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Hydro-Geochemistry of Qare-Sou Catchment and Gorgan Gulf, Iran: Examining Spatial and Temporal Distribution of Major Ions and Determining the River's Hydro-Chemical Type

Milad Kurdi, Hadi Farhadian, Teymour Eslamkish

Abstract**—**This study examined the hydro-geochemistry of Qare-Sou catchment and Gorgan Gulf in order to determine the spatial distribution of major ions. In this regard, six hydrometer stations in the catchment and four stations in Gorgan Gulf were chosen and the samples were collected. Results of spatial and temporal distribution of major ions have shown similar variation trends for calcium, magnesium, and bicarbonate ions. Also, the spatial trend of chloride, sulfate, sodium and potassium ions were same as Electrical Conductivity (EC) and Total Dissolved Solid (TDS). In Nahar Khoran station, the concentrations of ions were more than other stations which may be related to human activities and the role of geology. The Siah Ab station's ions showed high concentration which is may be related to the station's close proximity to Gorgan Gulf and the return of water to Qare-Sou River. In order to determine the interaction of water and rock, the Gibbs diagram was used and the results showed that water of the river falls in the rock range and it is affected more by weathering and reaction between water and stone and less by evaporation and crystallization. Assessment of the quality of river water by using graphic methods indicated that the type of water in this area is Ca-HCO_3-Mg. Major ions concentration in Qare-Sou in the universal average was more than but not more than the allowed limit by the World Health Organization and China Standard Organization. A comparison of ions concentration in Gorgan Gulf, seas and oceans showed that the pH in Gorgan Gulf was more than the other seas but in Gorgan Gulf the concentration of anion and cation was less than other seas.

Keywords**—**Hydro-geochemistry, Qare-Sou River, Gorgan Gulf, major ions, Gibbs diagram, water quality, graphical methods.

I. Introduction

WATER quality is a term that is used for describing biological, chemical and physical characteristics of water regarding the water proportion of useful applications [1]. Since the 1930s, river water quality has been one of the main topics of water environmental sciences [2]. The creation of strategies for preventing, control and removing kinds of biological and chemical pollutions in different places of rivers and refineries leads to the promotion of water quality and consumers' health care [3]. Today one of the essential strategies for coping with water shortage is conservation of fresh water resources. Thus, developing strategies of water resources quality management in Iran, which has been placed in the dry belt of the Middle-East, is the most important action for water policy makers. The most important element is to maintain the water resources quality for drinking from the production point to consumption point [4].

Rivers are the most important water resources that play an important role in determining the water required for agriculture, drinking and industry. In a study which was done by Kashefi Asl and Zaeimm dar [5] in Jajrood River for water quality management, they concluded that the density of salts and pollution of the river increased during successive years and the pollution source of house sewage and field water-seep were determined.

Qare-Sou catchment with an area of 1637.65 square kilometers is located in the northern slope of the Alborz Mountains and joins Gorgan Gulf located in the south of the Caspian Sea. Regarding the ecological and environmental importance of this river and the result of accepting human daily activities which lead to urban, industrial and agricultural sewage and industrial wastewater, this valuable water ecosystem has been exposed to risks of pollutants via human and natural resources [6]. Qare-Sou River is exposed to the most amount of urban and industrial pollutions especially agricultural pollution because of fertile farmlands and optimal usage of the river's water for human activities particularly in agriculture and having twice the amount of cultivation each agriculture year, having suitable climate and concentration of population in the urban and rural residential areas and establishment of industrial units [7]. Water of this river is used in agriculture along the way. Thus, quality of the water of this river plays an important role in agricultural and economical aspects. The quality of water is largely controlled by discharge-recharge pattern, nature of host and associated rocks as well as contaminated activities [8].

Today, regarding the shortage of potable water resources, increasing population and consequently increased demand, the examination of quality and hydro-geochemistry parameters is a momentous issue. Data and information of hydrometer stations constructed along the river were used for monitoring the water quality parameters of the river. This study aimed to examine the water quality and determine the chemical type of

M. Kurdi is with the Department of Mining and Metallurgical Engineering, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran (e-mail: milad_kurdi@aut.ac.ir).
H. Farhadian is with the Department of Mining, Faculty of Engineering, University of Birjand, Birjand, Iran (e-mail: farhadian@birjand.ac.ir).
T. Eslamkish is with the Department of Mining and Metallurgical Engineering, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran (corresponding author; e-mail: t.eslamkish@aut.ac.ir).

Qare-Sou River and Gorgan Gulf and consider temporal and spatial distribution of major ions and effective important quality variables by exploiting graphical methods such as Piper, Estif and Schoeller diagrams and compare the water quality of the Qare-Sou River and Gorgan Gulf with universal average values.

