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Assessment of the Impacts of Drought on Surface Water Resource Quality: A Case Study in Aleshtar, Lorestan Province, Iran

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Abstract

Evaluation of water quality along with water supply can be considered as a very important step in consumption optimization of water in all sectors including agricultural purposes, industries and even drinking water supply. Generally, recognition of water resources quality and quantity and its temporal and spatial changes are considered as a key element in management of water supplies. Natural and human-made manipulations in every region can change water resources quality physically, chemically and even bacteriologically. Due to the importance of water quality, a vast range of researches and analysis are being in process or have been done before. Iran have been suffered from long and intense droughts in recent decades. Drought is a creeping phenomenon with a huge annual damage. Iran has suffered a variety of droughts in recent years and annually significant losses have been inflicted on different parts of the country These have affected the country's resources socially and politically such as immigrations. The studied area is a part of Kashkan basin, which covers an area of 9560 square kilometers. In this research, by measuring the chemical parameters out samples taken from surface water and determining the occurrence periods of meteorological drought, the relationship between these events and the quality of surface water in Lorestan province was investigated in a 30-year period in hydrometric stations. The main objective of this research was analyzing the chemical parameters and their changes and trends considering droughts and dry spells in Kashkan basin. For this purpose, the chemical quality of the rivers with quality data of the basin was studied and analyzed. The results of this research showed that the contribution of each formation in the way of stream bed and also the role of droughts on surface water quality and how the quality of surface waters in each sub-basin has changed. Data analysis shows that chemical parameters in surface water have been degraded through the years although the geologic formations in the way of the stream are consonant but the water quality dropped a lot in quality which can be attributed to the droughts occurred during the study periods (e.g. EC rate has been increased from 382.52 μm/cm to 570 μm/cm). Finally, it was shown that surface water is still suitable (C_2S_1) for irrigation in agriculture despite qualitative decline.
Keywords: Drought, Kashkan Basin, Semi-arid, Surface water quality, SPI.

1. Introduction

Although more than three-quarters of the earth is covered by water, a small portion of the available water is applicable for health and agricultural use, because the water of oceans, seas and most lakes and many groundwater resources is unusable due to excessive salinity for sanitary, agricultural and industrial purposes. As a natural hazard, drought can cause economic and social damages (Bond et al., 2008). Drought occurs in high as well as in low rainfall areas (Wilhite and Glantz, 1985). Agriculture is the primary land use across the globe; it is also a major economic, social and cultural activity, and it is highly sensitive to climate variations (Howden et al., 2014). Meteorological drought that leads to hydrological drought can reduce surface and ground water levels (triggering hydrological drought) and can lead not only to reduced water availability but also to a deterioration of water quality (Mishra and Singh, 2010; Mosley, 2015). This condition also intensifies water shortages by lowering the amount of usable water within a region. Although drought impacts on water quantity are well known (Van Vliet and Zwolsman, 2008; Safavi and Malek Ahmadi, 2015). Water quality is the result of all processes and interaction that comes from the formations in the way where it reaches the ground or goes underground and is re-extracted through well and spring sources and precipitation frequencies which determines the volume of water in each event. In other words, water quality is a comprehensive description of the physical, chemical and bacterial conditions of water resources and depends on the concentration of all dissolved or suspended substances in water. In some cases, this sensitivity has increased so much that it has led to regional and international conflicts. The importance of water quality is not less than its quantity. However, in water balance studies, only quantitative balance is generally considered and quality balance is forgotten. Part of this is due to the spatial and temporal variability of water resources quality which complicates the studies of this kind. Climatic hazards such as occurrence of drought has a significant effect on planning and utilization of water resources in this regard, it is necessary to investigate various indices such as standardized precipitation (Goodarzi and Hoseini, 2018). Dry spells would be added to the problems of these countries. The rivers are scarce and may change a permanent river to seasonal or a temporary river or even a dried one in general. Also, by reducing the volume of water in the rivers, water quality would be degraded which causes water quality declines (Zahedi, 2005). In fact, this phenomenon is one of the main and recurring features of different climates. Drought may occur anywhere and cause water scarcity, but its characteristics such as severity, duration, and magnitude of drought and its effects vary from place to place. It took a relatively long time for mankind to realize the importance of water quality. Hydrological drought may also cause significant changes in water quality. The main necessity of this study is to investigate the effect of chemical parameters of surface water during drought periods using rainfall and discharge time series of rivers, trend of precipitation and discharge changes, drought periods and their continuity (based on one of the climatic and hydrological indices).

Lack of rainfall and drought have many impacts on the natural and human environments (Agrawala et al., 2001). It includes an increase in mean air temperature, EC rates, water shortage crisis and its effects on health, welfare, forest fires, spread of pests and diseases meanwhile drop in groundwater level and threat in food security also a decrease in surface water and finally mal effects on economic and social problems caused by the drought can be pointed out. In fact, drought would have direct and indirect effects on all aspects of the life and various sections of societies, especially the change of natural environment so that lack of understanding of its meaning causes doubts and stagnation in various sectors of economics, management and policy-making. Also, drought causes less structural damage than other natural hazards while assistance in the event of this phenomenon is more complex and difficult than other phenomena such as floods. Considering that drought is a natural phenomenon in the climatic conditions of Iran, naturally, the dry spells are far greater than the periods of wet spells. Therefore, it is very important to investigate how to allocate water with desirable quality in these conditions (dry spells). Water quality characteristics such as the increase in total dissolved solids, and their constituent ions and the decrease of dissolved oxygen, could cause agronomic problems to irrigated agriculture (Maestre-Valero and Martínez-Alvarez, 2011). Therefore, it is an important variable to consider in the development of irrigation (Assouline et al., 2015). Despite the fact that Lorestan province is among rainy provinces of the country, the occurrence of extensive periodic droughts has caused a qualitative and quantitative declined in all water resources of the province, including surface waters of Kashkan watershed. This quantitative drop has caused undesirable changes in the chemical quality of the total waters, especially surface waters in Kashkan watershed. The overall objective of this research was to evaluate the impact of drought on water quality and irrigation dependent agricultural production in the basin. Specific objectives were to: (1) determine the spatio-temporal distribution of meteorological drought in the basin and explore its relationship with hydrological drought; (2) assess the impacts of hydrological drought on basic surface water quality parameters; and (3) identify the potential effects of drought-driven water quality deterioration on irrigated agriculture.

