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Spatiotemporal variation analysis of water quality using multivariate statistical methods, Case study: Koohsar Lake, Western Iran

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ABSTRACT

The study of water resources and reviewing periodic and spatial changes in the quality of water in aquatic ecosystems are of important necessity due to the reasons including, climate change, water resource constraints, and increased human water requirements. Given the fact that Koohsar Lake water in Zanjan Province is one of the sources of drinking water in the region, the present study aimed to measure the values of 19 parameters of water quality in two seasons of summer and spring at four stations. The samples were transferred to a laboratory under steady-state and sunlight conditions and analyzed according to the standard methods. Statistical analyses were performed using SPSS software. Moreover, the study applied factor analysis using principle components to analyze the variance of data. In addition, the values of the parameters were compared with the permissible limits of drinking water of national standard. The results indicated a significant difference between the parameters studied at stations and different sampling times by repeated measurements. The results of factor analysis also showed that the total of three main components in the summer and spring were 96.573% and 98.581% of the variance of data respectively. The main parameters in the summer included Chlorophyll-a, Na, DO, pH, BOD, COD, TDS, EC, and nitrate. Also, EC, TDS, alkalinity, pH, COD, BOD, Ca, and ammonia were found as the main parameters in the spring. Also, it was found that except for the pH in the spring and at stations 3 and 4 which were below the standard minimum, the lake water in both seasons and all stations, in terms of parameters, was within the standard range and exhibited a good quality for drinking. Implications are discussed in light of the study findings.

Keywords: Koohsar Lake, Multivariate Statistical Methods, Parameters, Principle Component Analysis, Water quality.
Article type: Research Article.

INTRODUCTION

Nowadays, the importance of water and water resources is not hidden, not only because of its impact on human health, but also due to its vitality and inherent value (McCutcheon *et al.* 1993; Ouyang *et al.* 2006). Besides, water is regarded as one of the significant factors for the improvement and economic growth of societies. So that, the ecosystem's water quality can represent the health status and its ecological significance for humans and other living organisms (Kazi *et al.* 2009). However, human activity is considered as a major factor in the change of the surface water quality through atmospheric pollution, sewage drainage, pesticides and agricultural fertilizers, as well as heavy use of water resources. These activities have had a major impact on aquatic ecosystems, resulting in a decline in the quality of water and biodiversity, the loss of sensitive habitats, and a sharp drop in the quality of life of local residents (Ouyang *et al.* 2006). In fact, the development of human activities in the field of industry and agriculture are the major source of contamination in freshwater, both in the surface and underground levels (Tayebi & Sonhanardrkani 2009). In general, water quality is relative and can not be definitely quantified.

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However, although the introduction of quality indicators and various standards have partly resolved this problem, the first step in determining water quality is to measure the parameters that affect water quality (Rezaei *et al.* 2016; Fallah *et al.* 2021; Omidi *et al.* 2021; Fatih Ali *et al.* 2021; Alewi *et al.* 2022). In line with the growing needs of management which are changing through the environment, new technologies developed for controlling and evaluating water quality are developing at a fast pace (Post *et al.* 2018). The conventional procedures for assessing water quality are employed to measure several parameters at several stations and over several periods (Razmkhah *et al.* 2010). Multivariate statistical analysis is also a common method for assessing the quality of water resources and its statistical methods are recognized as effective tools for analyzing large environmental data matrices (Najafpour *et al.* 2008). The lakes as permanent water resources in the ecosystem have a special significance and should have a good quality, playing a significant role in terms of supplying and storing drinking water resources in the local and regional living communities, irrigation, aquaculture, mineral fertilizer modification, genes bank, ecosystems and habitats, contributing to the thermal adjustment of the area with respect to water heating capacity, the visual attraction, and the destination of natural tourism. Given the importance of quality of water resources, the study on the parameters of water quality has been the area of research for a plethora of studies (Tayebi & Sobhanardakani 2009; e.g., Faryadi *et al.* 2012; Mirroshandel & Khavandkar 2014; Sobhanardakani *et al.* 2014; Nazari & Sobhanardakani 2015; Sobhanardakani *et al.* 2016; Gholamipoor *et al.* 2016). Khalaji *et al.* (2017) pointed out that nowadays the study of water quality changes in lakes is of high priority. Therefore, the present study may fill the gap in the literature, by examining the spatiotemporal variation of water quality in Koohsar Lake, Zanjan Province, Western Iran. It is also worth emphasizing that the present study focuses on parameters including total dissolved oxygen, total suspended oxygen, chemical oxygen demand, pH, dissolved oxygen, biological oxygen demand, turbidity, hardness, electrical conductivity, phosphorus, nitrate, nitrite, ammonia, alkalinity, magnesium, sodium, calcium, potassium, and chlorophyll a.

