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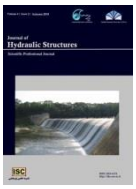

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Evaluation of the Effects of Geology and Agricultural Development State on the Quality of Surface Water Resources Affected by Constructing Reservoir Dams (Case Study: Marun – Jarahi Basin)

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Abstract

The statistical tests such as T-test and Kruskall-Wallis test were used to study and analyze the difference between the quantitative parameters before and after constructing dams and the effect of different factors on water quality. The results of statistical tests showed that the values of the investigated water quality parameters (except EC value) before constructing (pre) dams were significantly different from the values after constructing dams in reservoir downstream stations. Sulfate (SO^2) concentration in downstream stations of Marun Dam (Behbahan and Cham Nezam) reduced by 30 and 23 percent, respectively, and Cl- concentration increased 21 and 12 percent, respectively. Similarly, the difference between the values before and after constructing Jarreh dam at Mashin station was a 106% reduction in the concentration of sulfate ion (SO^{2-}_4) and a 78% increase in the concentration of chlorine ion (Cl-). The reason for this increase is probably due to the effect of river flows on the Formation and the relationship between the reservoir and the Formations where water has a long residence time and then reduced due to the exposure to the Geological Formations as well as the existence of agricultural activities downstream and before quality monitoring stations could be another reason for this claim. In addition, in the reservoir system, the concentration of soluble salt may be diluted by runoff from winter snowmelt and spring rains. Therefore, it can be concluded that water quality characteristics of Marun and Roudzard rivers in the studied basin has been affected by the constructed reservoir dams.

Keywords: Geology, Agricultural Development, Reservoir Dams, Water Quality.

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1. Introduction

For planning river flow control and management, statistical analysis is an important step for understanding the behavior and changes in constituents of water and flow quality. Literature review shows that water quality is constantly changing and many different human factors and activities through point sources, such as sewage treatment plants, and non-point sources such as runoff from agricultural activities and urban areas affect the quality and characteristics of river systems [1-6].

Edwards, Pinol et al. and Ahmad et al. stated that the main source of changes in water quality is stream flow [7-9]. Huang and Foo claimed that engineering and management changes in a river system may alter the characteristics of river water quality [10]. The dams are constructed in general for flood control, power generation, water supply, and etc. They can potentially change discharge and sedimentation and have a significant effect on water quality. The review of references indicates that there are various studies in this field [11-15].

Regarding the importance of Marun and Roudzard rivers for drinking and agricultural water supply and the position of Marun and Jarreh reservoirs on Gachsaran formation, the purpose of this study is to investigate the effect of geological state on water quality of Marun and Roudzard rivers. Also, regarding the development of agricultural lands after constructing dams, the effect of agricultural activities will also be investigated.

2. Materials and methods

2.1. Area of study

The study area is part of Marun - Jarahi catchment. Geologically, the study area is located in Zagros Structure belt. The outcrop geologic formations are Pabdeh marl and Gurpi formations as the oldest rocks of the area that are located on Asmari limestone formations, gypsum and marl layers of Gachsaran formation and alluvial sediments, respectively. It is mainly covered by Gachsaran Evaporite formations. Gachsaran formations consists of a series of alternating shales and gypsum marls, thin to medium layers of salt, and massive gypsum and anhydrite masses. This formation is thick and has a wide outcrop in the catchment. This rock unit contains salt layers and evaporated sediments (anhydrite) that are soluble in water. With such characteristics, this formation severely affects the quality of water in contact with it and reduces its quality [16,17]. Also, due to the high potential of soil and water in this catchment and the main plains located in the basin, two large reservoir dams were constructed called Marun Dam with a volume of about 1200 million cubic meters and Jarreh Dam with volume of 260 million cubic meters in Marun - Jarahi Basin. It has come into operation. According to the purpose of the study, only Behbahan irrigation and drainage network with an area of 14600 hectares is located in the downstream of Marun Reservoir Dam, which regarding the main drainage of the network can have significant effects on river water quality. Marun Reservoir Dam is located on Marun River and its watering began in 2000. Jarreh Reservoir Dam on Roudzard River has also been put into operation in 2011.