2. Materials and methods

2.1. Study area

This work was conducted in the metropolitan and semi-arid region in Lorestan province, Iran. Kashkan with an area of more than 9560 km^2 covers about 22% of the total Karkha river basin (KRB). This is where Karkha river basin itself is among the main six catchments of Iran (1-Caspian Sea basin, 2- Persian Gulf and Oman Sea basin, 3- Azarbaijan closed basin, 4- Central basin of Iran, 5- Hirmand and Hamoon basin 6- Persian Gulf and Oman Sea). Kashkan is located in the range of 47°12' to 48°59' of eastern longitude and 33°08' to 34°02' north latitude in the middle part of Zagros Chain in 450 Km southwest of Tehran. This area is located entirely in Lorestan province, Iran in terms of political divisions and Khorramabad, Aleshtar, Kouhdasht and Poldokhtar with an area of about 33% of the whole province have been expanded mainly in the form of the mentioned basin. The sub-basin with an area of 25,466 square kilometers is located at the outlet of the 21-183 hydrometer station named Pol-e-Kashkan. The minimum height of this basin is 522 meters above the sea level and the maximum height is 3503 meters. The elevation of the basin above sea level indicates the climatic position of that basin. In the high areas not only, rainfall is more than the lowlands, but also in the peaks of the altitudes, the precipitation is often in the form of snow that its hydrology is different from that of plains. Over 202 villages are located in the study area near the river. According to the definitions, the average height of the area is a figure that 50% of the land of the area of their height is above that limit and 50% of the area of elevation area is lower than that limit (Alizadeh, 2006). Figure 1 presents location map of the research area while hydrometric and synoptic stations of the studied area are shown in table 1.

2.2. Hydroclimatic data

Monthly precipitation data of the basin was extracted from rain-gauge stations in the basin and around the mentioned area were used in a 30-year period and average annual rainfall was determined (around 619 mm) (Lashanizand, 2001). The performance of this dataset has been previously evaluated with good results. Analyzing precipitation and other climatic parameters proves that the basin has the Mediterranean regime. Due to the existing missed data of the research period, they were tested for homogeneity by run test method. In general, the surface water is alternately under the influence of two types of dry spells and wet spells. Because the occurrence of each of these periods affects the surface water in terms of quantity and quality and causes countless issues and problems.

Table 1. Synoptic and hydrometric stations in the studt area

Station	River	Station ID Code	Area (Km^2)	Geographic attributes			No. of samples
				Height	Lat.	Long.	
Afarineh	Cholhol	21-179	799.46	800	19-33	53-47	361
Afarineh	Mid-Kashkan	21-177	6931.28	820	20-33	53-46	223
Cham Anjir	Khoramabad	21-175	1718.5	1140	26-33	48-14	268
Kakareza	Har-rud	21-169	1204.91	1530	41-33	16-48	205
Sarab seyedali	Doab	21-171	797.46	1520	47-33	12-48	218
Pol-Kashkan	Pol-Kashkan	21-173	3763.76	1000	35-33	53-47	204
Bar aftab	Madian-rud	21-181	111.37	790	19-33	49-47	211
Poldokhtar	Lower Kashkan	21-183	9560	650	19-23	43-47	277

It should also be noted that the distribution of precipitation in different seasons is consistent with the arrival of rainfall systems to the region. Most of the precipitation in the region is caused by wet currents that enter the region in more than half a year with low pressure center, directly from the west and after crossing the Mediterranean Sea and becoming rich in water vapor on the sea. Among the factors affecting the flow, various components of the basin include geology, surface and subsurface topography, soil characteristics and climatic components as well as human interventions. Passing water through different lands causes physical and chemical changes and these changes depend on geological characteristics of the points through which water has passed through which the most important geological factors affecting water quality are salt domes and marl formations. Geographical location and climate also have a great impact on water quality. So that low rainfall and high temperature and evaporation intensity increase the concentration of solute in the waters. The quality of surface water is strongly affected by hydrological conditions so that in the rainy season with increasing river discharge the concentration of different salts decreases, while in dry season the water quality decreases drastically. Considering the effects of geological formations on water resources, it has been tried to present a complete picture of the geology of the basin (Goodarzi et al., 2021). Figure 2, shows the geological map of the study area.

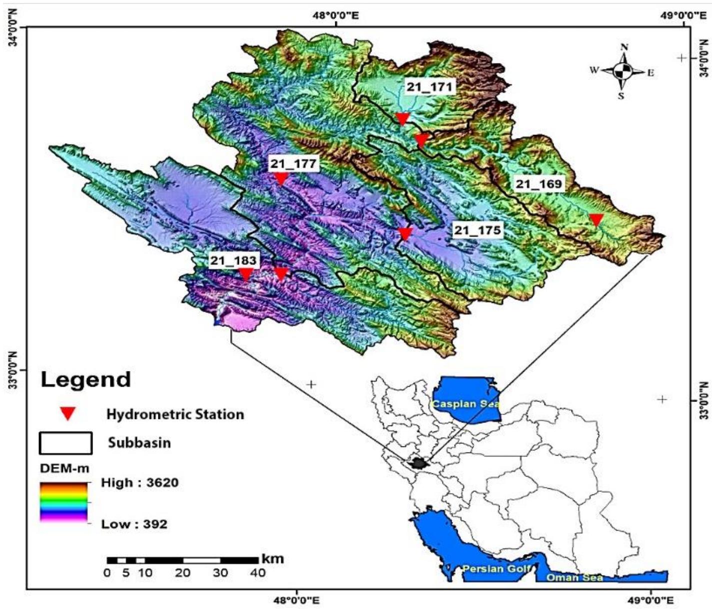


Fig. 1. Map location of the study area and hydrometric and synoptic stations in the area