MATERIALS AND METHODS

Sampling and analysis of samples

Koohsar Lake is about 23,000 m^2 and a maximum depth of 18 m. It includes the lakes formed in the southern profile of Alborz Mountains in Tarom Town, Zanjan Province, Western Iran and has been caused by the Zanjan and Guilan earthquakes in 1990 and the blockade of Koohsar River. Its height is 1600 meters above the sea level. Beside the source of drinking water for most of the inhabitants of Tarom Town and the water source used for the region's wildlife, the lake is also the ecotourism destination in the region. As depicted in Table 1, given the characteristics of the area, the form of the lake, the availability, and comparisons with similar studies, four sampling stations were selected in Koohsar Lake: the upstream areas (the river entrance to the lake), the central area (100 meters southwards upstream), the downstream area (in the southwest of the lake) and the water outlet area (the first place where the lake water passes through the basement, reaching the ground in that area).

Table 1. Geo-location of sampling stations.

Station number	Station position	Geographical coordinates	Altitude (m)	Distance to next station (m)
1	Upstream	°49 '4 "48 E ° 37 "14.9 '0 N	1593	100
2	Middle	°49 '4 "44.6 E °37 '0 "13.1 N	1593	187
3	Downstream	°49 '4 "37.9 E °37 '0 "10.3 N	1593	716
4	Exit the water	°49 '4 "9.9 E °37 '0 "4.1 N	1500	

In the temporal evaluation of water quality in Koohsar Lake, due to rainy weather of the spring, and mudding and flooding of the river and the lake, it is not possible to sample until mid-spring. At this time, the lake water reaches the highest volume and overflows. In the summer, with a rise in temperature and an increase in the evaporation of the lake water, the water level is noticeably reduced. In the autumn, the flooding of the lake occurs with the onset of rain, and in the winter, the surface water of the lake is about 20-cm thick snow and impossible to collect samples. As a result, because the statistical analysis of water quality alterations in the lake can provide the best results at the best possible time, the two seasons, spring and summer, were selected which both indicated the water deficit and elevation in the lake, and provided the longest sampling times available throughout the year. The first sampling was conducted in the middle of August 2016 and the others in late May and early June. Fig. 1 represents the position of the sampling points in the studied areas.

