Water. Environ. Sustainability. 1 (2): 33-40, 2021

Forscher Publication

Water and Environmental Sustainability
ISSN: 2710-3404
DOI: 10.52293/WES.1.2.3340
Homepage: https://www.journalwes.com/

Research paper

The effect of deep percolation in agricultural lands on contaminant concentration of groundwater

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ARTIClE INFO

Keywords:
Irrigation
Nitrate
Shahrekord plain
Contamination

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Received: 11 February, 2021
Accepted: 03 March, 2021
Available online: 05 April, 2021

ABSTRACT

Balance management and the health improvement of the limited groundwater resources are unavoidable to prevent of water scarcity. The irrigation drainable water is the main factors of groundwater contamination that depended on leaching amount, type of surface contaminants and used fertilizer provided the different levels of pollution. In this research, the effect of deep percolation amount on nitrate concentration and salinity in Shahrekord plain is analyzed. The sensitivity of chemical parameters such as Ca, SO4, Cl, Na, K, HCO3 relative to season variation, also nitrate distribution in 80 to 86 years are investigated. For this subject, 10 agricultural areas were identified and estimated their discharge volume and deep percolation. The result show that the groundwater nitrate concentration in the summer season is depended on depletion volume from the effective limitation with R-squared value equal to 0.9, except two cases that NO3 is under the wastewater effect. Na, K and HCO3 in the winter season have a significant difference rather than summer. Also nitrate mapping indicated that the considerable part of groundwater nitrate is .happen by leaching in the agricultural lands

Introduction

Limited water resources can be allocated for urban, industrial and agricultural consumption considering the required quality in accordance with the type of consumptions. Today, with the advent of extensive industrial activities and the use of fertilizers in agriculture, the most important source of human life is endangered. Electrical conductivity and concentration of sodium, chlorine, sulfate and nitrate ions in groundwater due to insoluble minerals and human activities such as intensive agricultural operations (application of chemical fertilizers), toxic effluents from industries or wastewater sources (Jalali, 2007).

Due to the importance of water in the health of communities, several studies have been conducted on pollutant sources, how pollutants spread in temporal and spatial dimensions and the relationship between pollution and environmental parameters. Chon and Ahn (1999) investigated the relationships between water quality, topography, geology, land use, and source of pollution. Belousova (2006) and Bocanegra et al. (2001) presented programs for groundwater risk management and protection (Mirabbasi and Rahnama, 2008). The effect of using treated wastewater in irrigation of agricultural lands of

Isfahan Borkhar plain on the concentration of chemical parameters of well water such as PH, EC, chlorine, bicarbonate, calcium and magnesium, sodium, sulfate, nitrate. Tabatabaei and Lalehzari (2013) located the occurrence of chemical contaminants using the interpolation method. He has introduced the entry of agricultural effluents and municipal sewage as the cause of pollution of Shahrekord alluvial aquifer.

Nitrate is the major form of nitrogen and the most common groundwater pollutant (Fetter et al., 1999). Among the various factors involved in the occurrence of nitrate pollution are domestic wastewater and the infiltration of drainage from agricultural lands that arise from the use of nitrogen fertilizers (Lalehzari and TABATABAEI, 2010).

Extensive research aimed at the study of nitrate in the water of Katz (2004) springs, wells (Lalehzari et al., 2013), Obeidat et al. (2007), rivers (Peeters et al., 2004), landfills (Zuquette et al., 2005) and underground dams (Ishida et al., 2011), using various tools such as kriging technique (Fetouani et al., 2008), simulation by MT3D (Lalehzari and TABATABAEI, 2010), soil nitrogen distribution model (Wriedt and Rode, 2006) and performed various solutions. Such as the use of plowing system, especially furrow plowing, sprinkler irrigation and subsurface drainage (Power et al., 2001) have proposed the construction of a sewage collection network (Ehteshami and Sharifi, 2007) to reduce the effects of pollution in groundwater.

The aim of this study was to investigate the effect of cropping seasons on electrical conductivity, nitrate, sulfate, calcium, chlorine, sodium, bicarbonate and potassium as well as the destructive effects of water harvesting and agricultural activities over time on increasing nitrate concentration in groundwater resources.

Material and Methods

Study area

Shahrekord watershed has an area of 1244 km^2, of which 551 km^2 is Shahrekord plain. This plain is located along the northwest to southeast at a distance between 32 degrees and 7 minutes to 32 degrees and 35 minutes north latitude and 50 degrees and 38 minutes to 51 degrees and 10 minutes east longitude (Fig. 1).