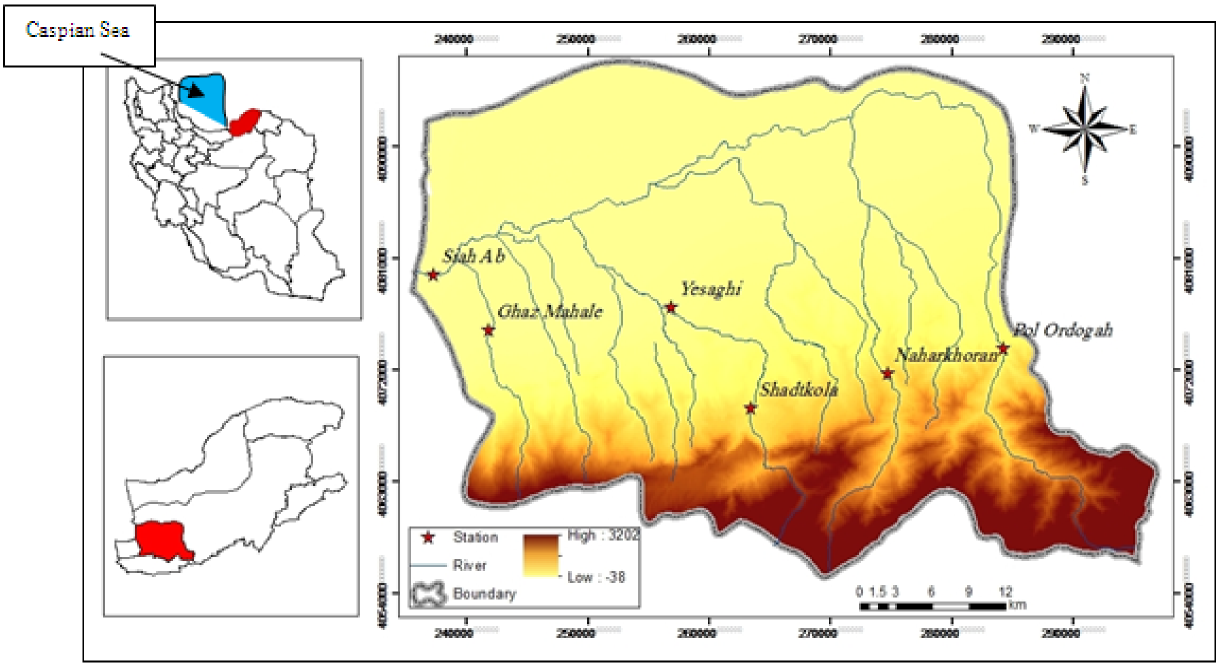

Fig. 1 Qare-Sou catchment territory, North of Iran [10]

Fig. 2 The aerial map of Gorgan gulf

Fig. 3 Position of sampling stations in the study area

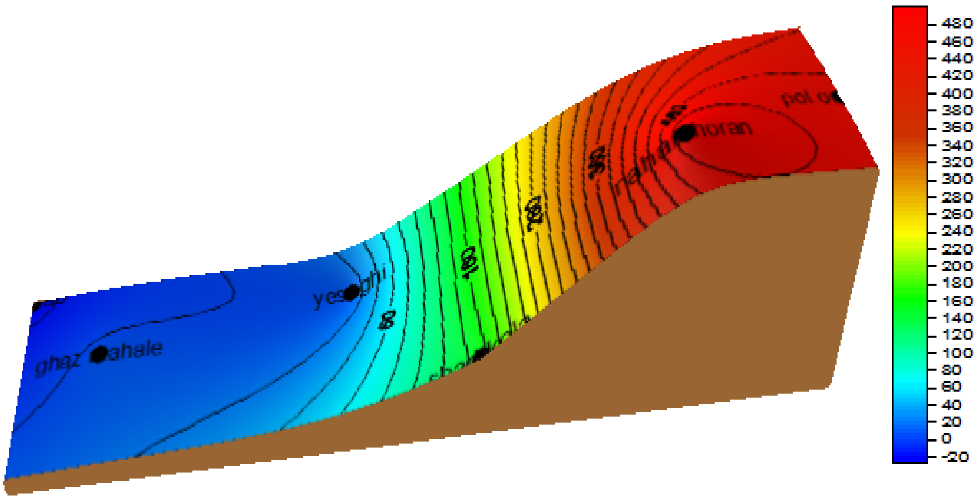

Fig. 4 Topography of sampling stations

TABLE I
CHARACTERISTICS OF HYDROMETRIC STATIONS

Station	River	Altitude	X	Y
Naharkhoran	Ziarat	500	274664	4071765
Shadtkola	Shastkola	150	263389	4068935
Siah Ab	Qare-Sue	-26	237291	4079672
Pol Ordogah	Garmabdasht	465	284254	4073732
Ghaz Mahale	Kurdkoy	5.5	241821	4075295
Yesaghi	Yesaghi	6	256827	4077110

TABLE II
ION MEASUREMENT METHODS

Methods	Ions
Atomic absorption	Na,K
E.D.T.A	Ca,Mg
Mohr method	Cl
Gravimetric	SO_4
Acid-base titration	CO_3
Alkalinity measurements	HCO_3

II. Materials & Methods

A. Study Area

Qare-Sou River (Fig. 1) has an area of 1637.65 km along the north mountainside of Alborz Mountain which is regarded as the most important nutrients of Qare-Sou River. From the west, it is extended to Gorgan and from the south reaches the Alborz Mountains, finally it ends in a village called Qare-Sou with a length of 89 km in the Caspian Sea [9]. The bed of Qare-Sou River is different with source and estuary which follows from geological status of this region and with respect to morphology the river is divided into mountain and level land [7]. Gorgan Gulf is the greatest gulf of Caspian Sea and its maximum depth is 4m. The total area of Gorgan Gulf is 400 km^2, its shape is triangle and its highest width is 12 km (Fig. 2).

B. Sampling and Analysis

Six hydrometer stations were used for the sampling of Qare-Sue (Table I, Fig. 3). Topography of the stations is shown in Fig. 4. For examination of Qare-sue's water quality during 2010, it was sampled in ten stages in different seasons. For examination of Gorgan Gulf's water quality, it was sampled from four points (Fig. 3). Also in each of the sampling stations in addition to sampling, physical and chemical parameters of water were measured by using a water checker portable machine (hatch brand). To determine ions, the mentioned methods in Table II were applied.

III. Discussion

A. Major Ions

The waters typically contain various ions, whose concentration variations determine its quality and applications. For example, a high concentration of Cl in the water can reduce water quality and it negatively impacts on the growth of the plants [11], [12]. The results of ions rate and examination of Anions and Cations distribution are shown in Table III in different dates of sampling in six hydrometric stations and Fig. 5 shows temporal and spatial Trends of change in different stations.

The trends of change of calcium, magnesium, and bicarbonate ions, which were more than others, were similar and the trend of chloride, sulfate, sodium, and potassium ions followed EC and TDS trends. In Nahar Khoran station, ions have higher density than other stations because of human activities and role of geology. Siah Ab station's ions have higher density because of being close to Gorgan Gulf and the return of water to Qare-Sou River.