In this study, five water quality data monitoring stations were used to study water quality of Marun and Roudzard rivers before and after constructing reservoir dams in the basin and due to their exposure to the qualitative effects of Gachsaran formation and agricultural lands. We selected 3 stations of Eydanak (upstream of the reservoir) and Behbahan and Cham Nezam

(downstream of the reservoir) on Marun River as well as Mashin station on Roudzard River in the downstream of Jarreh Dam. It should be noted that Cham Nezam station is Behbahan irrigation and drainage network after agricultural drainage outlet. Figure 1 shows the location of reservoir dams, and water quality monitoring stations in the study area.

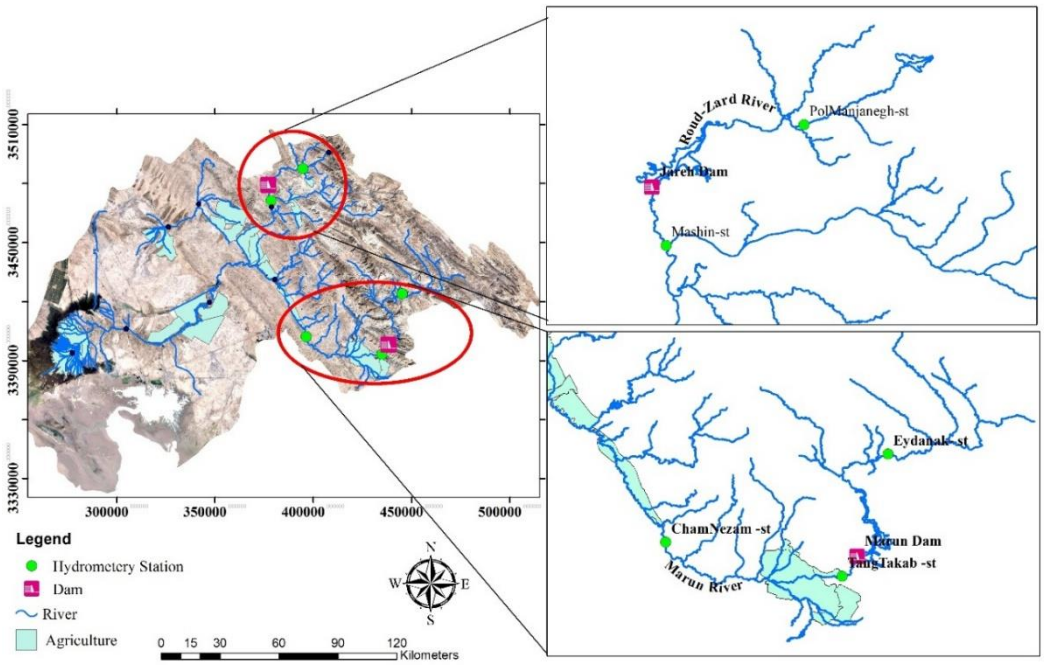

Figure 1. Location of the study area, reservoir dams and river quality monitoring stations

2.2. Data used

In order to compare and evaluate water quality parameters before and after constructing dams, monthly water quality data were used for all water quality monitoring stations in the river during 1977-2018 period. The statistical period considered from the records of water quality values of quality monitoring stations to evaluate the dam effects on the components of water quality parameters were classified into two statistical periods before and after constructing the dam, respectively. Regarding the time of constructing Marun Dam and regardless of the years of construction, respectively we considered two periods since 1977 to 1997 as the period before dam construction and the statistical period since 2001 to 2018 as the period after dam construction. Similarly, considering the time of construction of Jarreh Dam on Roudzard River, the whole statistical period was categorized into two periods of 1977-2010 and 2011-2018, respectively, before and after dam construction. Water quality components measured at monitoring stations are electrical conductivity (EC) (μ mho / cm), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chlorides (Cl^-) and sulfate (SO^{2-}_4) in mEq per liter. In order to analyze the qualitative parameters for the purpose of the study, among the measured qualitative parameters, only those parameters that have a greater relevance for identifying the effects of formations and agricultural lands in the study area have been considered and selected. The parameters such as electrical conductivity (EC), chlorine (Cl^-) and sulfate (SO^{2-}_4) were selected and evaluated according to the purpose of the study. It should be noted that in the

periods after constructing the dam measured at the studied stations water level reduced due to storage and tank filling as well as to drought (Figure 2).