Shahrekord plain is generally located on Cretaceous calcareous formations and is the result of the destruction of elevations and its transport and accumulation by surface and flood flows in the area. These changes have occurred with the north-south expansion trend and due to sedimentation conditions, the plain surface is relatively smooth. The slope of the land surface decreases between 20 per thousand in the northern areas to 5 per thousand in the central part and less than 2 per thousand in the southern areas and the outlet of the plain.

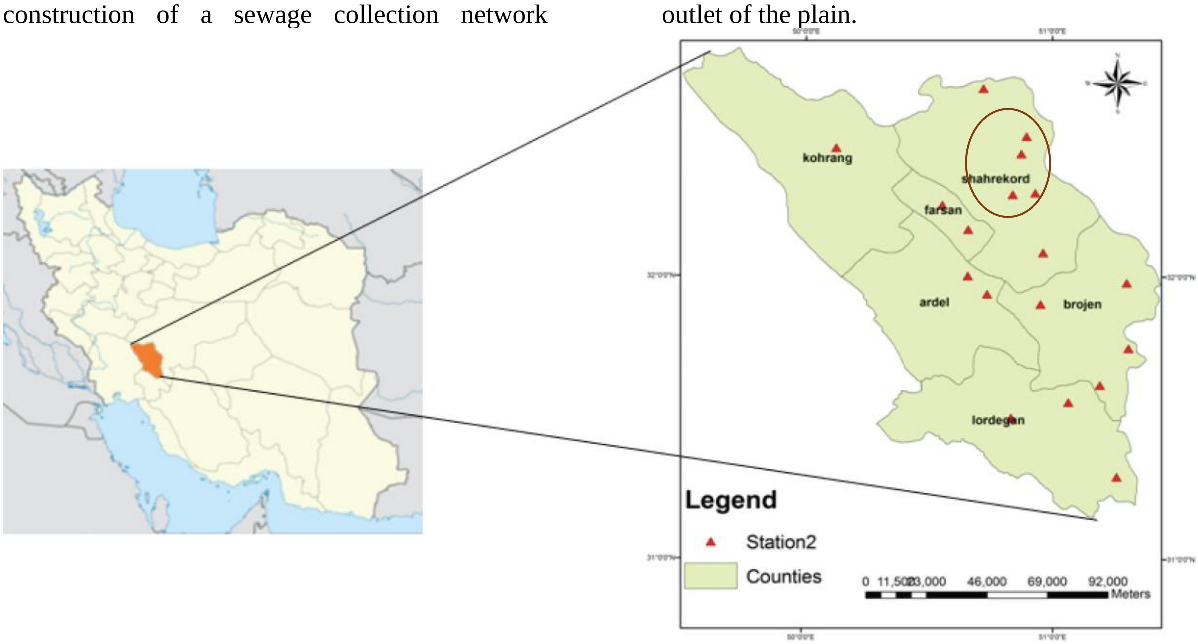

Fig.1. Location of the Shahrekord plain in the Chaharmahal & Bakhtiari province, Iran (Mohammadi et al. 2107)

Groundwater interaction with pollutant

Drinking water of cities and villages located in Shahrekord plain is supplied from wells that have been dug mainly in agricultural fields, so the quality control of pollutants has been considered. To conduct the research, first, the agricultural lands from which drinking water is harvested were identified. 10 areas with suitable distribution in the whole plain were selected and the discharge of drinking water wells and the radius of effect created by it were measured and calculated.

Agricultural wells located within the radius of impact of each drinking well were identified, then their discharge and operating hours were measured and the total water withdrawal from each area was obtained. According to reports, 20% of the water harvested for irrigation will be returned to groundwater due to deep infiltration.

Therefore, it is assumed that the percentage of deep penetration and the amount of fertilizer used are the same for all parts of the plain, which seems acceptable given the similar cultivation pattern in the plain. With the mentioned conditions, 10 areas in Shahrekord plain were obtained by measuring the coordinates of agricultural and drinking wells and combining it with land use layer. The studied areas and the location of wells in Shahrekord plain are summarized in Table 1. Taking into account the discharge of each of the agricultural wells located in the area (pumping discharge multiplied by the well operation time), the total volume of water withdrawn from that area in the first 5 months of the growing season (from April to August) is calculated for each of the ten areas.