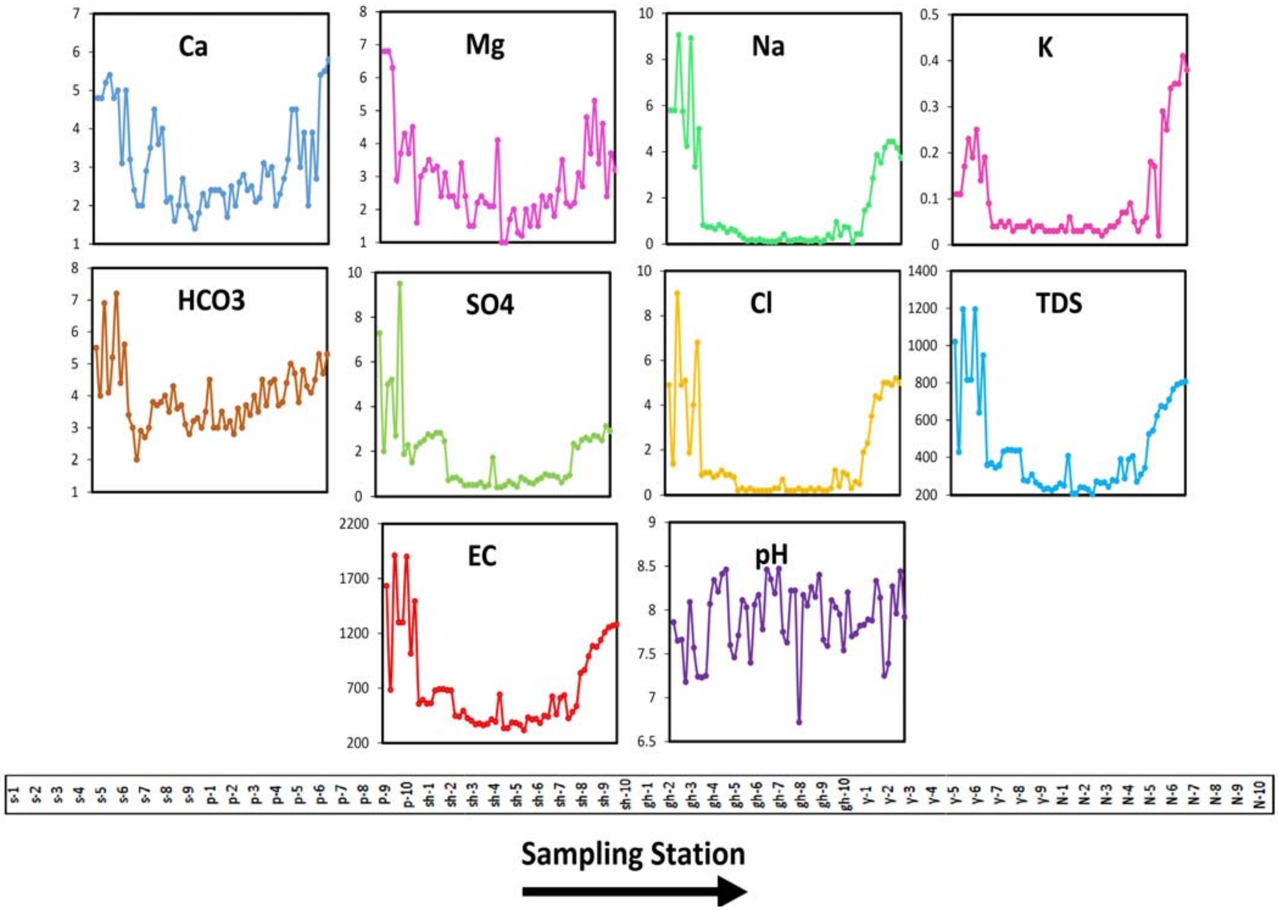

Fig. 5 Temporal and spatial change trends of ions in the sampling stations

TABLE III
THE NUMBER OF ANIONS AND CATIONS PRESENT IN THE QARE-SOU CATCHMENT

	s-1	s-2	s-3	s-4	s-5	s-6	s-7	s-8	s-9	.
Ca	4.8	4.8	5.2	5.4	4.8	5	3.1	5	3.2	.
Mg	6.8	6.8	6.3	2.9	3.7	4.3	3.7	4.5	1.6	.
Na	5.8	5.8	9.06	5.75	4.26	8.92	3.36	4.99	0.83	.
K	0.11	0.11	0.17	0.23	0.19	0.25	0.14	0.19	0.09	.
HCO_3	5.5	4	6.9	4.1	5.2	7.2	4.4	5.6	3.4	.
SO_4	7.28	2	4.99	5.2	2.7	9.5	1.87	2.28	1.53	.
Cl	4.9	1.4	9	4.9	5.1	1.87	4	6.8	0.9	.
TDS	1020	428	1195	815	816	1195	640	947	360	.
EC	1633	685	1910	1300	1300	1900	1016	1493	558	.
pH	7.86	7.65	7.66	7.18	8.09	7.57	7.24	7.23	7.25	.
	p-1	p-2	p-3	p-4	p-5	p-6	p-7	p-8	P-9	p-10
Ca	2.4	2	2	2.9	3.5	4.5	3.6	4	2.1	2.2
Mg	3	3.2	3.5	3.2	3.3	2.4	3.1	2.4	2.4	2.1
Na	0.74	0.74	0.65	0.83	0.71	0.52	0.65	0.58	0.4	0.26
K	0.04	0.04	0.05	0.04	0.05	0.03	0.04	0.04	0.04	0.05
HCO_3	3	2	2.9	2.7	3	3.8	3.7	3.8	4	3.5
SO_4	2.2	2.37	2.5	2.75	2.66	2.82	2.82	2.45	0.73	0.83
Cl	1	1	0.8	0.9	1.1	0.9	0.9	0.8	0.2	0.3
TDS	369	347	358	431	440	438	435	437	281	276
EC	593	559	563	678	690	691	682	679	448	440
pH	8.07	8.34	8.21	8.41	8.46	7.6	7.46	7.71	8.11	8.03
	sh-1	sh-2	sh-3	sh-4	sh-5	sh-6	sh-7	SH-8	sh-9	sh-10
Ca	1.6	2	2.7	2	1.7	1.4	1.8	2.3	2	2.4
Mg	3.4	2.4	1.5	1.5	2.2	2.4	2.2	2.1	2.1	4.1
Na	0.14	0.19	0.14	0.21	0.14	0.11	0.11	0.11	0.19	0.42
K	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.06
HCO_3	4.3	3.6	3.7	3.1	2.8	3.2	3.3	3	3.5	4.5
SO_4	0.85	0.71	0.5	0.52	0.52	0.52	0.62	0.44	0.52	1.71
Cl	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.7
TDS	310	268	252	231	236	226	240	262	251	407