2.3. Statistical tests

It is always important to select a parametric or nonparametric test when performing a test. One of the main criteria for this selection is Kolmogorov-Smirnov test. Kolmogorov-Smirnov test shows the normality of the data distribution. The parametric tests may be used if the data have a normal distribution, otherwise a nonparametric test should be used. For this purpose, parametric t-test was used to evaluate and compare changes in water quality parameters with normal distribution before and after dam construction. Similarly, at each of the stations with abnormal distribution, we used nonparametric Kruskal-Wallis test at the significant level of 0.05, respectively, to study the homogeneity of the mean, among the time series of each water quality combination from the pre and post periods of the dam construction [18].

3. Results and discussion

3.1. Analysis of statistical tests

According to the results of Kolmogorov-Smirnov test, the data of the quality monitoring stations in Marun River were significant at 5% confidence level (p-value> 0.05), which means that the data at these stations have a normal distribution and insignificant for Hydrometric station in Roudzard River and the data do not follow the normal distribution. For this purpose, parametric t-test was used to study the differences in the concentration values of the qualitative parameters before and after the construction of reservoir dams in Marun River and we used non-parametric Kruskal-Wallis non-parametric test for the stations in Roudzard River. The results of both tests for the stations studied are shown in Tables 1 and 2.

Table 1. The results of statistical t-test for each qualitative parameter since the periods before and after constructing Marun Dam

Station	River/ Dam	Constituent	p-value	Decision
		t-test		
Eydanak	Marun/Marun Dam	Cl	0.083	ND
		SO4	0.667	ND
		EC	0.053	ND
behbahan		Cl	0.000	SD
		SO4	0.000	SD
		EC	0.221	ND
chamNezam		Cl	0.004	SD
		SO4	0.000	SD
		EC	0.637	ND

Table 2. The results of Kruskal Wallis statistical test for each qualitative parameter since the periods before and after constructing Jarreh dam

Station	River/ Dam	Constituent	p-value	Decision
Kruskal Wallis Test				
polmanjanigh	RoudZard/ Jarreh Dan	Cl	0.109	ND
		SO4	0.092	ND
		EC	0.118	ND
Mashin		Cl	0.000	SD
		SO5	0.000	SD
		EC	0.81	ND

Note: ND, no difference; SD: significantly different 95% confidence level

T-test and Kruskal-Wallis test (Table 3) showed that a difference was found in chlorine and sulfate ions in some of the quality monitoring stations in Marun and Roudzard rivers. Cl^- and SO^{2-}_4 parameters before and after dam construction were significantly different at Behbahan and Cham Nezam stations at the downstream of reservoir dam ($P<0.05$). Also, Mashin station at the downstream of Jarreh Dam had significantly different concentrations of sulfate and chlorine ions before and after the dam construction. No significant difference was found at the upstream stations of Marun and Jarreh dams considered as the only basis for the changes and did not have a significant effect on the purpose of the study. Only by analyzing the load values of downstream stations can we comment on the purpose of the study. The significant differences in the concentration of chlorine and sulfate ions are due to the effects of various factors, mainly due to the effects of the geological formation of the area and the agricultural lands along the river margin.

3.2. Data analysis

According to the graphical analysis shown in Fig. 2, it can be concluded that the magnitude of the fluctuations in the period after the construction of each of Marun and Jarreh reservoir dams in each of the statistical periods (2001-2018 and 2012-2018) for all stations is much smaller than the period before constructing the dam (1977-1997 and 1977-2010).