To study the effect of water volume on nitrate concentration and electrical conductivity, field sampling was performed in each area of drinking water wells located in the center of the area in August 1398 and their nitrate concentration by spectrophotometry in summer and winter as well as conductivity. Electrically the samples were measured and their relationship with the volume of water collected was compared.

Table 1. Situation of the sampling points

Mean		X	Y	No. of wells	Exploitation
O1	Nafch	488564	3573404	8	1.2
O2	Chaleshtor	475494	3592629	12	2.5
O3	Shahrekord	474389	3596709	9	2.4
O4	Farokhshahr	474389	3599159	6	1.8
O5	Hafshejan 1	480848	3574493	11	1.7
O6	Hafshejan 2	482011	3574453	10	3.4
O7	Noabad	489045	3573255	9	1.4
O8	Vardanjan	483907	3584123	7	4.3
O9	BahramAbad	480751	3579373	11	2.1
O10	Pirbalout	477697	3585818	13	3.7

Chemical concentration

To study the effect of irrigated seasons on changing the concentration of pollutants, 6 points of the study area that were most affected by agricultural operations were selected and the concentrations of major ions including nitrate, sulfate, sodium, chlorine, potassium, calcium and bicarbonate were selected. And their electrical conductivity was determined. The amount of changes under the influence of agricultural operations in the crop season compared to the winter when the agricultural harvest is not done was divided into elements by drawing, analysis and statistical analysis.

Results and Discussion

Between points, well area No. 9, which is located among domestic sewage wells, is greatly affected by these wells and its high concentration is less affected by agricultural operations. Also, well No. 10 can be due to the discharge of sewage from these villages due to being located downstream of Arjenak, Pirbalout and Harchegan villages.

By removing the two mentioned cases, a high correlation is obtained between the amount of water that is re-infiltrated into the groundwater and the nitrate concentration will be obtained (R^2 = 0.9). The same comparison was made in winter and the results are shown in Fig. 2. According to the figure, no correlation can be found between the drained water and the nitrate concentration of groundwater. This confirms that more extraction of groundwater and its return with low efficiency and the use of nitrogen fertilizers that were considered in the selection of these points has increased nitrate.

Many studies in the past also consider agricultural drainage as the main cause of nitrate contamination (Cepuder and Shukla, 2002, Fetouani et al., 2008, Ishida et al., 2011).

Continuation of this process due to the return of deep infiltration into the water balance, has less effect on the small loss of groundwater, but requires energy and has irreparable effects on the quality and health of drinking water. On the other hand, clearing groundwater is difficult and time consuming due to its unavailability and slowness.

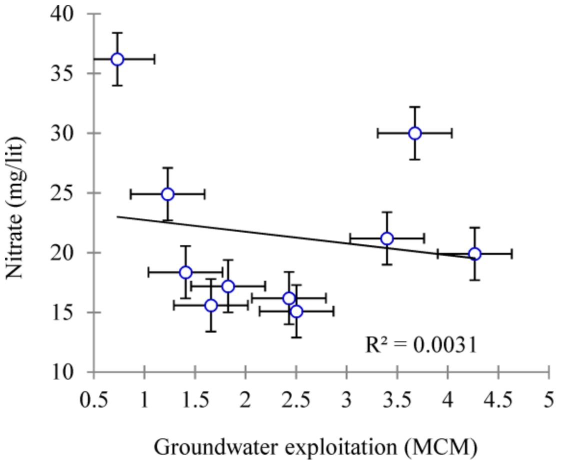

Fig. 2. Nitrate concentration for different amounts of groundwater exploitation

Considering the rate of changes in electrical conductivity relative to the volume of discharged water, no specific trend and much dependence was observed (R^2 = 0.19) which is due to the lack of decomposition and conversion of salt in the soil and its changes are slow (Fig. 3). It is necessary to mention that the water used in agriculture in Shahrekord plain does not have high average salinity and agricultural lands are usually lands without high salt. Therefore, leaching due to low irrigation efficiency increases groundwater salinity.