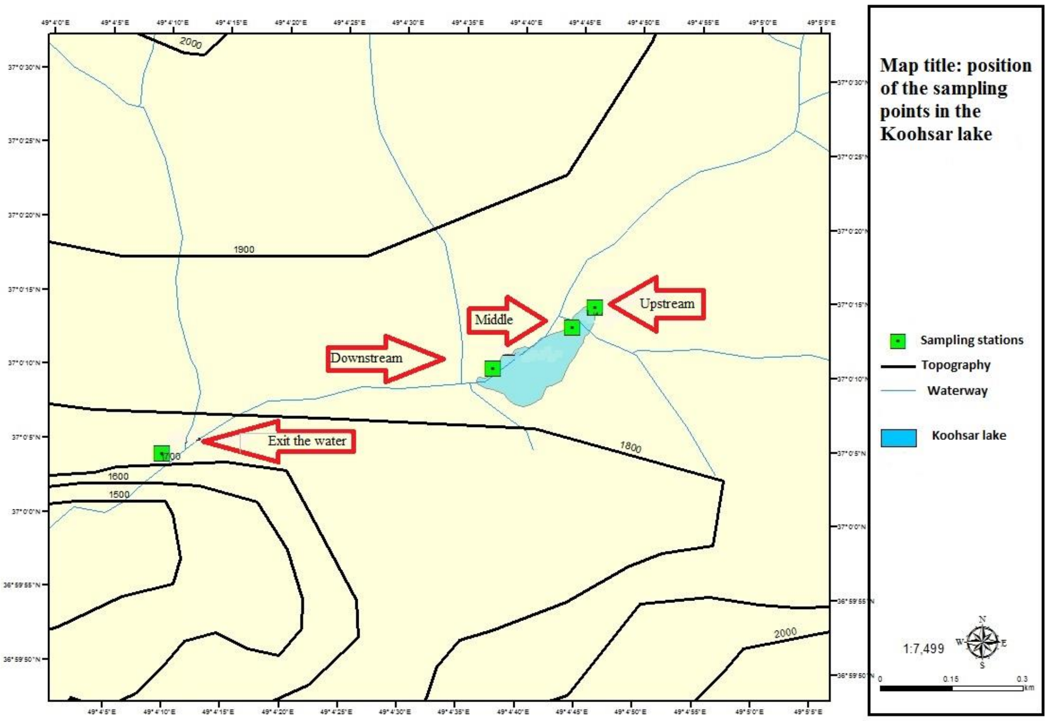

Fig. 1. Map of the position of the sampling points in the studied area.

Sampling method

Sampling was conducted with polyethylene containers, which were washed three times by the lake water before sampling. Samplings from four stations were carried out in the two seasons with three replications and in total of 24 times. The samples were taken to the laboratory as soon as they were taken from the water depth of 20 cm inside the ice-cold clover under constant temperature and far from the sunlight. The values of other parameters in the water samples were measured and recorded in the laboratory, except for the DO and pH of the samples which were measured and recorded in the sampling location by the dissolved oxygen measuring device and the pH meter, respectively. Overall, a total number of 19 parameters were measured and 456 analyses were conducted.

Methods of measuring the parameters of the studied water quality

Table 2 represents the unit of measurement, the reference method, and the method of testing the parameters of this study.

Statistical fractionation

The collected data were first categorized by Excel software and then by SPSS software version 21. The mean values, standard deviation, and maximum and minimum data were calculated with respect to the time and place of sampling for all the parameters. Using this software, the data were completely compared with each other in terms of temporal and spatial variations. For further statistical analysis of the data, factor analysis (FA) was used using the principal components method (PC).

In order to compare the data in four sampling stations and two different times of spring and summer, the technique of Repeated Measures analysis was used. In order to use the values of the parameters obtained in the statistical analysis, some of the data which did not represent precise and definite values and were found to be below the diagnostic value of the meter were changed to definite values close to the results. These data were changed as follows: The turbidity value, lower than 3 NTU at all stations and on both sides, was changed to 2.9; The nitrite less than 0.03 in the downstream in both seasons were changed to 0.02; and COD values less than one in summer at upstream apart from the water stations were changed to 0.9.

Table 2. Unit of measurement, reference method and test method for parameters.

Number	Description of test	The unit	Reference method
1	pH		S.M- 4500-H^+B
2	DO	mg L^{-1}	S.M-2810 B
3	Turbidity	NTU	S.M-2130 B
4	TSS in 103 °C	mg L^{-1}	S.M- 2540 D
5	TDS in 180 °C	mg L^{-1}	S.M- 2540 C
6	COD	mg L^{-1} O_2	S.M- 5220 B
7	BOD	mg L^{-1} O_2	S.M- 2510 D
8	Alkalinity	mg L^{-1} $CaCO_3$	S.M- 2320 B
9	P	mg L^{-1} P	S.M- 4500-P D
10	Nitrate	mg L^{-1} NO_3	S.M- 4500-NO_3^- B
11	Nitrite	mg L^{-1} NO_2	S.M- 4500- NO_2^-B
12	Na	mg L^{-1} Na	S.M- 3500 Na
13	K	mg L^{-1} K	S.M- 3500 k
14	Total hardness	mg L^{-1} $CaCO_3$	S.M- 2340 C
15	Ca	mg L^{-1} Ca	S.M- 3500-Ca B
16	Mg	mg L^{-1} Mg	S.M- 3500-Mg E
17	EC	µs cm^{-1}	S.M-2510B
18	Ammonia	mg L^{-1} NH_4	S.M- 4500-NH_3 C
19	Chl-a	mg L^{-1}	(1999)10200 H

RESULTS AND DISCUSSION

Table 3 reveals the results of measuring different parameters in the summer for each station.

Table 3. Average values of the analysis of summer season samples.