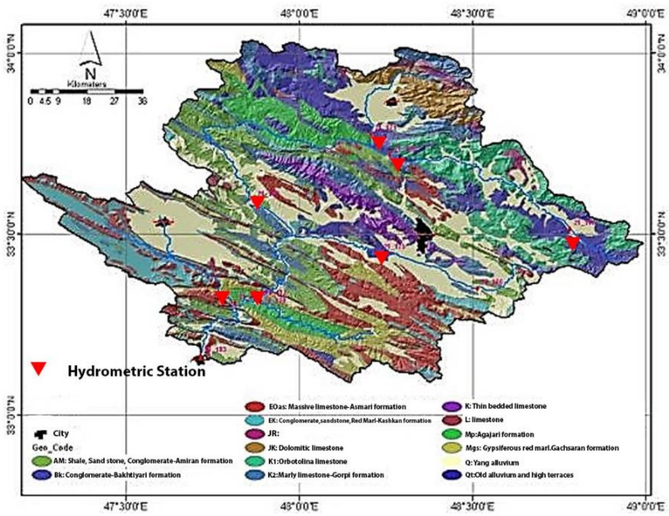


Fig. 2. Geologic map of the study area (Kazemi et al., 2022 adapted from Stockline, 1968)

Daily discharge and physicochemical data (in general at least one measurement per month along with extra sampling during floods) from hydrological stations of the river basin were collected from the National Water Agency. We used the period of record from 1981 to 2016 as a common period for all the stations. The aim of this study was to identifying wet and dry spells and the occurred droughts using SPI and then determine the impacts of drought on water quality. The test results for the annual series of chemical parameters of water quality in Aleshtar are summarized in the table below. Using correlation and regression methods, relationship and effects between variables were calculated with the help of SPSS and Excel software (Table 3).

2.3. Standardized Precipitation Index

The standardized precipitation index (SPI) (Mckee et al., 1993) is the most commonly used drought index due to its limited data requirements and flexibility to assess precipitation deficits over user-defined accumulation periods (Barker et al., 2016). It was recommended as the standard index worldwide by the World Meteorological Organization and the Lincoln Declaration on Drought (Hayes et al., 2012; Stagge et al., 2015; Van Loon and Laaha, 2015). The SPI was computed following the methodology of Mckee et al. (1993) using a gamma probability distribution. Negative values of SPI correspond to lower than the mean precipitation, and positive values indicate higher than the average rainfall.

If the monthly rainfall time series of the stations in the region are introduced as P_i, in which the index i indicates the year and the index j indicates the month corresponding to the water year (i = 1 for October and j = 12 for September). Rainfall time series with different periods can be obtained using the following equation:

$$R_{ik} = \sum_{j=1} P_{ij} \quad i = 1, 2, 3, ... \quad j = 1, 2, .., 12 \quad k = 1, 2, ..., 6 \tag{1}$$

Standard precipitation index (SPI) is obtained based on the height of cumulative precipitation (R_k) for the base period K related to (i) of the hydrological year as Eq. 3:

$$SPI_{ik} = \frac{R_k - \bar{R}_k}{S_k} \quad i = 1,2,3, ... \quad j = 1,2,\dots,12 \quad k = 1,2,\dots,6 \tag{2}$$

where S_k and $\bar{R}_k$ are the mean cumulative rainfall height and the standard deviation of the cumulative rainfall height for the base period k, respectively. Table (1) shows the classification of different drought conditions by SPI method (Amini et al., 2019).

Table 1. Meteorological drought classification based on SPI index

No	Range of SPI	Drought Condition
1	SPI ≥ 2.0	Extremely wet
2	1.5 ≤ SPI < 2.0	Very wet
3	1.0 ≤ SPI < 1.5	Moderately wet
4	-1.0 ≤ SPI < 1.0	Weak drought
5	-1.5 ≤ SPI < -1.0	Very dryness
6	-2.0 ≤ SPI < -1.5	Moderately dryness
7	SPI < -2.0	Extremely dryness

The occurrence of continuous drought has somewhat overshadowed the chemical quality of the surface runoff of the basin and caused problems and limitations related to the various uses of these waters so that by reducing the volume of surface waters of the basin due to occurrence of dry spells, these flows in addition to saline and heavy water have had some changes in the quantity and quality in their existing materials (Lashanizand, 2001).

Table 2. Annual series of chemical parameters of water quality in Aleshtar

Hydrometer station	Cl				So4				pH				TDS			
	P	E (P)	Var (P)	Z	P	E (P)	Var (P)	Z	P	E (P)	Var (P)	Z	P	E (P)	Var (P)	Z
Aleshtar	16	18.7	5	-1.2	17	18.7	5	-0.77	20	18.7	5	0.6	15	18.7	5	-1.68
	EC				SAR				SSP				TH			
	17	18.7	5	-0.77	18	18.7	5	-0.14	17	18.7	5	-0.77	15	18.7	5	-1.68

Table 3. The results of the relationship of dry spells and wet spells on water quality in Aleshtar

Chemical parameters	periods	correlation coefficient	Significance			Correlation	coefficient of determination	Coefficient of indeterminacy
			0.01	0.05	0.10			
Ca++	Dry spell	-0.20						
	Wet spell	-0.7						
Mg++	Dry spell	0						
	Wet spell	-0.22	Sig.	Sig.	Sig.	y=1.4 x-0.23	0.05	0.95
Na+	Dry spell	0.36						
	Wet spell	-0.40	Sig.	Sig.	Sig.	y=0.26 e-0.03x	0.2	0.8
Hco3-	Dry spell	-0.28						
	Wet spell	-0.26	Sig.	Sig.	Sig.	y=-0.4 Ln(x)+3.8	0.07	0.93
cl^{-}	Dry spell	0.20						
	Wet spell	-0.33	Sig.	Sig.	Sig.	y=0.5 x-0.2	0.11	0.89
So4^{--}	Dry spell	0.22						
	Wet spell	0.05						
pH	Dry spell	0.39			Sig.	y=7 e0.02x	0.15	0.85
	Wet spell	0.14			Sig.	y=7.6x0.01	0.02	0.98
T.D.S	Dry spell	-0.25						
	Wet spell	-0.26	Sig.	Sig.	Sig.	y=-29 Ln(x)+290		
EC	Dry spell	-0.22						
	Wet spell	-0.26	Sig.	Sig.	Sig.	y=-47 Ln(x)+400	0.07	0.93
SAR	Dry spell	0.36						
	Wet spell	-0.4	Sig	Sig	Sig	y=0.2 e-0.02x	0.16	0.84
SSP	Dry spell	0.30						
	Wet spell	-0.24	Sig.	Sig.	Sig.	y=10x-0..2	0.06	0.94
TH	Dry spell	-0.20						
	Wet spell	-0.20		Sig.	Sig.	y=-18 Ln(x)+207	0.04	0.96