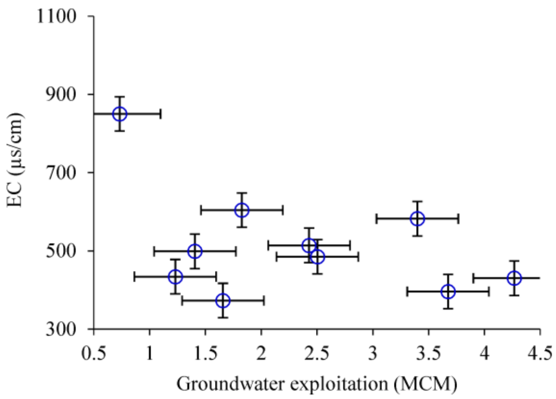

Fig. 3. Salinity variation in the sampling points of the plain

The effect of agricultural activities on groundwater quality

The mean nitrate concentration in winter and summer was not significantly different from each other (Table 2). The difference between nitrate concentrations in winter and summer is shown in Fig. 4. According to the figure, except for well 1, the changes due to the seasons have slightly increased or decreased. Pacheco and Cabrera (1997) also studied the effect of seasonal change on nitrate concentration, which showed the results of nitrate concentration more in rainy seasons. Relatively heavy rainfall in winter and irrigation operations in summer have caused nitrate balance in Shahrekord plain. Nitrate was selected as the main option for groundwater quality control to study and control the temporal changes of pollutants in different years.

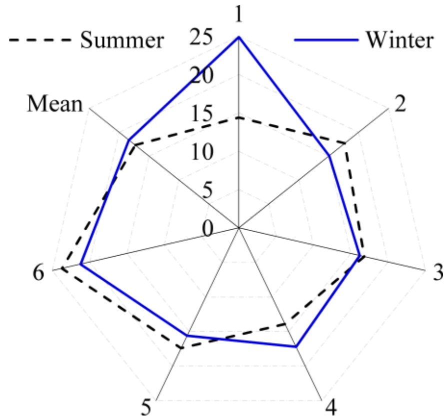

Fig. 4. Nitrate concentration in summer and winter seasons (mg/l)

Regarding the results obtained from nitrate pollutants, it is necessary to mention some points:

1) Every year, the highest concentration of nitrate is observed in the western part of the plain, the main reason for which is the existence of sewage disposal wells and the outlet of Shahrekord water treatment plant.

II) Changes in the concentration and volume of domestic wastewater do not change much during different years, therefore, increasing the nitrate concentration will occur under the influence of agricultural wastewater.

III) Considering that the direction of groundwater flow is from east to west, so the high level of pollution in the west will not affect the eastern regions and the only source of nitrate pollution in the eastern parts is the infiltration of irrigation water.

IV) The measured values of nitrate concentration are less than the suggested standard of drinking water recommended by the World Health Organization (50 mg/lit), but as the trend continues, the probability of reaching dangerous concentrations increases.

V) The average electrical conductivity in summer (498 µs/cm) was higher than in winter (482 µs/cm) but this difference was not significant (Table 2).

Difference in electrical conductivity between the six regions in the two seasons is not significant and the range of changes in temporal and spatial dimensions was small (Fig. 5). This level of salinity is tolerable in most plants. Salinity in agricultural lands can be increased in the long run and can be problematic. Therefore, strategies such as increasing irrigation efficiency and reducing demand are solutions (Don et al., 2005).

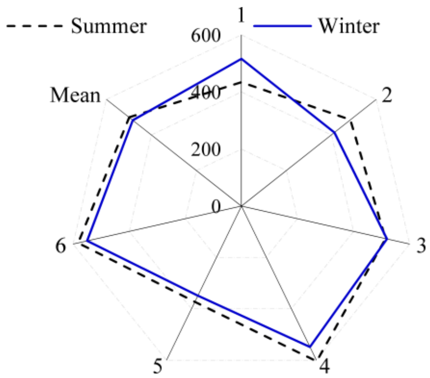

Fig. 5. Electrical conductivity in summer and winter seasons (μs/cm)

Wells located in the southern part of the plain (4, 5 and 6) have more calcium in winter than in summer (Fig. 6), but the statistical analysis presented in Table 2 does not show a significant difference between the seasons in this case. Give. Zoning of calcium concentration in Shahrekord aquifer has shown that parts of the southern plain have more calcium due to geological structure, dissolution of carbonate formations and transfer of upstream salts.

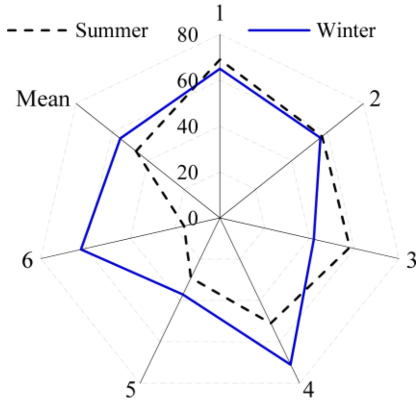

Fig. 6. Calcium concentration in summer and winter seasons (mg/l)

The diagram of the difference in sodium concentration in milligrams per liter in the sampled areas is plotted in Fig. 7. According to the figure, sodium concentration in winter is significantly higher at 5% confidence level than in summer (Table 2). This result is probably due to the chemical deformation of sodium due to cooling of the soil environment and sodium is added as a solution to groundwater.