Parameters	Station 1	Station 2	Station 3	Station 4	Total mean value	Standard
pH	6.967	6.967	6.733	6.600	6.817	6.5-9
DO	9.667	8.033	7.933	6.600	8.058	6.3
Turbidity	2.9	2.9	2.9	2.9	2.9	5
EC	300.33	330	284	317.67	308	1000
COD	0.900	33.833	9.967	0.900	11.4	
BOD	0.900	10.967	4	0.900	4.192	3
Hardness	116.33	115.67	116	136	121	500
TSS	8	5	5	5	5.75	25
TDS	168.600	198	170.400	190.800	184.95	1500
Nitrate	6	7	4	5	5.5	50
Nitrite	0	0	0	0	0	3
Ammonia	0.02	0.01	0.0767	0.0167	0.0308	0.05
Alkalinity	98	90	108	89.33	96.33	
P	0.03	0.02	0.0267	0.0233	0.0250	
Ca	76	77.33	76.67	104.33	83.58	300
Mg	2.8667	4.3333	2.4	6.8333	4.1083	30
Na	1.2	0.8	0.8	0.3	0.7750	200
K	0	0	0	0	0	
Chl-a	0.1812300	0.1182000	0.1145733	0.0046133	0.1046542	

Given measuring the focused parameters, the results of samples in the spring season from each station were obtained. The mean values of the parameters are depicted in Table 4. As shown in the table, except for the TSS due to consistency and absence of standard deviation in the summer, as well as the nitrate concentration due to the standard deviation of zero in the spring, and also turbidity due to the equal values at all stations and on both sides, the other parameters reveal a significant differences between stations and two sampling seasons ($P < 0.05$).

Factor analysis findings

Factor analysis was applied using principal components which aimed at analyzing the principle components and reducing the number of major variables in order to examine the quality and conditions of the present study. In this way, the variance in multivariate data is split into components which have major variables, depending on the variance from large to small (Nasiri & Ebrahimi 2012). In the decomposition of the principle components into the number of variables, an element exits, but ultimately, factors that show the highest amount of variance are extracted (Rezaei *et al.* 2016). Normalization of data is not required in this test and the normal hypotheses test is not used (Jolliffe 2003). The present study thus applies principle components analysis method to determine the dominant parameters and the time and space differences.

Table 4. Average values of spring time sample analysis parameters.

Parameters	Station 1	Station 2	Station 3	Station 4	Total mean value	Standard
pH	6.700	6.633	6.033	6.000	6.342	6.5-9
DO	10.833	8.433	8.267	7.567	8.775	6.3
Turbidity	2.9	2.9	2.9	2.9	2.9	5
EC	329.33	330	318.33	299.33	319.25	1000
COD	5	4.433	11.767	3.067	6.067	
BOD	3	2	4.933	1.167	2.775	3
Hardness	329.33	330	318.33	299.33	319.25	500
TSS	2	5	3	4	3.5	25
TDS	197.400	197.400	190.700	179.400	191.225	1500
Nitrate	6	5	6	7	6	50
Nitrite	0.0467	0.0400	0.0200	0.0567	0.0408	3
Ammonia	0.0133	0.0100	0.0333	0.0100	0.0167	1.5
Alkalinity	131	148	140.67	119.67	134.83	
P	0.1567	0.0800	0.0833	0.0967	0.1042	
Ca	84.67	80	89.67	80.33	83.67	300
Mn	9.2	8.6667	7.3	6.3	7.8667	30
Na	33.0667	29.4333	30.5	25.2	29.55	200
K	41.2000	41.2000	35.6667	35.6000	37.6000	
Chl-a	0.0124667	0.0008667	0.0002000	0.0008000	0.0035833	