Since the surface runoff of this basin are used in and out of the province, they are of great importance and value in various sectors of drinking, agriculture and industry. So firstly, dry and wet spells were dissociated for a 30-year period. Then, Water quality including anions (Cl, SO_4, HCO_3), and cations (Na, Mg, Ca, K) and other variables including SAR, PH, TH, TDS and EC in the joint statistical period from 1981 to 2016 was considered. It should be noted that data over 30 years were collected and non-joint periods were ignored (Goodarzi and Kazemi, 2022). In order to analyze water quality in terms of drinking water, Schoeller diagram was used. For this study, water quality parameters including electrical conductivity (EC), pH, total dissolved solids (TDS), Sulphate (SO_4), sodium absorption ratio (SAR), Calcium (Ca), Magnesium (Mg), Sodium (Na), Chlorine (Cl), concentration of bicarbonate ions (HCO_3) and total hardness (TH) of hydrometric stations in Kashkan basin were extracted daily for a 30-year period. In this research, after collecting data on the discharge of hydrometric stations and also collecting statistics on chemical quality parameters of surface waters of all sub-basins of Kashkan, a 30-year index period which is a desirable statistical period for hydrological designs was selected. The quality of the available statistics was confirmed using different methods such as theoretical comparison of simultaneous statistics of different stations and control of very high or very low amounts. Since the accuracy of the statistics is dependent on homogeneity test, homogeneity test was performed on the available data. In order to control the homogeneity of the data, two methods of graphical mass curve and non-graphic, thigh test or sequence test were used. The criterion of water deficit and wet spells in a basin is based on measurement of surface flow in the hydrometric station (which is recorded daily as the discharge value). The most basic element to obtain the above parameters is to determine the threshold level. In other words, by choosing a threshold level, drought analysis becomes easier. The threshold level can be the average river flow. To determine the level of hydrological drought threshold in the studied basin, Dracup equation was used.

$$\left[x_{\circ} = xm - e \times s = xm\left[1-(e \times cv)\right]\right] \tag{3}$$

where:

$X_{\circ} =$ threshold level

$xm =$ Average data

$= S$ Standard deviation

$= cv$ Coefficient of variation

$e =$ Effective factor

If e is zero, then $x_{\circ} = xm$, i.e., the threshold of the hydrological drought and the mean flow of the river are equal (Panu and Sharma, 2002).

Passing water through different lands causes physical and chemical changes and these changes depend on geological characteristics of the points through which water has passed through which the most important geological factors affecting water quality are salt domes and marl formations. Geographical location and climate also have a great impact on water quality. So that low rainfall and high temperature and evaporation intensity increase the concentration of solute in the waters. The quality of surface water is strongly affected by hydrological conditions so that in the rainy season with increasing river discharge the concentration of different salts decreases, while in dry season the water quality decreases drastically.

2.4. Water quality evaluation

An attempt has been made to evaluate the water quality by using Piper diagram too. Piper diagram identified Na–Cl as the dominant type of water in most of the samples. The presence of Ca–Cl facies suggests the possible ion exchange (Na with Ca) reaction. Schoeller diagrams are used to show the relative concentrations of anions and cations typically expressed in mill equivalents per liter. Multiple samples may be plotted on a single diagram to distinguish similar patterns in the ratios of particular anions and cations. In Schoeller diagram, if the values of the parameters are in milligrams per liter, the numbers of each parameter are used and if it is in mill equivalents per liter, the right and left of the diagram are used. The explanation in the diagram is that the division of water quality according to Schoeller diagram is a six-fold classification which is good, acceptable, moderate, inadequate, temporarily drinkable and non-drinkable (Alizadeh, 2006). Wilcox diagram was presented in 1948. This diagram is a very common method for classification of water in terms of agriculture in hydrological studies. In this diagram, horizontal axis is allocated to water salinity (in mhos/cm) and vertical axis to sodium adsorption ratio (SAR). The coordinates of each water are located in an area marked by the letters C for salinity and S. The values 1, 2, 3 and 4 respectively indicate low, medium, high and very high. For example, if water is located in C_3S_2 region, it means that the salinity of this water is high and its sodium is moderate, or C_1S_2 water is water with low salinity and moderate sodium. According to Wilcox classification, the very good waters all have EC less than 250 µm per centimeter and are in C_1S_1 class. Good waters are in C_2S_2, C_2S_1, C_1S_2 and medium quality waters in C_3S_2, C_2S_3, C_3S_3 and C_3S_1 classes and the rest are inadequate. These are in C_4S_3, C_4S_2, C_4S_1, C4S4, C_3S_4, C_2S_4, and C_1S_4.

Of course, it should be noted that the larger their index, the more inappropriate their quality becomes, and it is only in special circumstances that some of these waters can be used. For example, in soil with coarse texture, high drainage and salinity tolerant plants

(Mahdavi, 2005). Durov Diagram is an alternative to the Piper diagram, which is also a specialized graph type for charting the chemistry of a water samples. Durov diagram is based on the percentage of major ion mill equivalents in sample waters. Durov diagram is a specialized graph type for charting the chemistry of water samples. It is based on the percentage of major ion mill equivalents in sample waters. Durov diagrams are extensively used in hydro-geochemistry to assess groundwater quality by plotting significant ions such as calcium, magnesium, chloride, and sulfate concentrations In addition, the Durov diagram allows direct comparison of two parameters including pH and TDS.

3. Results and Discussion

The Sarab Sayed Ali Station is located on Aleshtar River and determines the quality of the river before joining the Harrud River. Aleshtar River covers an area of 776.572 km^2 and 59.28% is calcareous formation, 3.77% shale and marl, 0.09% conglomerate and 36.85% of young alluvial sediments and is the main use of the area overlooking the Sarab Seyed Ali station, medium rangeland. Pol Kashkan hydrometric station is located about 102 km downstream of Kaka Reza station on the Kashkan River. The relationship between temporal and spatial variations of rainfall with discharge was considered in relation to the relationship between average annual precipitation and average annual discharge. The correlation between precipitation and discharge in the basin is clearly proved the appropriate explanation coefficient (Figure 3). Specifications of studied hydrometric stations in Kashkan watershed are shown in Table 4.