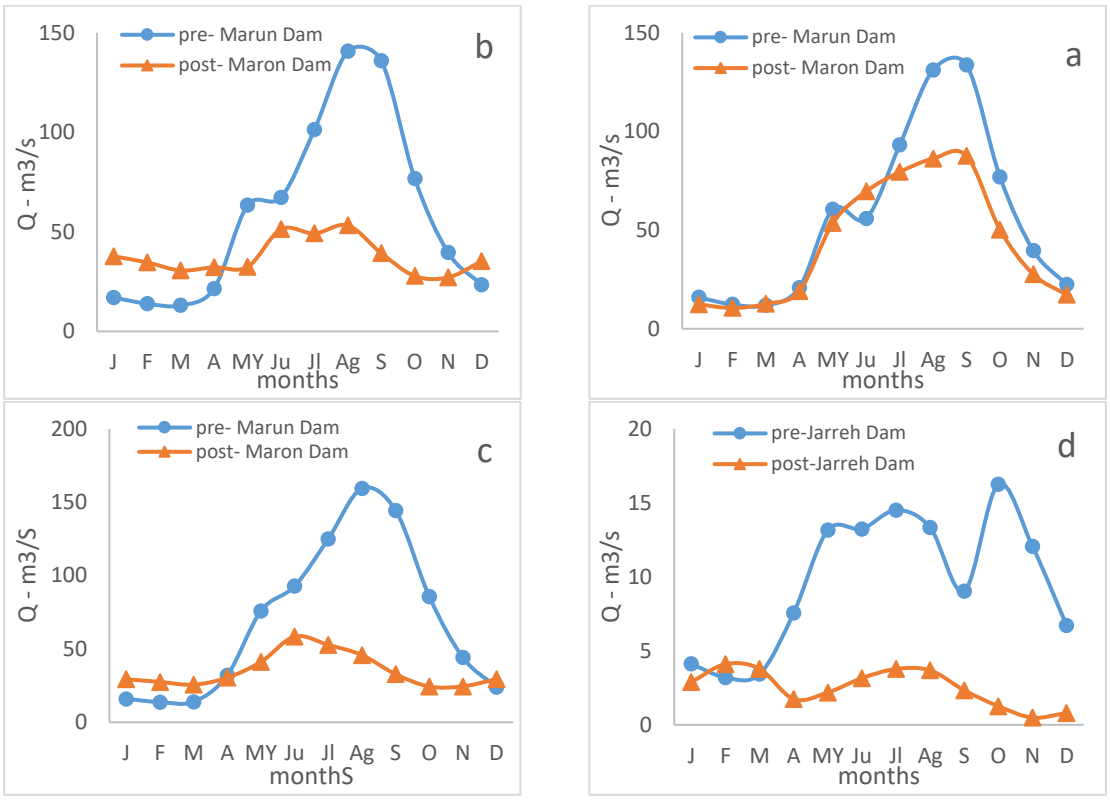

Figure 2. Monthly discharge in hydrometric Stations in Marun and Roudzard Rivers Before and After constructing Dams (a: Eydanak, b: Bebahan, c: Cham Nezam, d: Mashin)

A set of concentrations of water quality constituents including electrical conductivity (EC), chlorine (Cl^-) and sulfate (SO^{2-}_4) at each of the upstream and downstream water quality monitoring stations in Marun and Zard rivers over a period of 40 years. 1977 to 2018 is shown in Figure 3.