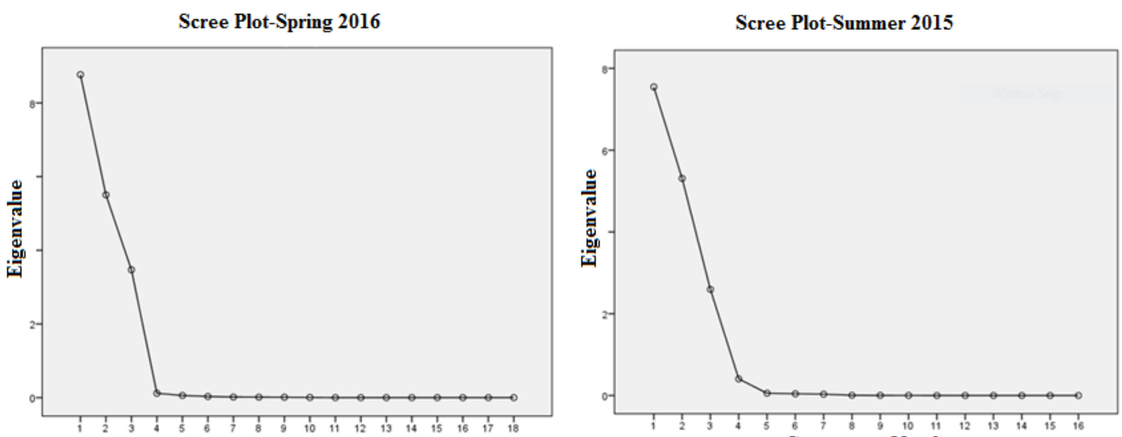

Fig. 2. PC peak graph chart results of measured parameters in summer and spring.

Using PC test, 16 parameters (having variances) analyzed for each element in the main component are summarized in Fig. 2. As shown in Table 5, in the summer, the first component explained 43.736% (including chlorophyll-a, sodium, dissolved oxygen and acidity), the second explained 31.461% (including soluble solids, electrical conductivity and nitrate), and the third 21.376 % (including oxygen biodegradation and chemical oxygen demand) of the variances of the data. Also, the first and second components explained a total of 75.197%, while the first, second, and third, in total, explained 96.573%. In the spring, according to Table 5, the first component explained 34.645% (including electrical conductivity, total soluble solids, alkalinity, magnesium and pH), the second explained 32.681% (including phosphorus, chlorophyll-a, and dissolved oxygen), and the third 31.255% (including chemical oxygenation, bioavailability, calcium and ammonia). Also, the first and second components explained 67.326 % of the variance, while the first, second, and third components explained 98.581%. Fig. 3 presents the interaction of the first component with the second component, the interaction of the second component with the third component, and the interaction of the first component with the third component in a symmetric form.

Table 5. The results of factor analysis using principle components in summer and spring.

Component	Total sum of squares of loads (summer)			Total sum of squares (spring)		
	Total	Percentage of variances	Percentage of the total	Total	Percentage of variances	Percentage of the total
1	6.998	43.736	43.736	6.236	34.645	34.645
2	5.034	31.461	75.197	5.883	32.681	67.326
3	3.42	21.376	96.573	5.626	31.255	98.581

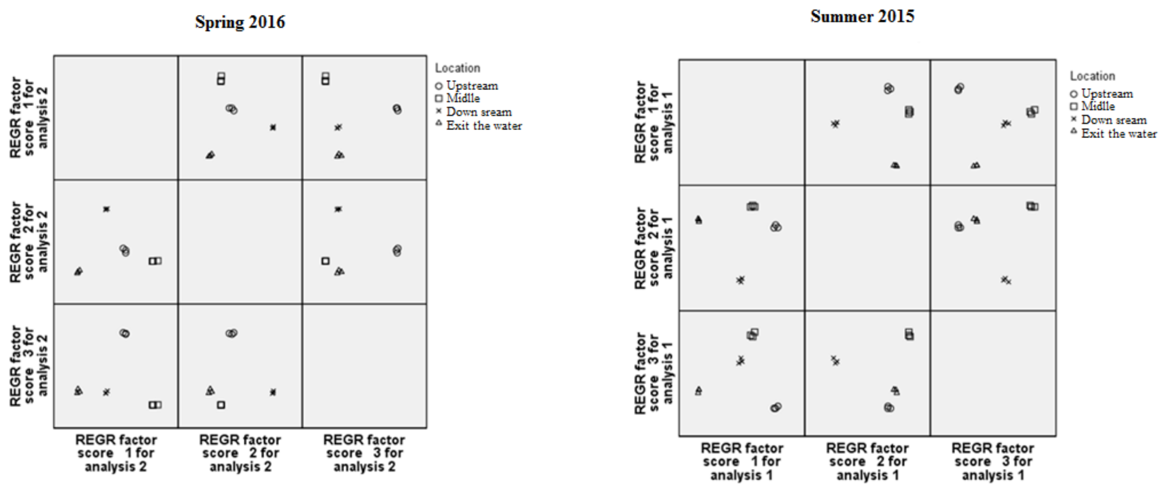

Fig. 3. Distribution of summer and spring season components.