EC	493	427	403	370	377	362	375	415	393	642
pH	7.4	8.06	8.17	7.78	8.46	8.35	8.19	8.47	7.75	7.63
	gh-1	gh-2	gh-3	gh-4	gh-5	gh-6	gh-7	gh-8	gh-9	gh-10
Ca	2.4	2.4	2.3	1.7	2.5	2	2.6	2.8	2.4	2.5
Mg	1	1	1.7	2	1.3	1.2	2	1.5	2.1	1.5
Na	0.14	0.14	0.19	0.23	0.16	0.13	0.14	0.23	0.1	0.16
K	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.02	0.03	0.04
HCO_3	3	3	3.5	3	3.2	2.8	3.6	3	3.7	3.4
SO_4	0.42	0.42	0.5	0.67	0.56	0.44	0.85	0.75	0.62	0.58
Cl	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.3	0.2
TDS	209	209	242	240	229	205	273	265	268	245
EC	335	335	387	383	366	316	432	414	420	382
pH	8.22	8.22	6.72	8.17	8.05	8.26	8.15	8.4	7.66	7.59
	y-1	y-2	y-3	y-4	y-5	y-6	y-7	y-8	y-9	.
Ca	2.1	2.2	3.1	2.8	3	2	2.3	2.7	3.2	.
Mg	2.4	2.1	2.4	1.8	2.6	3.5	2.2	2.1	2.2	.
Na	0.4	0.26	0.96	0.39	0.74	0.71	0.1	0.44	0.44	.
K	0.04	0.05	0.07	0.07	0.09	0.05	0.03	0.05	0.06	.
HCO_3	4	3.5	4.5	3.7	4.4	4.5	3.7	3.8	4.4	.
SO_4	0.73	0.83	1	0.94	0.94	0.87	0.64	0.85	0.96	.
Cl	0.2	0.3	1.1	0.4	1	0.9	0.3	0.6	0.5	.
TDS	281	276	389	290	388	406	272	311	346	.
EC	448	440	624	461	610	635	426	483	536	.
pH	8.11	8.03	7.95	7.54	8.2	7.7	7.73	7.82	7.83	.
	N-1	N-2	N-3	N-4	N-5	N-6	N-7	N-8	N-9	N-10
Ca	4.5	4.5	3	3.9	2	3.9	2.7	5.4	5.5	5.8
Mg	3.1	2.7	4.8	3.7	5.3	3.4	4.6	2.4	3.7	3.2
Na	1.46	1.7	2.85	3.86	3.53	4.18	4.44	4.44	4.18	3.74
K	0.18	0.17	0.02	0.29	0.25	0.34	0.35	0.35	0.41	0.38
HCO_3	5	4.7	3.8	4.8	4.3	4.1	4.5	5.3	4.7	5.3
SO_4	2.33	2.16	2.5	2.6	2.5	2.7	2.66	2.49	3.12	2.91
Cl	1.9	2.3	3.5	4.4	4.3	5	5	4.9	5.2	5
TDS	525	544	622	675	669	709	765	790	800	806
EC	837	866	990	1085	1076	1139	1210	1254	1270	1282
pH	7.89	7.88	8.33	8.14	7.25	7.39	8.27	7.96	8.44	7.92