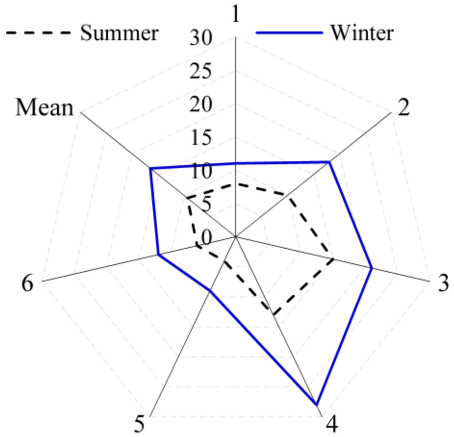

Fig. 7. Sodium concentration in summer and winter seasons (mg/l)

Sulfate concentration in all studied wells is higher in summer than in winter (Fig. 8), but this difference is not significant in any of the 1 and 5% levels (Table 2). Ahn and Chan (1999) did not observe a significant change in sulfate concentration by studying seasonal changes in sulfate. On the other hand, the high amount of sulfate in the growing season indicates the effect of sulfate fertilizers and air temperature on increasing the concentration of this pollutant.

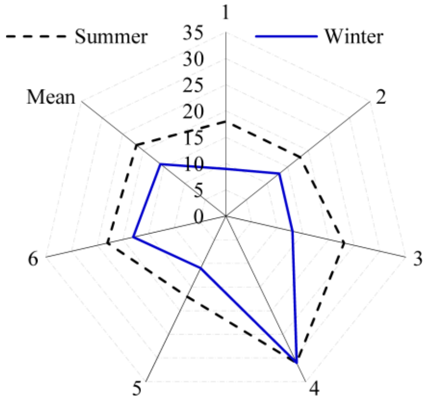

Fig. 8. Sulfate concentration in summer and winter seasons (mg/l)

The average of 36.6 mg/l chlorine in summer has decreased to 29.3 mg/l. The rate of change of chlorine in the dimension of place and in two times is very similar to the rate of change of sulfate. So that regions 4 and 5 have the highest and lowest values, respectively (Fig. 9). Similar to sulfate, the difference between chlorine and seasonal change was not significant. Past studies also do not show the effect of seasonal change on chlorine concentration (Ahn and Chon, 1999).

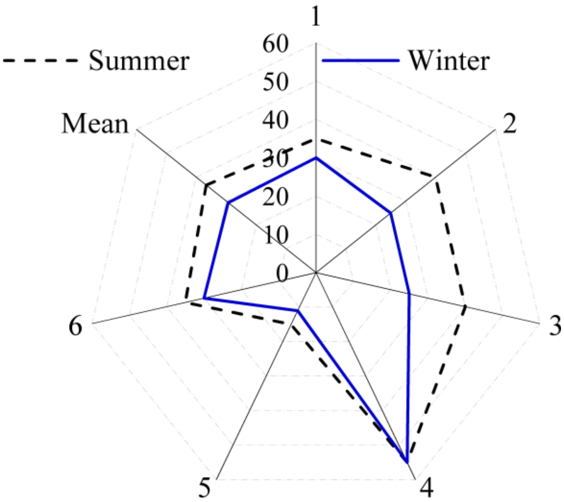

Fig. 9. Chlorine concentration in summer and winter seasons (mg/l)

The amount of potassium in winter compared to summer has doubled in all parts of the plain (Fig. 10). The increase in potassium in winter is mostly due to the decrease in temperature because the use of potash fertilizers takes place in summer. According to Table 2, the difference between the seasons is significant at the level of 1%.