Given the overlap of sampling station symbols, it can be concluded that choosing the sampling stations has been correctly done, and the accuracy of choosing sampling stations is confirmed for both summer and spring.

DISCUSSION

According to the study findings, while upstream and downstream stations in the summer show the highest amounts of pH, the water-outflow station in the spring shows the lowest amounts. In sum, average values of pH in the spring were lower than in the summer. This increase in acidity is the result of melting snow and ice on the mountains around the lake and leaching the humus soils of the forest into the lake watershed. Compared to the standard values, except for the spring where the pH values of the downstream stations are less than the minimum standard limit (6.5), in the spring at other stations, and in the summer at all stations, pH values were within the standard range. In contrast to the present study, in the study conducted by Khalaji *et al.* (2017) at Zayandehrud Dam, Central Iran, pH values were in the acidity range (8.04 - 8.2) at all stations and sampling steps. Given the inverse relationship between the water temperature and the water-soluble oxygen concentration, because of the increase in water temperature, DO in the summer were lower than in the spring. Based on the results, the average DO contents at the stations were 8.058 and 8.775 mg L^{-1} in the summer and the spring, respectively. In addition, due to proximity of the upstream station to the estuary, DO at this station was higher than at the other stations, i.e. 9.667 and 10.833 mg L^{-1}, in the summer and spring, respectively. This is due to the fact that the rivers exhibit a high oxygen content due to intense water turbulence and the dissolution of airborne oxygen in the water. At the outflow station, probably because of the movement of water in the basement and the decreased possibility of dissolution of oxygen in water, DO at the outflow station was lower than at the other stations. These results are in line with those reported by Khalaji *et al.* (2017) who found that DO in Zayanderoon Dam decreased by an elevation in the temperature at the sampling stations. In the present study, The highest electrical conductivity (EC) was 330 µs cm^{-1} in both summer and spring at the middle station, while its lowest was 284 µs cm^{-1} in the spring at the water outflow. The spatial variation of the EC values in both summer and spring is based on the measurements taken according to the spatial variation of the TDS values. Contrary to this study, the maximum and minimum values of EC in the study conducted by Rezaei *et al.* (2016) in Maroon dam, Southern Iran, were the most important causes of EC for high concentrations of TDS in this Dam. Based on the results, the patterns of spatial and temporal alterations of the COD and BOD were consistent with each other (Tables 4-5). The highest amount of COD and BOD was measured to be 33.8 and 10.9 mg L^{-1}, at the middle station in the summer season respectively. COD and BOD values in the summer were higher than in the spring, probably due to rising water temperatures in the summer and the intensity of the organic oxidation process in the area. This finding is in line with the study of Abdolabadi *et al.* (2014) in Atrak River in the northern Khorasan, Eastern Iran. In the case of hardness, except for the outflow station where exhibited the highest value (136 mg L^{-1}) in the summer and the lowest (105.6 mg L^{-1}) in the spring, the other stations did not displayed differences from each other in terms of hardness. The probable cause of increasing hardness at the outflow station in the summer may be the greater dissolution of calcium carbonate in water when passing through the water from the ground. Increased hardness of water in the outflow of the rivers flowing from other sources has been also previously observed in other studies. In a study, conducted by Jedari *et al.* (2010) in Doroudzan Lake and Kor River, Southern Iran, it was suggested that due to limestone formations and its penetration to sediments of the river, the elevation of ions forming the hardness might be expected. The amount of suspended solids generally shows very low values. Due to the proximity of the lake to the water source and the short distance of the water routes from the source to the lake, there is little opportunity for the entrance of suspended matter to the river and the lake. In addition, the bed of the river and the lake is rocky, except for some parts of the upstream area of the lake where the river is discharging, as a result, the river water and Koohsar Lake are clear. Besides, the absence of any kind of human activity around the lake can be a reason for the low amounts of suspended solids. In the summer and spring, TSS values in Koohsar Lake were 5.75 and 3.5 mg L^{-1}, respectively. Unlike the TSS values in this study, in the study of Sadeghi *et al.