Ions based on meo/L, TDS based on mg/Land the EC based on μmho/cm.

B. Pattern of Major Ions Distribution

Pattern of major ions distribution shows the effect of human activities and different stones on water quality [13]. Temporal and spatial distribution of different ions is shown in Figs. 6-12.

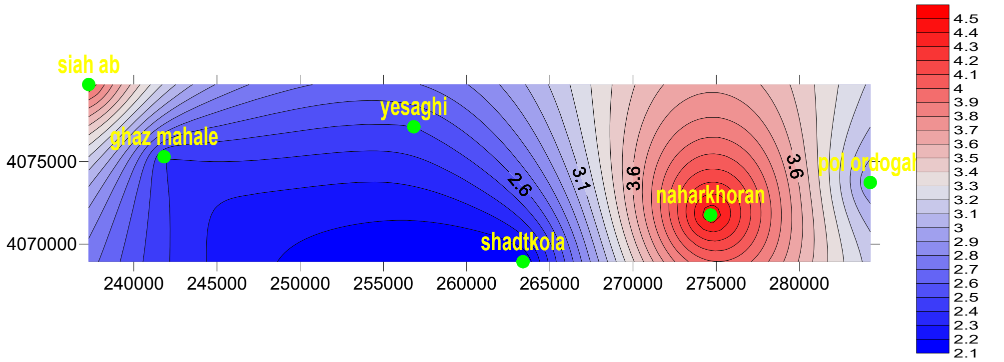

Fig. 6 Distribution of Calcium in Qare-Sou

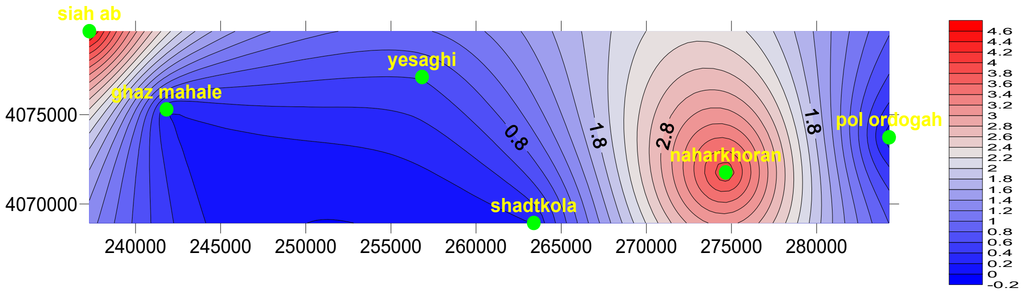

Fig. 7 Distribution of Chlorite in Qare-Sou

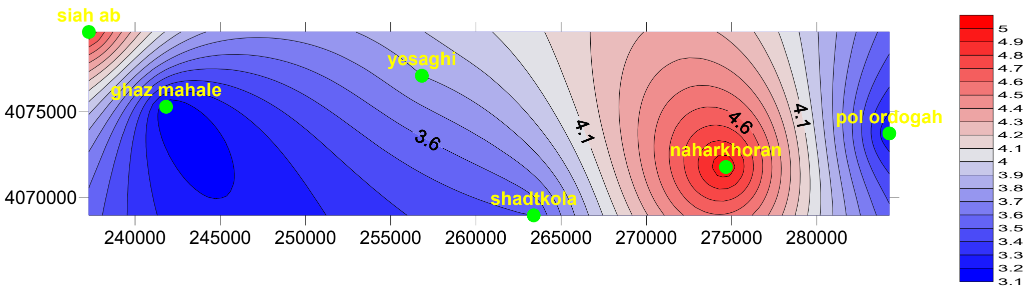

Fig. 8 Distribution of Bicarbonate in Qare-Sou

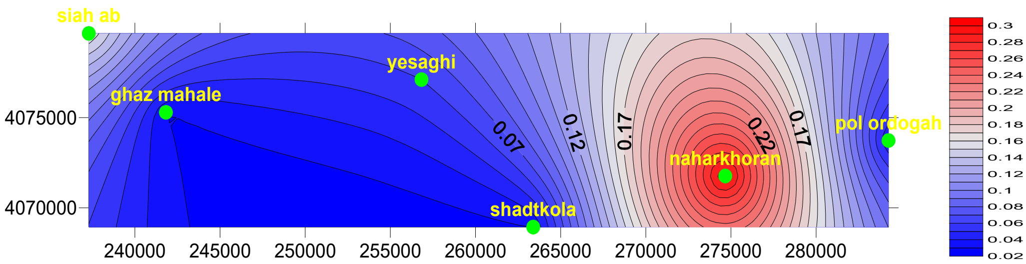

Fig. 9 Distribution of Potassium in Qare-Sou

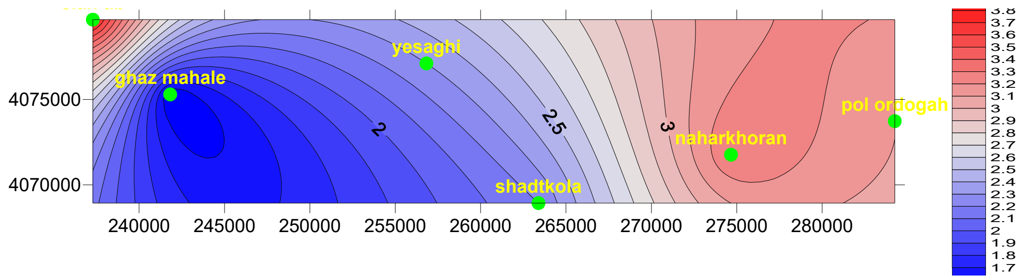

Fig. 10 Distribution of Magnesium in Qare-Sou

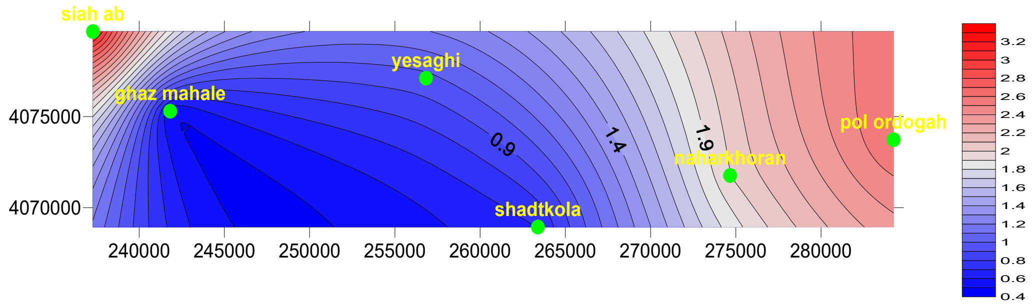

Fig. 11 distribution of Sulfate in Qare-Sou

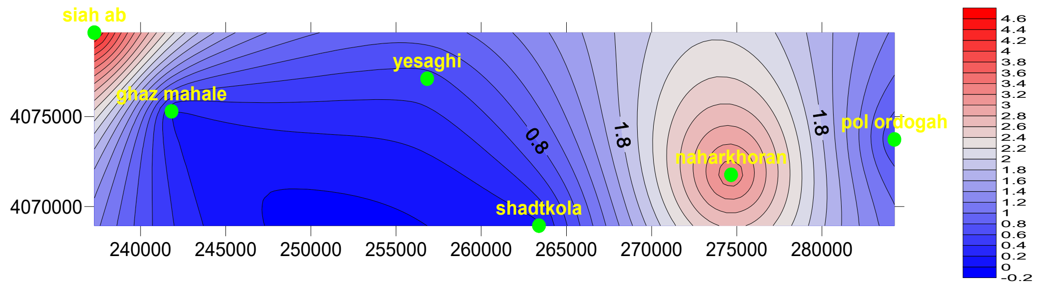

Fig. 12 Distribution of odium in Qare-Sou

As it is shown in Figs. 6-12, the rate of ions in Naharkhoran and Siah Ab stations are higher than other stations and there is no significant change in other stations.

C. Mechanism of Major Ions Chemistry Control

Materials carried by rivers could have different origins such as physical, chemical and biological origins. The major sources of dissolved salts in a river include sea salts carried by atmosphere and deposited in the river (cyclic salts); weathering of Sulfate, Carbonate minerals, evaporate minerals and human activities can be the main reasons which will be discussed later.

- Salt Cycle

The amount of chloride ion in surface water decreases with increased distance from the sea without the interference of terrestrial and ground origin [14]. However, a contrast has also been made by Chen et al. in the Changjiang River [13]. In this study, as it is shown in Fig. 5, the Chloride ion decreases with increasing distance from the sea but it increased significantly in Nahar khoran station, its origin probably belongs to human activities or Evaporitic weathering.

- Weathering

In 1970, Gibbs presented a diagram in which TDS is drawn against weight ratio Na/(Na+Ca) that is used for determining the relative significance of three major and natural mechanisms including sedimentation resulting from atmospheric precipitation, evaporation, crystallization and stones weathering controlled by water chemistry [15]. Plot of TDS versus Na/ (Na+Ca) for Qare-Sou (Fig. 13) determined that the data of this river is placed in stone range and is more affected by weathering of reaction between water and stone and less affected by evaporation and crystallization.

- Human Activities

Chemistry of major ions could be affected by human activities [16]. Recently, this effect has been increased regarding the boom of industrial and agricultural activities. In this study, in Nahar khoran station an unusual increase of ions concentration was observed which is probably caused by human activities.