In order to investigate the temporal changes of electrical conductivity values in different stations, first the annual average was calculated in the station and by drawing a graph, EC changes were investigated. It shows the changes of EC values in terms of μm/cm during the statistical period in each station. As can be seen in the above figure, the EC values in all stations have a relative increase over time, so that in Sarab Seyed Ali station, it has reached from 300 μm/cm in 2007 to about 570 μm/cm in 2016. The results of the analysis and analysis of the chemical variables of water were studied during the statistical years. The accuracy of the experiments was checked by calculating the amount of error in the ion balance, and this error is within 1% and is acceptable.

The balance between positive hydrogen ions and negative hydroxide ions determines the acidity or alkalinity of water. When the pH of a water sample is determined, it actually specifies the concentration between hydrogen ions. Figure 4, presents average monthly discharge in Doab Aleshtar basin located in Sarab Seyed Ali hydrometric station. As it is noticeable, April with an average of 16.6 cubic meters per second and September with an average of 4.07 m3/s have the highest and lowest discharge rates, respectively. Also figure 5 shows that spring with an average of 12.3 m^3/s and summer season with an average of 4.2 m^3/s have the highest and lowest discharge rates, respectively. The diagram of flow duration curve in Doab Aleshtar Basin is shown in Figure 6 at Sarab Seyed Ali hydrometric station.

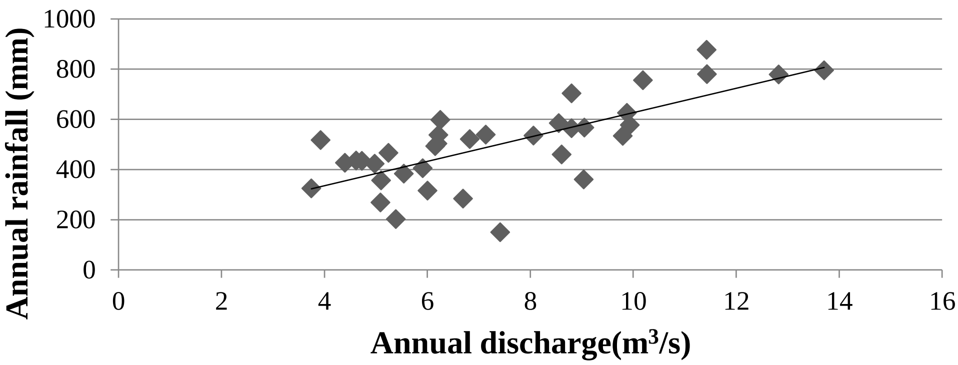


Fig. 3. Mean annual discharge and mean annual precipitation relation in Sarab Seyed Ali.

Table 4. Hydrometric station attributes of the study area

Station	River	Area (Km^2)	Geographic attributes			No. of samples	Data Quality
			Height	Lat.	Long.		
Afarineh	Cholhol	799.46	800	19-33	53-47	361	Relatively relevant
Afarineh	Mid-Kashkan	6931.28	820	20-33	53-46	223	relevant
Cham Anjir	Khoramabad	1718.5	1140	26-33	48-14	268	relevant
Kaka reza	Har-rud	1204.91	1530	41-33	16-48	205	Relatively relevant
Sarab seyed ali	Doab	797.46	1520	47-33	12-48	218	Relatively relevant
Pol-Kashkan	Pol-Kashkan	3763.76	1000	35-33	53-47	204	Relatively relevant
Bar aftab	Madian-rud	111.37	790	19-33	49-47	211	relevant
Poldokhtar	Lower Kashkan	9560	650	19-23	43-47	277	relevant