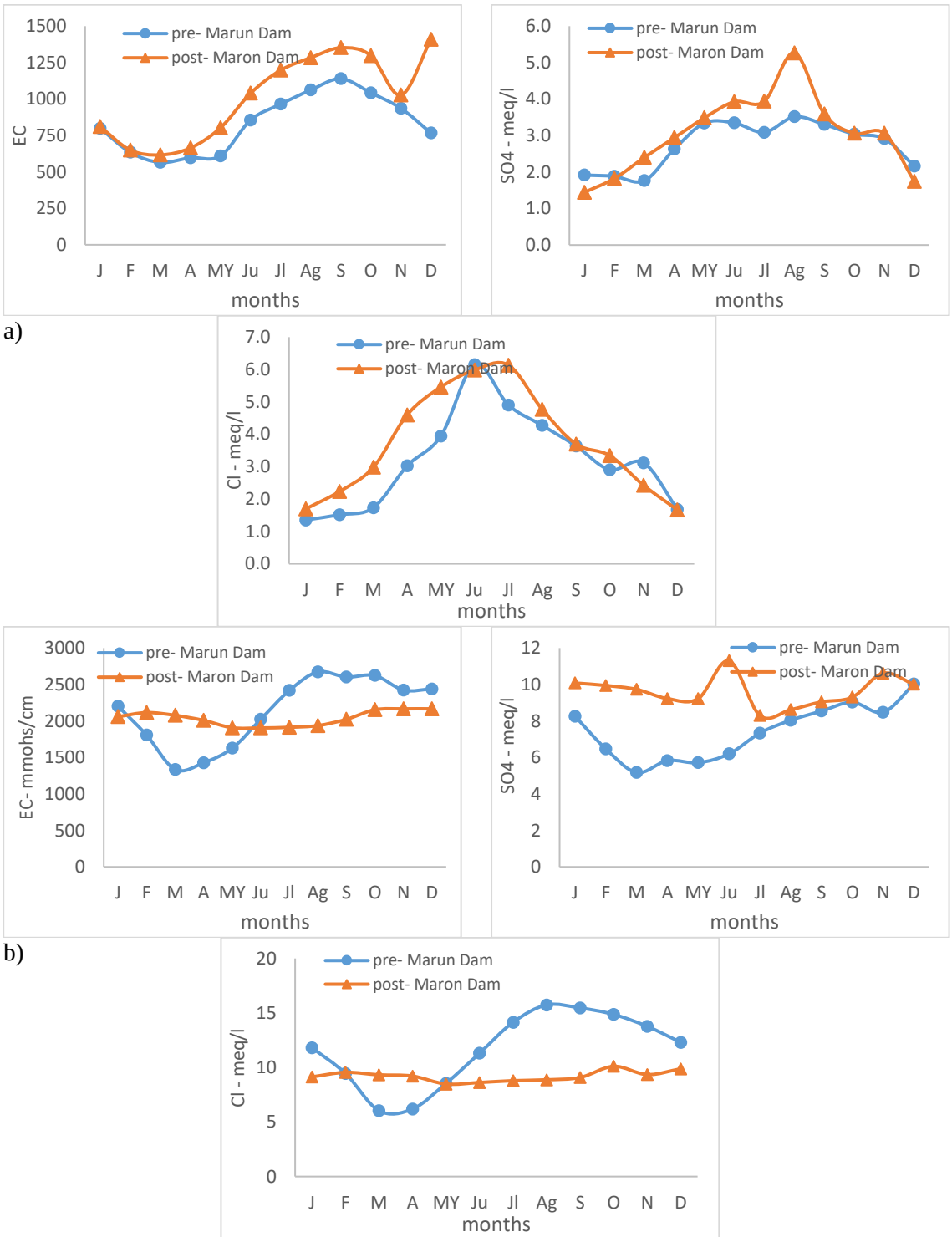

Figure 3. Monthly time series of concentration values of water quality parameters at Marun and Roudzard rivers stations in statistical periods before and after constructing dams (a: Eydanak, b: Behbahan