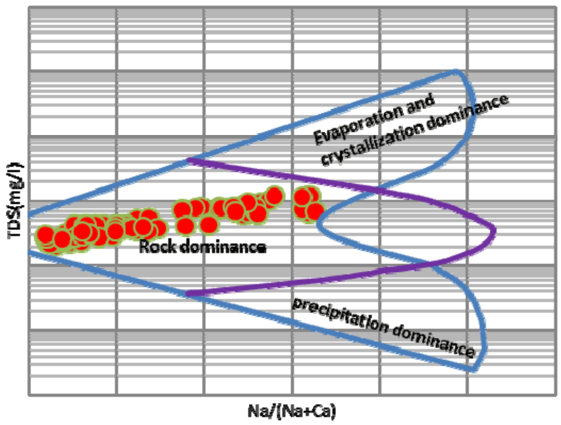

Fig. 13 Gibbs diagram for the Qare Sou Catchment

D. Water Quality

For the examination of the water quality of this river, graphical methods were used. Graphical methods have two aims for showing the analysis of water quality, first illustrating the data for analysis, and then discovering the relationship and existing order between data [17].

- Piper Diagram

Piper diagram is a diagram specialized in water. By using this diagram, the type of water can be determined. Determining the type of water is done with regard to focus point [18]. This diagram is more useful for recognition of the relationship between ions among samples than other graphical methods [19]. Piper diagram of Qare sou is shown in Fig. 14.

- Durov Diagram

This diagram is actually the opened form of Piper diagram in which, in addition to the aforementioned, TDS, pH was added for the examination of water quality changes. Durvo diagram related to Qare-sou catchment is shown in Fig. 15.

- Schoeller Diagram

This diagram is used for further examination and analysis of the water sample for drinking consumption. In Fig. 16 the Schoeller diagram for Qare-sou is shown.

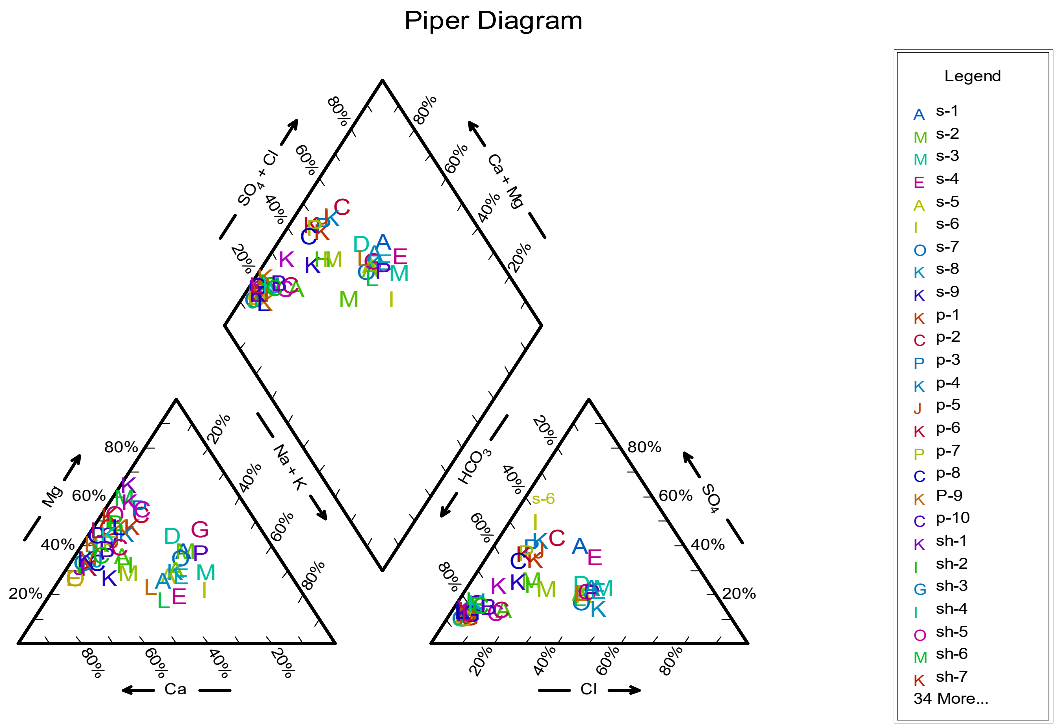

Fig. 14 Piper diagram of Qare-sou catchment.