* (2015), the average values in Atrak River, Northern Iran, with a muddy bed were 75.89 mg L^{-1}. In addition, the highest TDS was obtained in the summer and at the middle station (198 mg L^{-1}), while the lowest in the summer and at the upstream station (168.6 mg L^{-1}). The highest nitrate (7 mg L^{-1}) was obtained in the summer at the middle station and in the spring at the outflow. The nitrate values at the stations and in both seasons showed little alterations. No nitrite concentrations were detected at any of the stations in the summer. In the spring, quantities of nitrite were measured and the highest amount was found to be 0.06 mg L^{-1} at the outflow station. Despite the findings of this study, in the study conducted by Jedari *et al.* (2010) in the lake of Doroodzan Dam in Fars Province, Iran, the highest nitrate and nitrite were found as 12 and 0.5 mg L^{-1} in March respectively. The highest ammonia (0.07 mg L^{-1}) was observed in the summer and at the downstream station. Its highest amount in the spring (0.03 mg L^{-1}) was related to the downstream station. Lack of lake water and rising water temperature and, consequently, a decreased DO can be attributed to an elevated amount of ammonia in the downstream of the lake. In line with the present study, ammonia values varied from 0.02 to 0.8 mg L^{-1} at sampling stations in Jajrood River, Iran, reported by Kashefi-Asl & Zaeem (2009). The highest amount of water alkalinity (148 mg L^{-1}) in Koohsar Lake was measured in spring and at the intermediate station. Daraie *et al.* (2014), once working on the quality of water resources in Borujerd City, Eastern Iran, reported the highest and lowest alkalinity as 462 and 281 mg L^{-1}, which were higher than the highest value obtained in the present study. In the summer, no significant change was found between the stations in the amount of phosphorus. The highest amount (0.15 mg L^{-1}) was measured in the spring and at the upstream station. No significant difference was also obtained among the phosphorus values in other stations in this season. As Nasseri *et al.* (2004) suggest, 0.01 to 0.1 mg L^{-1} phosphorus is sufficient to accelerate eutrophication. In accordance with the present study, Mirroshandel & Khavandkar (2014) in their study in Anzali Wetland, Northern Iran, found the highest and lowest phosphorous values as 1.354 and 0.007 mg L^{-1}, respectively, with the highest and lowest mean values of 0.386 and 0.112 mg L^{-1}, respectively, indicating the tendency of the wetland toward eutrophication. In the case of calcium, the highest value (104 mg L^{-1}) was observed in the summer at the outflow station. The reason for rising calcium in the summer season at this station can be the dissolution of calcium-containing compounds in the underground water route. The results of this study are consistent with the levels of lake water hardness and its increase at the outflow station. There is not much difference among calcium levels at the stations in the spring. The highest amount of magnesium in the spring and at the upstream station was found to be 9.2 mg L^{-1}. This can be attributed to the melting snow and ice and consequently, leaching soils in the Koohsar River Basin. In the study of Kashefi-Asl and Zaeem (2009) in Jajrood sampling stations, Iran, the highest and lowest calcium values were 62 and 37 mg L^{-1}, while the highest and lowest magnesium were 19 and 6 mg L^{-1}, respectively. Sodium levels were much lower in the summer than in the spring. Potassium level was not detected in any of the stations in the summer. While in the spring, significant amounts of potassium were measured at each of the four stations. In the spring, after the melting snow and ice in the mountains of the catchment area of the lake, the entrance of leached soils led to a sharp rise in the sodium and potassium values in the lake. While the highest amount of sodium in the lake was 1.2 mg L^{-1} in the summer and at the upstream station, however, in the spring their highest concentrations at the upstream station were 33 and 41.2 mg L^{-1}, respectively. According to the geological map of the country (Iran), edited in 1979, in the geological organization of the Koohsar Lake basin, there are sedimentary deposits containing Mika minerals, which are the source of potassium. Andesites and tuffs, also known as sodium, are present in the geological formation of Koohsar Lake watershed. Similar to the results related to the sodium and potassium alterations in the present study, Faryadi *et al.* (2012), based on the results of analysis of the principle components, measured sodium and potassium in Tajan River, Northern Iran at three sampling stations, reporting them as the first components exhibiting the most alterations. It was also reported that carbonate formations, called limestone and dolomite were the source of calcium, schist was that of potassium, while clay, marn, diorite, and green tuff those of sodium.