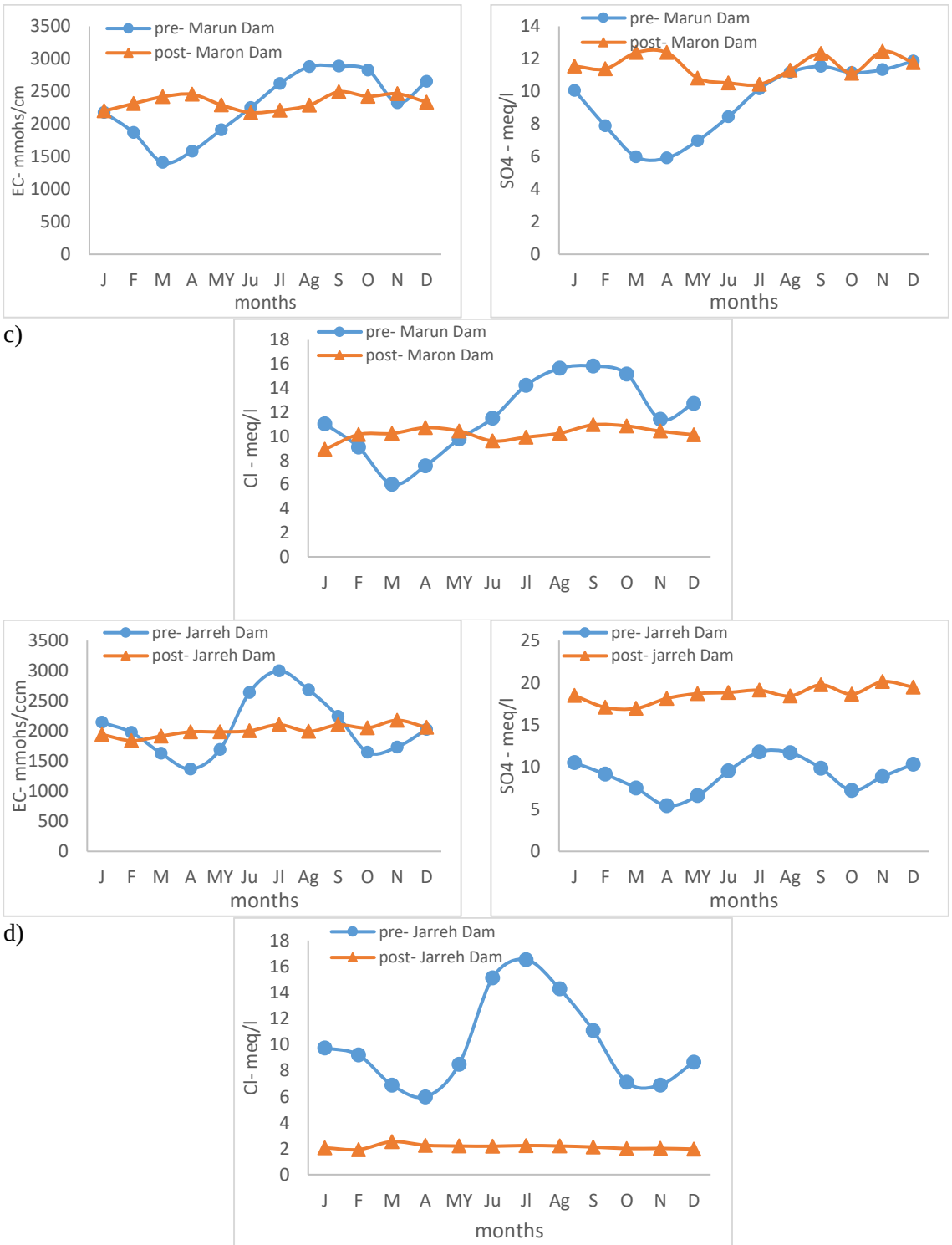

Figure 4. Monthly time series of concentration values of water quality parameters at Marun and Roudzard rivers stations in statistical periods before and after constructing dams (c: Cham Nezam, d: Mashin)

According to Figures 3 and 4, it can be stated that the concentration values of water quality parameters at each of the qualitative monitoring sites in the statistical periods before and after constructing the dam show, however, that the periods after constructing the dam have been uniform but the periods before constructing the dam there have been more fluctuations. There are several reasons for these changes. The range of the concentration fluctuations at the downstream stations of the dam is greater than the concentration values at the upstream stations (Fig. 3a). Some of them may depend on the flow changes and season condition.

All data are more uniform than the period before constructing the dam, and this may reflect the effect of the reservoir on water quantity (Fig. 2) and quality (Fig. 3 and 4). Under optimum conditions and before constructing the dam, as shown in each of the values of the concentration of qualitative parameters at the studied stations, the increase in flow causes dilution of the concentration of the parameters and consequently reduces the concentration value of the parameters at a specific time when the discharge is increased. However, in some cases increasing discharge does not reduce or dilute the concentration of qualitative parameters and is influenced by various factors such as the relationship between more geological layers along the river flow path with higher discharges, increasing the concentration of water quality. For this purpose, as shown in Figures 2, 3 and 4, for the concentration values of the qualitative parameters before and after dam construction we can say:

Study of the period before dam construction: At Eydanak station, EC parameter concentration affected by geological and agricultural factors has increased with increasing flow rate in different months. Similarly, for sulfate concentration values, the main reason for the increase with increasing flow in the period before dam construction was the relationship between the geological layers and the passing flow. At the downstream of Marun Reservoir Dam at Behbahan station, the same situation applies to Eydanak station. At Cham Nezam station, as the last qualitative monitoring point of the river at the downstream of the dam and Behbahan station, pre-construction conditions and trend changes in concentration of water quality parameters continued and were similar to its upstream station i.e. Behbahan. Also, in Roudzard River before the construction of Jarreh Dam, the concentration of Mashin station parameters increased due to geological layers in the river bed and the relationship between the river flow and the formation.