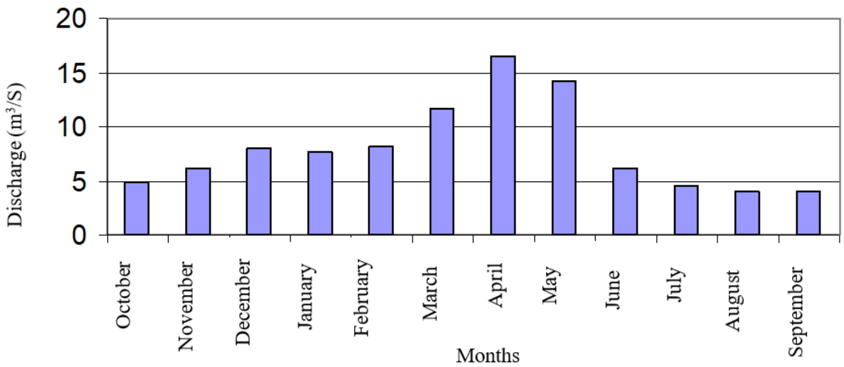


Fig. 4. Monthly discharge change in Sarab Seyed Ali Doab of Aleshtar

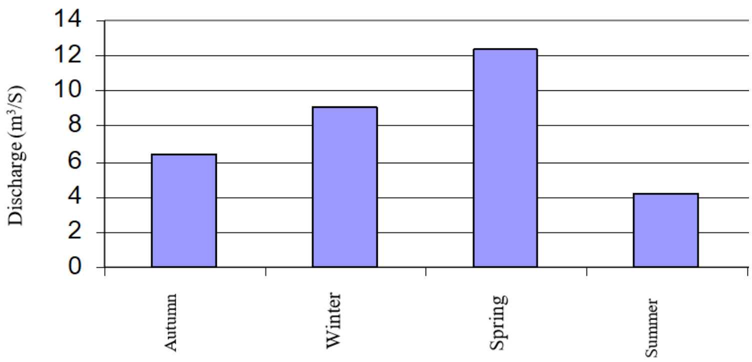


Fig. 5. Seasonal change of Discharge in Sarab Seyed Ali Doab of Aleshtar

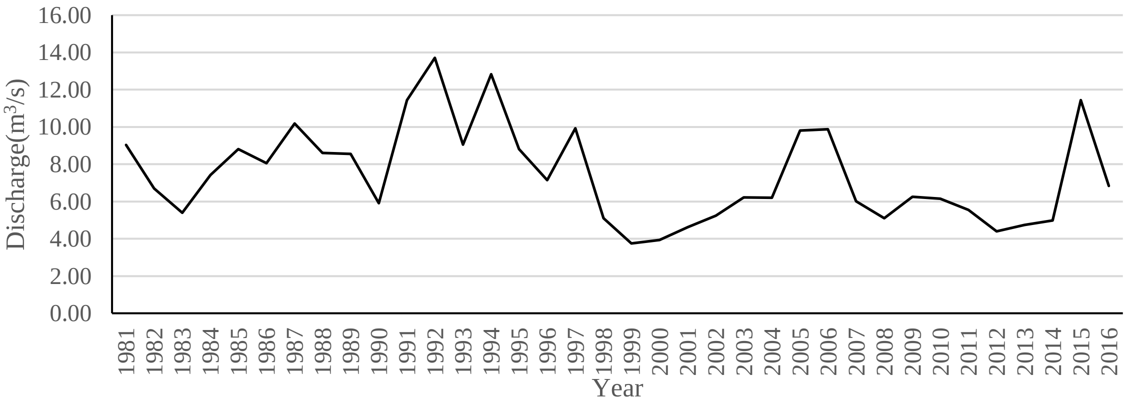


Fig. 6. Annual change of discharge in Sarab Seyed Ali Doab of Aleshtar

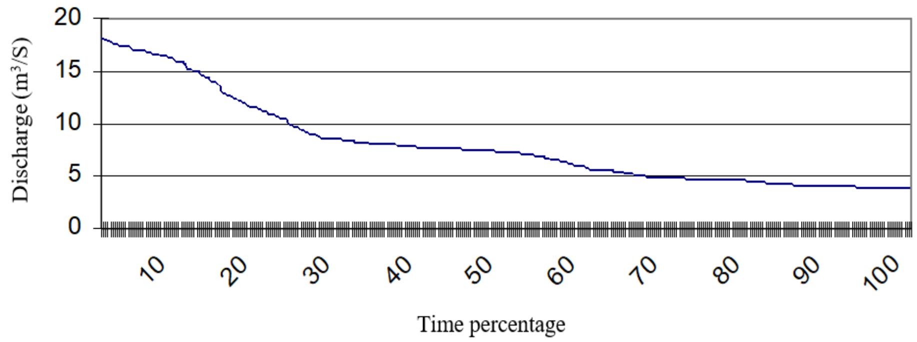


Fig. 7. River Flow duration curve in Sarab Seyed Ali Doab of Aleshtar

Since the accuracy of the statistics is dependent on homogeneity test, homogeneity test was performed on the available data. In order to control the homogeneity of the data, two methods including double mass curve (graphic test), and non-graphic, run test methods were used.

In addition to the experiments and determination of the aforementioned physical and hydro-chemical variables, the amount of discharge of the river has been recorded at the time of taking the samples. The analysis of surface water quality in Kashkan basin was done based on the above data. In order to verify the results of the chemical analysis of the samples, the ion balance and the ratio of electrical conductivity to the total of cations in mill equivalents per liter were used. After verifying the existence of a significant relationship between variables in logarithmic, linear, exponential states, a relationship with higher correlation coefficient was selected and the corresponded relationships were mentioned. It should be noted that in this study, the amount of discharge at the moment of sampling has been considered. After determining the annual and seasonal hydrological drought threshold in each sub-basin, the river discharge at the moment of sampling was in the condition of water shortage or flooding. It is also necessary to mention this point, after determining seasonal hydrological threshold in Kashkan sub-basins and separating sampling statistics in water deficit and normal status or wet spells from each other. In some sub-basins no sampling in the deficit condition was done, so the other data of the sample was ignored. Drought index changes in Doab Aleshtar in November showed that in 10 years we have seen weak to moderate wet condition and also 10 years of poor to moderate drought. The drought index in December has expanded slightly in the positive part of the index. In January, the intensity of droughts is increasing and is becoming severe, which we see in 1982. In February we have moderate and severe drought intensity in the fourth and fifth year of the research period. In March, the number of years of drought and wetness was almost equal and the range of positive negative indicators was equal. The negative index has spread to more than -2 and has been observed in the fifth year of severe drought, but the frequency of dry and wet years is similar. In May, we experienced severe drought in the fifth year of the study period (Kazemi, 2021). There are also many years of drought and drought. SPI in the scales of 1-month, 3-month, 6-month, 9-month, 12-month. 24 and 36-month were determined for all the years (1981-2016), but due to lack of space only dominant samples are presented below. Drought condition changes through SPI index can be seen for different months of the studied period in figures 8 to 15.

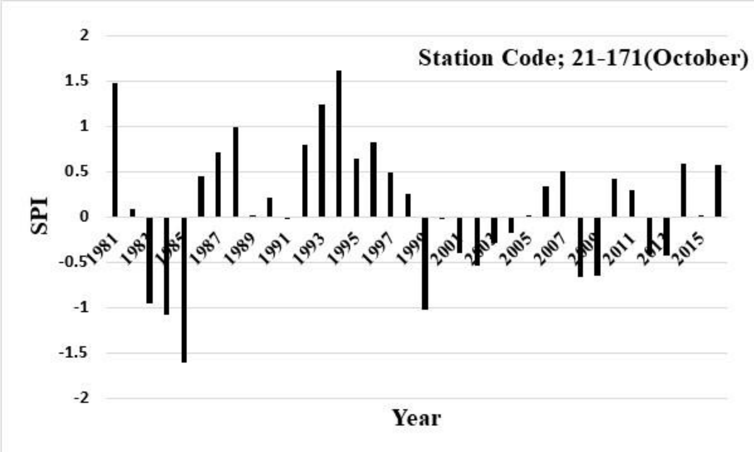


Fig. 8. Monthly SPI changes through the studied period (October)

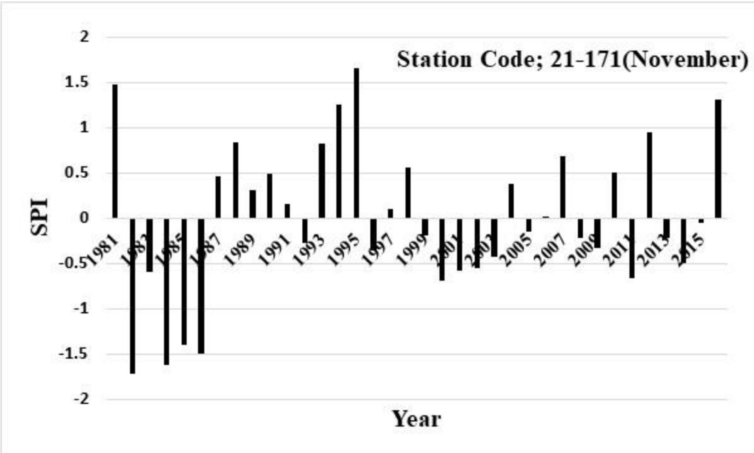


Fig. 9. Monthly SPI changes through the studied period (November)