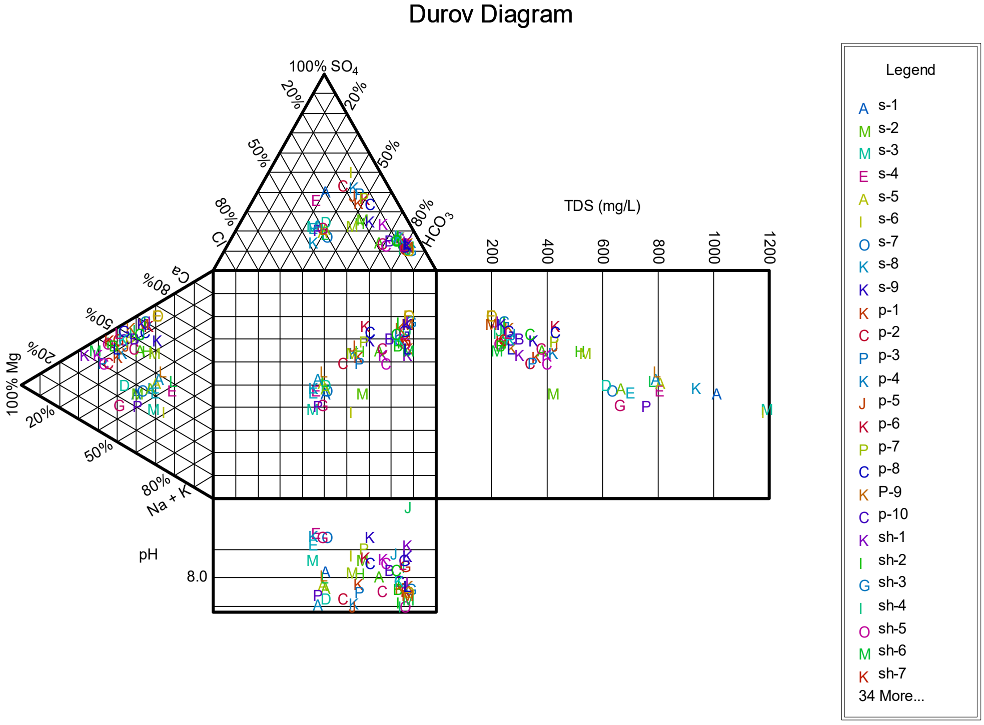

Fig. 15 Durov diagram of Qare-sou catchment

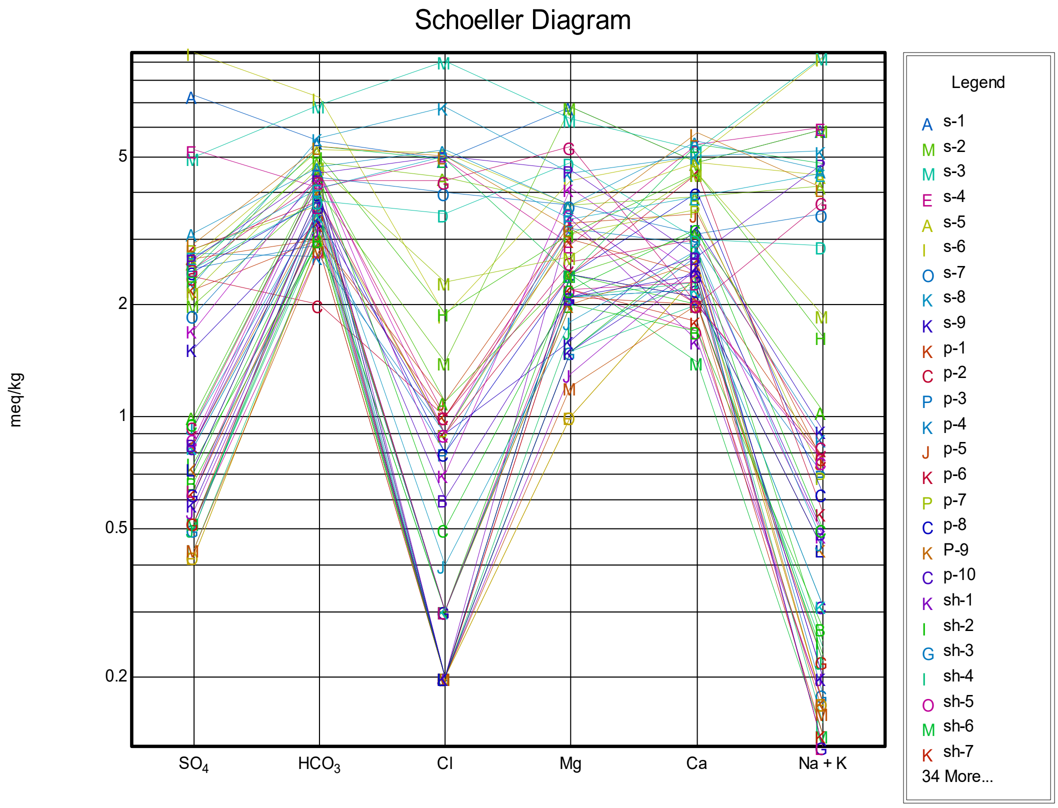

Fig. 16 Schoeller diagram of Qare-sou catchment

TABLE IV
RESULTS OF WATER QUALITY OF QARE-SOU (WATER TYPE, SATURATION)

sample	Water Type	Total hardness(mg/L)	Calcite Saturation	Aragonite Saturation	Partial Pressure of CO2(atm)
s1	Mg-SO4	580.48	0.9368	0.7725	0.004161
s2	Mg-HCO3	580.48	0.6214	0.4571	0.004928
s3	Na-Cl	575.47	0.8554	0.6911	0.008122
s4	Na-SO4	415.33	0.1689	0.004578	0.01367
s5	Ca-HCO3	425.34	1.189	1.025	0.002387
s6	Na-SO4	465.38	0.7679	0.6036	0.01036
s7	Mg-Cl	340.28	0.06385	-0.1005	0.01321
s8	Ca-Cl	475.38	0.3292	0.1649	0.01689
s9	Ca-HCO3	240.19	0.0222	-0.1421	0.01021
p1	Mg-HCO3	270.22	0.6913	0.527	0.001487
p2	Mg-SO4	260.22	0.7118	0.5475	534.9×10-6
p3	Mg-HCO3	275.23	0.7364	0.5721	0.00104
p4	Mg-SO4	305.25	1.059	0.8942	609.6×10-6
p5	Ca-HCO3	340.28	1.229	1.064	601×10-6
p6	Ca-HCO3	345.27	0.5649	0.4006	0.005343
p7	Ca-HCO3	335.27	0.3099	0.1456	0.007053
p8	Ca-HCO3	320.26	0.6353	0.471	0.004207
p9	Mg-HCO3	225.18	0.8227	0.6584	0.001831
p10	Ca-HCO3	215.17	0.7081	0.5438	0.001926
sh1	Mg-HCO3	250.21	-0.005511	-0.1698	0.00947
sh2	Mg-HCO3	220.18	0.7094	0.5451	0.00185
sh3	Ca-HCO3	210.17	0.9674	0.8031	0.001483
sh4	Ca-HCO3	175.14	0.3754	0.2111	0.003019
sh5	Mg-HCO3	195.16	0.9436	0.7793	577.8×10-6
sh6	Mg-HCO3	190.16	0.807	0.6427	851.4×10-6
sh7	Mg-HCO3	200.16	0.7653	0.601	0.001266
sh8	Ca-HCO3	220.18	1.108	0.9436	602.8×10-6
sh9	Mg-HCO3	205.17	0.3869	0.2226	0.003626
sh10	Mg-HCO3	325.27	0.4073	0.243	0.005954
gh1	Ca-HCO3	170.13	0.8907	0.7264	0.001081
gh2	Ca-HCO3	170.13	0.8907	0.7264	0.001081
gh3	Ca-HCO3	200.16	-0.7103	-0.8747	0.02853
gh4	Mg-HCO3	185.15	0.6825	0.5182	0.001207
gh5	Ca-HCO3	190.15	0.7569	0.5926	0.001692
gh6	Ca-HCO3	160.13	0.8255	0.6612	921.8×10-6
gh7	Ca-HCO3	230.19	0.9106	0.7463	0.001505
gh8	Ca-HCO3	215.17	1.122	0.9572	708.2×10-6
gh9	Ca-HCO3	225.18	0.3906	0.2263	0.004664
gh10	Ca-HCO3	200.16	0.3065	0.1422	0.005016
Y1	Mg-HCO3	225.18	0.8227	0.6584	0.001831
Y2	Ca-HCO3	215.17	0.7081	0.5438	0.001926
Y3	Ca-HCO3	275.22	0.8586	0.6942	0.00293
Y4	Ca-HCO3	230.18	0.3249	0.1606	0.006044
Y5	Ca-HCO3	280.23	1.088	0.9241	0.001622
Y6	Mg-HCO3	275.23	0.4151	0.2508	0.005137
Y7	Ca-HCO3	225.18	0.4445	0.2802	0.003995
Y8	Ca-HCO3	240.19	0.609	0.4446	0.003342
Y9	Ca-HCO3	270.22	0.7471	0.5828	0.003766
N1	Ca-HCO3	380.3	0.9699	0.8055	0.003664
N2	Ca-HCO3	360.29	0.9357	0.7714	0.003528
N3	Mg-HCO3	390.32	1.11	0.9453	0.001016
N4	Ca-HCO3	380.31	1.125	0.9608	0.001976
N5	Mg-Cl	365.31	-0.1346	-0.2989	0.0126
N6	Na-Cl	365.3	0.2819	0.1176	0.008939
N7	Mg-Cl	365.3	1.066	0.9019	0.001373
N8	Ca-HCO3	390.31	1.122	0.9577	0.003278
N9	Ca-Cl	460.37	1.548	1.384	960.3×10-6
N10	Ca-HCO3	450.36	1.104	0.9401	0.003574