Study of the period after dam construction: At Eydanak station at the upstream of Marun Dam, the conditions of dam construction have no effect on the variability of water quality parameters of the station, but it is clear that in the period after dam construction, even with reducing the river flow parameters increased that is probably affected by successive droughts, and the increase has been attributable to the effect of geological formations of the study area and upstream agricultural activities. At Behbahan station, studied water quality parameters reduced after Marun Dam construction due to water storage in the reservoir, but EC, SO^{2-}_4 and Cl^- values increased and have been stable. This is due to the effect of formations due to seasonal conditions and runoff production in the basin and the discharge rate of the reservoir flow related to the geological layers of the area. The changes in concentration values of water quality parameters at Cham Nezam station after construction of Marun Dam indicate that with reducing flow rate similar to the condition of Behbahan station, water quality parameters of Cham Nezam station continued to be uniform and constant. The study of Mashin station state in the period after Jarreh Dam construction showed that by reducing the flow rate, the electrical conductivity became uniform and steady compared to before the construction of the dam.

The statistical data including the maximum, average, minimum, and standard deviation values for concentrations of water quality constituents in the periods before and after the construction of

each of the catchment dams at the monitoring stations are shown in Table 3.

According to Table 3 and examining the ratio of maximum to minimum concentrations of water quality constituents, the highest ratio before the construction of the dam at each of Marun River Monitoring Stations was related to chlorine ion (32/93), which was decreasing from upstream to downstream (Cham Nezam station). Also, the calculated ratio of sulfate downstream increased in this study. In the post study, the highest ratio of maximum to minimum values of concentration of each of the parameters is related to the sulfate ion (49) and the lowest value of the ratio of maximum to minimum values is related to electrical conductivity. The source of the abundance of sulfate in the river is due to the dissolution of gypsum due to the geological structure of the area and the aforementioned Gachsaran formation. Also, the source of chlorine concentration in the river may be due to agricultural activities, rain water and evaporite deposits.

Table 3. Statistical Parameters of Water Quality Concentration Values from Statistical Periods before and after Marun and Jarreh Dams at Each Quality Monitoring Station

Station	Constituent	n	Max	Min	Mean	SD	Median	R(Max/Min)
for concentration values from 1979 to 1999 (pre-Marun dam)								
Eydanak	Cl^-	252	24.7	0.75	3.18	2.19	2.86	32.93
	SO_4	252	8.29	1.03	2.74	1.06	2.58	8.05
	EC	252	2850.0	350.0	831.03	269.04	794.50	8.14
Behbahan	Cl^-	252	28.0	1.45	11.64	4.65	11.95	19.31
	SO_4	252	26.25	2.60	7.43	2.93	7.00	10.10
	EC	252	4130.0	830.0	2117.43	592.37	2134.80	4.98
ChamNezam	Cl^-	252	26.50	1.65	11.66	4.47	11.98	16.06
	SO_4	252	23.28	1.92	9.37	3.41	9.02	12.13
	EC	252	3925.0	970.0	2283.25	658.44	2291.50	4.05
for concentration values from 2002 to 2019 (post-Marun dam)								
Eydanak	Cl^-	216	11.71	0.58	3.74	2.03	3.36	20.19
	SO_4	216	14.30	0.55	3.06	1.78	2.86	26.00
	EC	216	9711.0	339.80	1012.59	683.93	909.50	28.58
Behbahan	Cl^-	216	16.13	2.94	9.20	2.42	9.28	5.49
	SO_4	216	51.05	1.04	9.62	3.54	9.36	49.09
	EC	216	2942.0	845.00	2036.30	352.06	2067.50	3.48
Cham Nezam	Cl^-	216	16.04	1.63	10.22	2.28	10.10	9.84
	SO_4	216	21.17	4.79	11.54	2.39	11.20	4.42
	EC	216	3408.00	1045.00	2338.87	412.56	2286.00	3.26
for concentration values since 1979 to 2011 (pre-Jarreh dam)								
Mashin	Cl^-	396	38.82	0.65	9.89	5.70	8.60	59.72
	SO_4	396	19.62	3.4	9.05	2.97	8.735	5.77
	EC	396	5778.0	696.0	2051.90	734.04	1932.50	8.30
for concentration values since 2013 to 2019 (post- Jarreh dam)								
Mashin	Cl^-	84	5.26	0.98	2.15	0.48	2.13	5.37
	SO_4	84	24.16	12	18.64	2.33	19.1	2.01
	EC	84	2640.0	1450.0	2011.9	238.4	2000.0	1.82