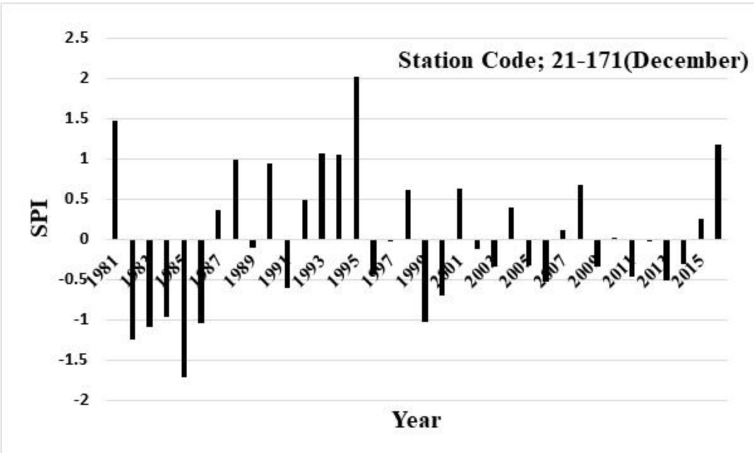


Fig. 10. Monthly SPI changes through the studied period (December).

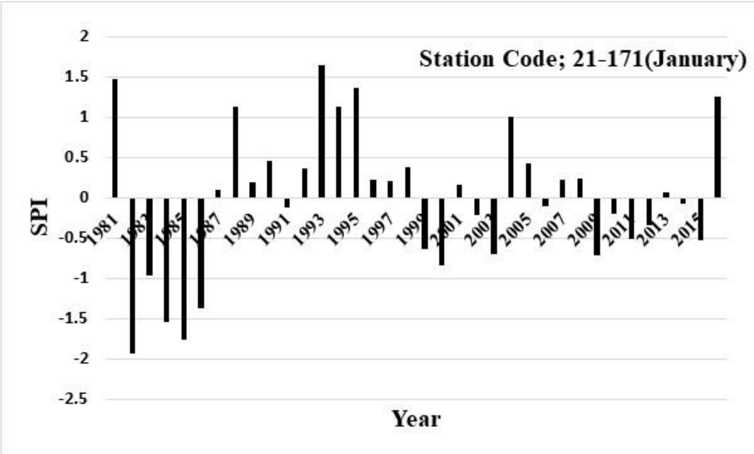


Fig. 11. Monthly SPI changes through the studied period (January).

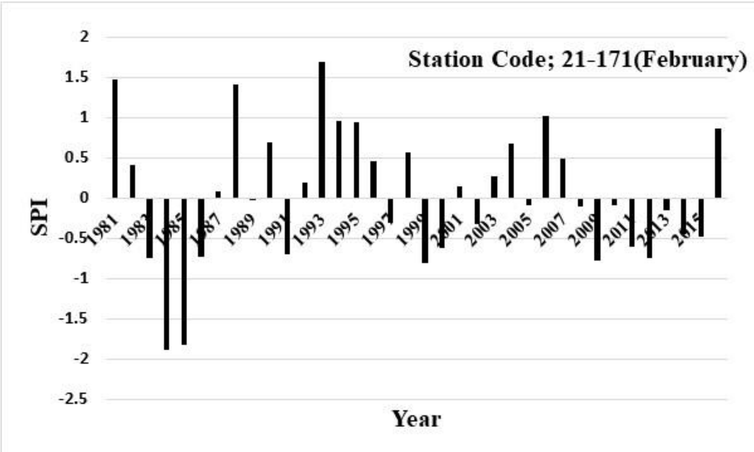


Fig. 12. Monthly SPI changes through the studied period (February).

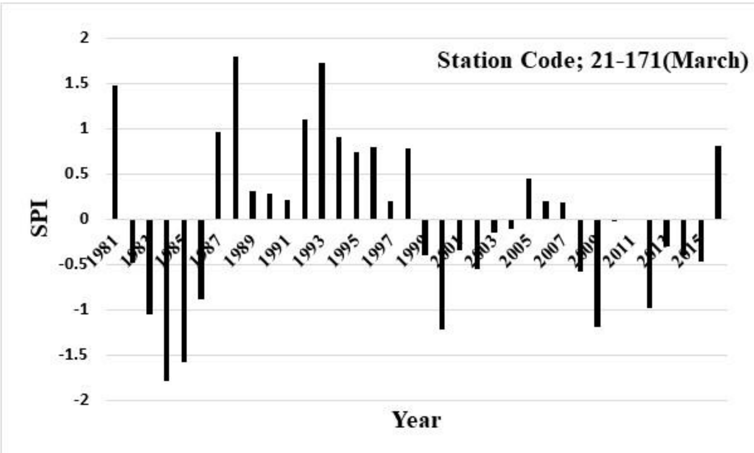


Fig. 13. Monthly SPI changes through the studied period (March).

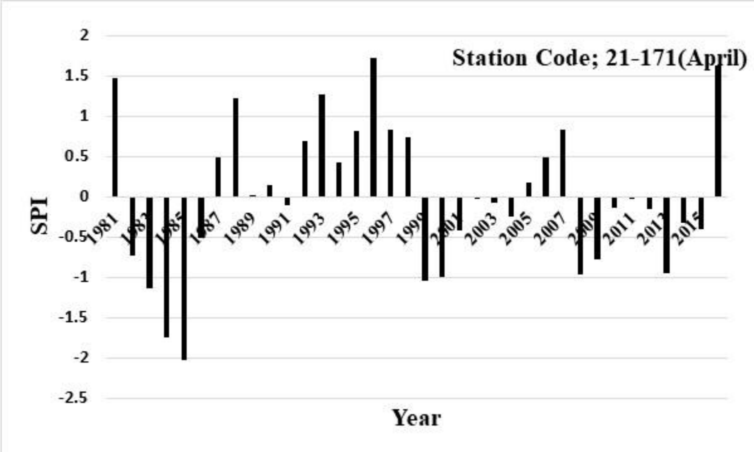


Fig. 14. Monthly SPI changes through the studied period (April)

