative weights is computed:

(1) $$W_i = \frac{w_i}{\sum_{i=1}^{9} w_i}$$

In this equation, W_i is the relative weight of parameters and w_i is the weight parameter. Then, the concentration of each parameter is measured in relation to the World Health Organization standards and the result of dividing the measured concentration of each parameter to the allowed concentration of parameter is multiplied in the weight of each parameter. WQI index is calculated by the sum of the values obtained for all the index parameters:

(2) $$WQI = \sum_{i=1}^{n} W_i \times \frac{C_i}{S_i} \times 100$$

Where Ci is each parameter's concentration in water sample and Si is the World Health Organization standard for each parameter. WQI indicator classifies water samples quality into five qualitative classes. The index value and its corresponding class are shown in Table 3.

Table 2: The absolute and relative weight of water qualitative parameters in calculating WHO

Mg	50	3	0/097
Na	200	4	0/129
K	12	2	0/065
SO4	250	5	0/161
Cl	250	5	0/161
TDS	500	5	0/161
HCO3	120	1	0/032
Ca	75	3	0/097
pH	5/8	3	0/097

Table 3: Qualitative Classification of water by WQI index

WQI value	Water Quality class
High quality	50>
Appropriate quality	50-100
Poor quality	100-200
Very poor quality	200-300
Unusable	300>

Results and Discussion

Given the values of WQI in various wells, the water quality in western part of the plain is better than eastern areas. Thus, when we move from the west to the east of plain, the quality of water decreases. WQI value in well number one and two which are located in the most western part are in the lowest level and in well Numbers 10, 11, 12 which are located in the most eastern part is the maximum level as in 2003 the index value in these areas begins from 15 and reach to 256 in the eastern part and also in 2004, this trend is observed and the WQI value varies from 18 in eastern areas to 206 in western part. Table 4 shows WQI value for all wells under study in years 2003 and 2004.

Table 4: WQI value for the studied wells

Year		2003		2004
Well's number	WQI	class Quality	WQI	class Quality
1	15	high	81	high
2	3	High	23	High
3	35	Appropriate	57	Appropriate
4	47	Appropriate	68	Appropriate
5	123	Weak	116	Weak
6	59	Appropriate	63	Appropriate
7	411	weak	108	weak
8	79	Appropriate	84	Appropriate
9	83	Appropriate	91	Appropriate
10	12	weak	123	weak
11	562	Very Weak	209	Very Weak
12	611	weak	122	weak

With regard to the classification of water quality, most wells in the western regions were suitable for drinking, but in the eastern part, especially well number 11, the water quality is very unsuitable and is highly limited for consumption. Qualitative class of well's water during 2003 to 2004 despite changes in the values of WQI had no difference. The greatest improvements in WQI index from 2003 to 2004 is related to well No11 that the index value decreased 47 points and the highest quality decrease is related to well No. 10 that the qualitative index for well no. 12 increased 12 points.

Of the 12 wells of the study, the water quality of 2 wells were in the high class, 5 wells in the appropriate class, 4 wells in weak class and one well were in the very weak class. In other words, 17 percent of the wells studied can be used as drinking water without any restrictions. In 41 percent of the wells, the quality of water was not problematic for use and these wells can be used for drinking water. 33% of the wells have water with low quality for drinking and action should be taken to improve water quality in the wells before drinking. And in only well 11, the water quality is very low and its use is not recommended for drinking.

The relationship between qualitative parameters and WQI index correlations was calculated. The highest correlation of WQI index belonged to parameters of TDS and SO4. Correlation between WQI and TDS in 2003 and 2004 equals to 0/99 and its correlation with SO4 parameter in 2003 and 2004 were 0/97 and 0/98 respectively. This shows that the hardness and sulfate of groundwater in this area is limited and the values of these parameters have a great impact on the WQI index. It is important to note that these parameters with extra weight were included in calculating WQI, which reflects the importance of these factors in determining water quality. Lowest WQI index correlation was with HCO3 and pH parameters, this low correlation shows that the area's water is not limited regarding these parameters. Correlation values for all parameters are presented in Table 5.

According to the correlation table, it is determined that judgment about the quality of water in traditional method has defects compared to using water quality index. For example, if investigating the quality of water was done with regard to pH, the quality of water of all wells was in the high class, or conversely if the TDS was elected as the basis for judging, the quality of water in all the wells was classified as poor class. So, as indicators of water quality parameters simultaneously analyzed several parameters to judge the quality of the water, they are more suitable than conventional methods for water quality monitoring.

Table 5: **Correlation coefficient value between WQI values the and water qualitative parameters used in calculating**

Mg	Ca	K	pH	TDS	Year
0/9	0/93	0/32	-0/08	0/99	2003
0/8	0/92	0/73	0/01	0/99	2004
	SO4	Cl	HCO3	Na	Year
	0/98	0/94	-0/13	0/99	2003
	0/97	0/64	-0/44	0/93	2004

Conclusion

The aim of this study was to assess the quality of groundwater resources of Saveh plain. The qualitative information of 12 selected wells in the field during 2003 and 2004 were used. The qualitative parameters included Na, K, SO4, Cl, TDS, HCO3, Ca and pH, respectively. The nine parameters were used in calculating the WQI index.

The results showed that the water quality is much better in the western part of the eastern plains, and as we move from the East of the Plain to the West, the water quality increases. The water quality in the western part belongs to the high class and in the eastern parts belongs to the weak class. Of the 12 wells of the study, the water quality of 2 wells belong to the high class, 5 wells are in the appropriate class, 4 wells are in weak class and one well belongs to the weak class.

Investigating the correlation between WQI and qualitative parameters showed that the TDS parameter with 0/99correlation has the highest coordination with this index. Also, the -0.44 correlation between WQI and HCO3 indicates the low impact of HCO3 in calculating WQI, it can be concluded that the groundwater resources of Saveh plain has no problem with HCO3 and this parameter does not affect the area's water quality.

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