Regarding the mean concentrations of water quality constituents in the period before and after constructing the dam shown in Table 1, the percentage of changes in the mean quality parameters in each position of water quality monitoring stations is shown in Table 4. As shown in Table 4, the values of concentration changes of water quality parameters studied are decreasing and increasing. The concentration values of quality parameters in Marun River at Eydanak station before constructing Marun Dam were reduced in all parameters but to determine

the effects of dam construction on downstream water quality as shown in the Table, at Behbahan station percentage change in quality parameters before and after the dam construction, sulfate ion concentration (SO^{2-}_4) was reduced by 30% and chlorine (Cl^-) and electrical conductivity (EC) concentrations increased by 21 and 4%, respectively, due to the effects of the downstream geological formations as well as outflows from power plants and seasonal conditions. Also at Cham Nezam station, which is located downstream of Marun Dam and after Behbahan irrigation and drainage network, the changes in SO^{2-}_4 and EC concentration values reduced compared to before the dam construction and percentage of Cl^- concentration changes increased by 12% that is due to major agricultural activities prior to the quality monitoring station and the entry of agricultural drains into the river. The ratio of changes in concentration of water quality parameters in Roudzard River under the influence of Jarreh Dam in the two studied periods showed that the trend of changes in sulfate ion concentration was significantly reduced by 106% due to control and improvement of the effects of downstream sulfate concentration after the dam construction. Chlorine and electrical conductivity changes after the dam construction are also increasing, with a significant 78% increase in chlorine content, which may be due to climatic conditions due to the entry of outflow drains of agricultural activities and the discharge output of Jarreh reservoir directly related to the regional geological formation.

Table 4. Changes in water quality concentration parameters at the studied stations

Station	River	Constituent	Change% $((\overline{X}_{Post} - \overline{X}_{Pre}) / \overline{X}_{Pre}) * 100)$
Eydanak	Marun	Cl^-	-18
		SO^{2-}_4	-11
		EC	-22
Behbahan	Marun	Cl^-	21
		SO^{2-}_4	-30
		EC	4
ChamNezam	Marun	Cl^-	12
		SO^{2-}_4	-23
		EC	-2
Mashin	RoudZard	Cl^-	78
		SO^{2-}_4	-106
		EC	2

4. Conclusion

Sulfate ions are potentially derived from natural sources such as geological layers. Sulfate concentrations in natural waters are less than 80 mg / l (2.2 mEq per liter) but in places near discharge of industrial effluents or areas where gypsum-rich geological conditions are even higher than 400 11 mg / L (11 mEq / L). The high concentration of sulfate ions at the stations indicates the existence of gypsum formations along the river path and the main reason for the

entry of agricultural water and geological formations within the reservoir dams. Also, it has a direct relationship with the amount of discharge that reduced in the river in low flow rate months. Chlorine is also one of the constituents that its concentration increases in water resources in proportion to the growth of the human community. Its sources can be geological layers, industrial effluents (plants), pesticides and agricultural activities, and even atmospheric sources such as rainfall. Regarding the fatal effects of high concentrations of chlorine on aquatic life as well as the carcinogenic effects of water on humans, chlorine has become one of the important indices of surface water quality evaluation.

According to the results and studies conducted on the evaluation of the geological formation of the area, which is mainly Gachsaran formation, as well as the activities of the riverfront agricultural lands, in general these factors can have different effects during the pre- and post-reservoir periods on the quality of river water flow so that before constructing reservoirs due to atmospheric conditions in different seasons and high outcrop (exposure) of geological formations affected by these atmospheric conditions such as rainfall at basin level runoff is produced due to formations and flow rate increased as the downstream flow increased the outcrop of the layers increased and river water quality reduced. Therefore, under climate and seasonal conditions water quality reduced and the concentration of the studied qualitative parameters increased. However, during post-construction and filling of the reservoir, the dam reservoir location can cause involvement of the formation with the reservoir and combined with different qualities caused by atmospheric precipitation and snowmelt, thus after the dam construction formations cannot have much relationship with the flow rate because it is discharged from the reservoir due to the downstream needs. Also, regarding agricultural activities and their effects on the river by comparing the concentration values of qualitative parameters under the station conditions, water quality changes under the influence of Behbahan irrigation and drainage network on the river margin are higher than before the dam construction, because after filling Marun Dam, the agricultural lands and activities are developed and the agricultural drainage affects the river, increasing the concentration of water quality parameters in the river. Therefore, it can be concluded that water quality characteristics of Marun and Roudzard rivers in the studied basin have been affected by the constructed reservoir dams.

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