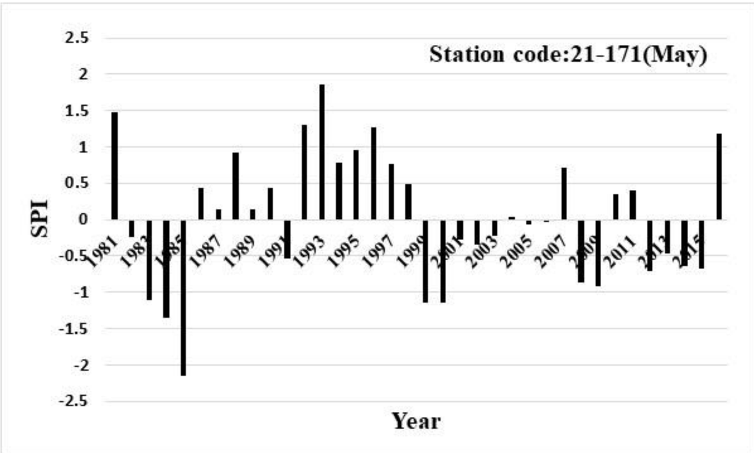
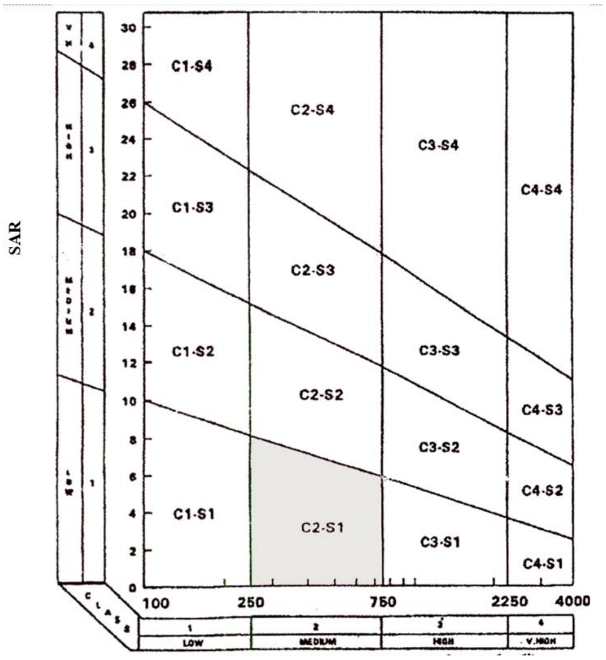


Fig. 15. Monthly SPI changes through the studied period (May)

One of the goals of water chemistry investigation is to determine the chemical type of these waters. To determine the type of water, the anionic and cationic factors that cause the acidity or alkalinity of water should be examined and balanced and measured in terms of their concentration. In this way, its type or its dominant state is chemically determined. Various methods have been provided to check the type of water. Since the chemical quality analysis of the waters has some complexities, so in order to facilitate the aforementioned problem, the technique of displaying water quality status is used. In this regard, different methods have been used, the simplest of which is to provide statistics in the tables of chemical quality analysis of water. In 1923, Collins introduced the first graphical method in which the concentration of each of the cations and anions was shown in different colors or designs, in a graph called the bar diagram. A number of these graphs named Schoeller, Wilcox and Piper were used to determine the drinking and agricultural capabilities of surface waters of all sub-basins of Kashkan basin. Based on the Langelier diagram, the amount of strong acids and alkaline ions is increasing along the flow path, and this indicates the significant effects of geological formations along the path. As mentioned, based on the Piper diagram, a specific chemical type cannot be considered for the water coming out of the Keshkan basin, but it is somewhat closer to the calcium bicarbonate type. According to the lithology of limestones and mineralization and alterations in this mass of rocks, this chemical type of water can be justified.

In this research, in order to examine the above results more precisely, Durov's diagram was also used. This graph is drawn based on the total percentage of anions and cations in mill equivalents. One of the advantages of Drew's diagram compared to Piper's diagram is the better representation of different water types and hydro-chemical processes such as ion exchange and mixing of waters with different qualities. This diagram is able to show three general types of water sources well.

To determine the quality of irrigation water, Wilcox diagram was drawn (Fig. 15). In order to investigate water quality for drinking, Schoeller's diagram was used (Fig. 16).



EC µm/cm

Fig. 15. Wilcox diagram of Aleshtar at Sarab Seyed Ali station

4. Conclusion

Alshtar River covers the surface flow of an area of 776,572 square kilometers and 59.28% of limestone formations, 3.77% of shale and marl, 0.09% of conglomerate and 36.85% of young alluvial sediments. Over 218 water quality samples were taken and analyzed. Samples quality were guaranteed by the authorities of Water Resources Company. The relationship between these events and the quality of surface water in Lorestan province was investigated in a 30-year period in hydrometric stations. The results of the Sarab Seyed Ali sub-basin showed that 67% of the years were normal and the frequency of moderate to high drought was with similar conditions. The frequency of hydrological drought under normal conditions was 52% and severe meteorological drought was 14% of the study period. Water samples were collected from selected locations and analyzed for major physico-chemical parameters. Experimental results show that the water has alkaline with pH varying from 7.2 to 8.2. Concentrations of Na and Cl were positively correlated with EC. The lowest value of EC in Sarab Sayed Ali station on the Doab Aleshtar is about 382.52 µm/cm. The entry of water volume with an average flow rate of 8.32 cubic meters per second recorded at the Sarab Sayed Ali station from the Doab Aleshtar with this rate of EC into the main river (Kashkan) which happens after the Kakarza station, causes a relative decrease in water quality. It causes a relative increase in the measured EC values at the Pole Kashkan station. The values of EC in all stations have a relative increase over time, so that in Sarab Seyed Ali station, it has reached from 300 µm/cm in 1981 to about 570 µm/cm in 2016.

The overall conclusion that deep and extensive drought and carbonate formations have heavily affected the water quality but still it is suitable for agricultural and even drinking purposes in downstream to Sarab Seyed Ali Aleshtar.

5. Disclosure statement

No potential conflict of interest was reported by the authors

6. Acknowledgment

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