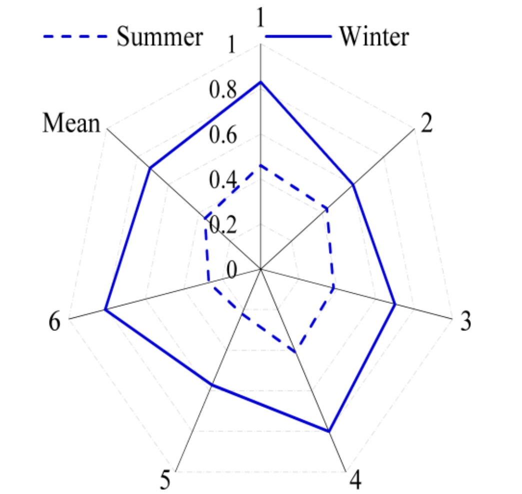

Fig. 10. Potassium concentration in summer and winter seasons (mg/l)

Bicarbonate analysis also shows a significant difference between the hot and cold seasons of the year at a confidence level of one percent. The concentration of bicarbonate in winter is 72 mg/l more than in summer. Fig. 11 shows the difference in ion concentration in the south of the plain more than elsewhere. Significant increase in the concentration of monovalent ions of sodium, potassium and bicarbonate in winter indicates the effect of cold and the growing season on the decomposition of sodium bicarbonate and potassium bicarbonate in groundwater.

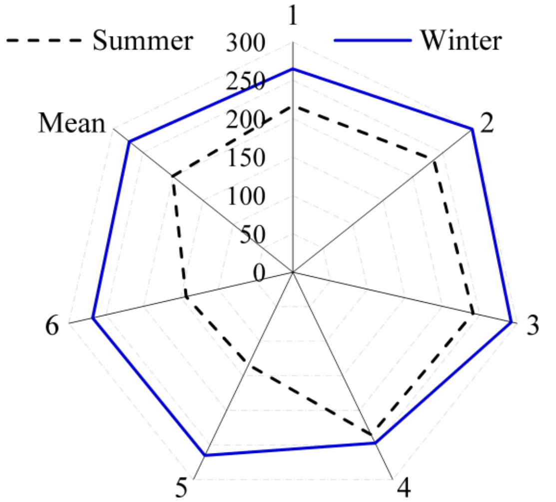

Fig. 11. Bicarbonate concentration in summer and winter seasons

One of the tools for interpreting groundwater quality is determining the water type of the region (Tabatabaei and Lalehzari, 2009). The estimated water type of Shahrekord plain according to the concentration of salts (Table 2), especially in winter, is calcium bicarbonate, which has been proven in the study of Lalehzari and Tabatabaei (2010) (Fig. 12). According to the trend of the chemical decomposition of the samples and plotting the percentage of each solute, it shows the accumulation of concentration around bicarbonate and calcium.

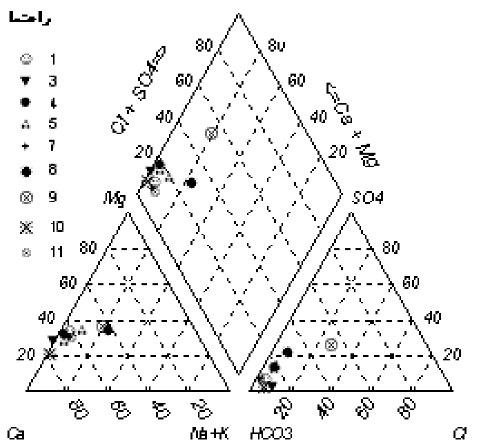

Fig. 12. Distribution pattern of chemical parameters of groundwater

Table 2. Statistical analysis of the contaminant concentration using

Contaminant	$NO3^{ns}$	EC^{ns}	$SO4^{ns}$	Cl^{ns}	Na^{*}	Ca^{ns}	K^{**}	$HCO3^{**}$
Summer	21.3a	498a	21.6a	36.6a	9.3a	46a	0.36b	200b
Winter	20.7a	482a	15.8a	29.3a	16.5a	55a	0.71a	272a

a,b: means values in the same column, followed by a different letter are significantly different at Fisher LSD test.

ns No Significant, * Significant at 0.05 probability level.** Significant at 0.01 probability level.

Conclusion

Among the most important factors that play a role in nitrate pollution in groundwater, Shahrekord plain has received the most impact from agricultural drainage. Except for parts of the southern plain whose vulnerability is due to sewage discharge well extraction of groundwater resources and its consumption with low efficiency of surface irrigation, in addition to wasting water, also reduces its quality. The use of pressurized irrigation systems with higher water consumption efficiency seems to be a good option to prevent the problem. Because in addition to a slight improvement in consumption, because its losses are more in the form of evaporation, so that the deep penetration does not have many adverse effects on reducing the quality of water resources.

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