The highest amount of chlorophyll-a was obtained in the summer at an upstream station (0.18123 mg L^{-1}). This parameter has been decreasing at subsequent stations and significantly reduced at the outflow station. In the spring, its highest level was 0.0124667 mg L^{-1} at the upstream station. In the summer, due to the small depth at the upstream and downstream stations, and consequently, elevated intensity of light penetration to the depth, the production of chlorophyll in certain volume was upraised. The upstream station has especially a greater chance of absorbing sunlight than any other stations due to the time of the sunlight exposure to the surface. In the spring, by adding the amount of water in the lake, the depth of the middle station also elevates, resulting in a much lower concentration of chlorophyll at the intermediate station than at the upstream one. In general, the lower level of chlorophyll content in the spring compared to summer are due to the upraised volume of water discharging to the lake, the elevated water circulation due to the flooding of Koohsar River, the reduced temperature and also evaporation in the spring compared to the summer season. According to Harding *et al.* (1986), there is a correlation between the water surface temperature and chlorophyll concentration, and temperature is one of the important factors in the spatial distribution and its concentration. Similar to the present study, Gholamipoor *et al.* (2016), in a study on the rivers discharging to Anzali wetland, Northern Iran reported that the highest concentration of chlorophyll-a was 4.5 μg L^{-1} in July. In accordance with this result, the study of Vahidi *et al.* (2016) in the Valesht Lake, Mazandaran Province, Northern Iran, the highest amounts of chlorophyll-a were measured in August and September. According to the results of variance analysis, in the Factor Analysis test, the principle components of the results in the summer are the most effective parameters in the first component, including chlorophyll-a, sodium content, dissolved oxygen, and acidity, respectively. In the next stage, the results of this test showed that the most effective parameters in the second component, which is weaker than the first one, include the solubility solids, electrical conductivity, and nitrate. Finally, the amount of oxygen biologic and chemical oxygenation in the third component has a positive effect on the weakest component compared to the first two components. Also, in the spring, the results of analysis of variance in the functional test were analyzed by principle components analysis. As the results indicated, the most effective positive parameters in the first component are electrical conductivity, total solids, solubility, alkalinity, magnesium, and pH, respectively. The most effective parameters in the second one, which is weaker than the first, include phosphorus, chlorophyll-a, and dissolved oxygen, respectively. Finally, the chemical oxygen demand, biochemical oxygen demand, calcium, and ammonia in the third component display a positive effect on the weakest component compared with parameters in the first two. In sum, based on the results obtained and taking into account the importance of the first component in both parts of the site, the most important parameters of this study indicating the spatial variations in the Koohsar Lake water quality, include chlorophyll-a, sodium, soluble oxygen, acidity, electrical conductivity, total soluble solids, alkalinity, and magnesium. In fact, the analysis of the changes in these eight parameters would suffice in the future studies on Koohsar Lake, especially the rapid assessment of the qualitative alterations in its water. Moreover, according to the repeated test results, the parameters such as potassium, sodium, phosphorus, nitrite chlorophyll-a, and magnesium exhibited the most changes from summer to spring. According to the present study, it is necessary to prioritize the above-mentioned parameters in the study of water monitoring in the lake in addition to the parameters positively affecting the components. Also, comparing the values obtained by the standards of quality parameters for drinking water according to National Standard No. 1053 and the Standards of the Environmental Protection Department showed that the optimal and suitable quality of water is available at all stations. Besides, in the both seasons, all parameters, are at permissible values except for acidity, which was lower at the downstream and outflow stations in the spring. Meanwhile, the elevations in some parameters in the summer compared to the spring can be explained in terms of special conditions in the summer, including intense heat, evaporation of the lake water, reduced water ininflow to the lake, and a marked drop in the depth of the lake.

CONCLUSION

Results of this study showed the appropriate quality of drinking water in Koohsar Lake. Taking into account the factors, including the use of Koohsar Lake water as the drinking water for the residents of Tarom, its youth, originality, economic values, naturalness, and ecotourism, it is essential to protect this ecosystem and maintain a regular monitoring of its water quality. Moreover, it deserves to be the priority of the trustees, such as the Environmental Protection Agency and the Ministry of Energy. Furthermore, the results of this study can provide a rapid assessment of the lake water quality for further studies.

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