E. Results of Quality of River Water

Results of water quality of Qare-sou were obtained by AQ.qA software which is shown in Tables IV and V. As it is shown in Table IV, various types are illustrated regarding water type in different dates of sampling and it indicates that we cannot assign a specific type to it and the type of water depends on carried materials in the upstream and added materials to the river, but according to the examination of statistics for determining water type, we could recognize the type of water as Ca-HCO_3-Mg. It is clear that the hardness of water in Naharkhoran and Siah Ab stations are more than other stations. In spite of usage of Qare-sou water for agriculture, results of Qare-sou water quality examination indicate that water in Nahar khoran Siah Ab stations is not useful for irrigation and agriculture but the rate of damage in other stations is less and can be used; however, in the long run it may cause some damages to farmlands. In ions examination, Chloride and Sodium ions showed a relatively good correlation (Fig. 17) and this can be a reason for the high salinity of Qare-sou and inappropriateness for agriculture.

TABLE V
RESULTS OF WATER QUALITY OF QARE-SOU (FOR IRRIGATION AND AGRICULTURE)

Sample	Salinity Hazard	Sodium Adsorption Ratio	Magnesium Hazard
s1	High	2.41	58.6
s2	Medium	2.41	58.6
s3	High	3.78	54.8
s4	High	2.82	34.9
s5	High	2.07	43.5
s6	High	4.14	46.2
s7	High	1.82	54.4
s8	High	2.29	47.4
s9	Medium	536×10-3	33.3
p1	Medium	450×10-3	55.6
p2	Medium	459×10-3	61.5
p3	Medium	392×10-3	63.6
p4	Medium	475×10-3	52.5
p5	Medium	385×10-3	48.5
p6	Medium	280×10-3	34.8
p7	Medium	355×10-3	46.3
p8	Medium	324×10-3	37.5
p9	Medium	267×10-3	53.3
p10	Medium	177×10-3	48.8
sh1	Medium	88.5×10-3	68
sh2	Medium	128×10-3	54.5
sh3	Medium	96.6×10-3	35.7
sh4	Medium	159×10-3	42.9
sh5	Medium	100×10-3	56.4
sh6	Medium	79.8×10-3	63.2
sh7	Medium	77.8×10-3	55
sh8	Medium	74.2×10-3	47.7
sh9	Medium	133×10-3	51.2
sh10	Medium	233×10-3	63.1
gh1	Medium	107×10-3	29.4
gh2	Medium	107×10-3	29.4
gh3	Medium	134×10-3	42.5
gh4	Medium	169×10-3	54.1
gh5	Medium	116×10-3	34.2
gh6	Medium	103×10-3	37.5
gh7	Medium	92.3×10-3	43.5
gh8	Medium	157×10-3	34.9
gh9	Medium	66.7×10-3	46.7
gh10	Medium	113×10-3	37.5
Y1	Medium	267×10-3	53.3
Y2	Medium	177×10-3	48.8
Y3	Medium	579×10-3	43.6
Y4	Medium	257×10-3	39.1
Y5	Medium	442×10-3	46.4
Y6	Medium	428×10-3	63.6
Y7	Medium	66.7×10-3	48.9
Y8	Medium	284×10-3	43.7
Y9	Medium	268×10-3	40.7
N1	High	749×10-3	40.8
N2	High	896×10-3	37.5
N3	High	1.44	61.5
N4	High	1.98	48.7
N5	High	1.85	72.6
N6	High	2.19	46.6
N7	High	2.32	63
N8	High	2.25	30.8
N9	High	1.95	40.2
N10	High	1.76	35.6

With a comparison of ion concentration of Qare-sou and standards and other rivers (Table VI), it is observed that concentration of major ions in Qare-sou is more than the universal average but less than the allowed range determined by the World Health Organization and China Standard Organization. A comparison of the presented ions in the Gorgan Gulf, other seas and oceans (Table VII) showed that the rate of pH in the Gorgan Gulf is higher than other seas and the rate of acidity is less but the presented rate of Anion and Cation is less than other seas, and yet the introduced rate of carried materials and ions in Qare-sou which directly comes to Gorgan Gulf are higher than the universal average value of rivers.

F. Distribution of Major Ions in Natural Water

The distribution of major ions for Qare-sou and Gorgan Gulf in comparison to the results of distribution of major ions of other rivers and seas is shown in Figs. 18-22. In these figures, the chloride ion was considered as a major variable [20]. Results of examination of the relationship between Chloride and Calcium (Fig. 18) and the relationship between Chloride and Sodium (Fig. 20) showed that Gorgan Gulf is less than the minimum limit but Qare-sou is almost equal to the universal average of rivers. In the examination of the relationship between Chloride and Magnesium (Fig. 19), Chloride and Potassium (Fig. 20) and Chloride and Sulfate (Fig. 22), Gorgan Gulf is situated in the predicted range. Qare-sou is almost equal to the universal average but its rate of Sulfate is more than the universal average.

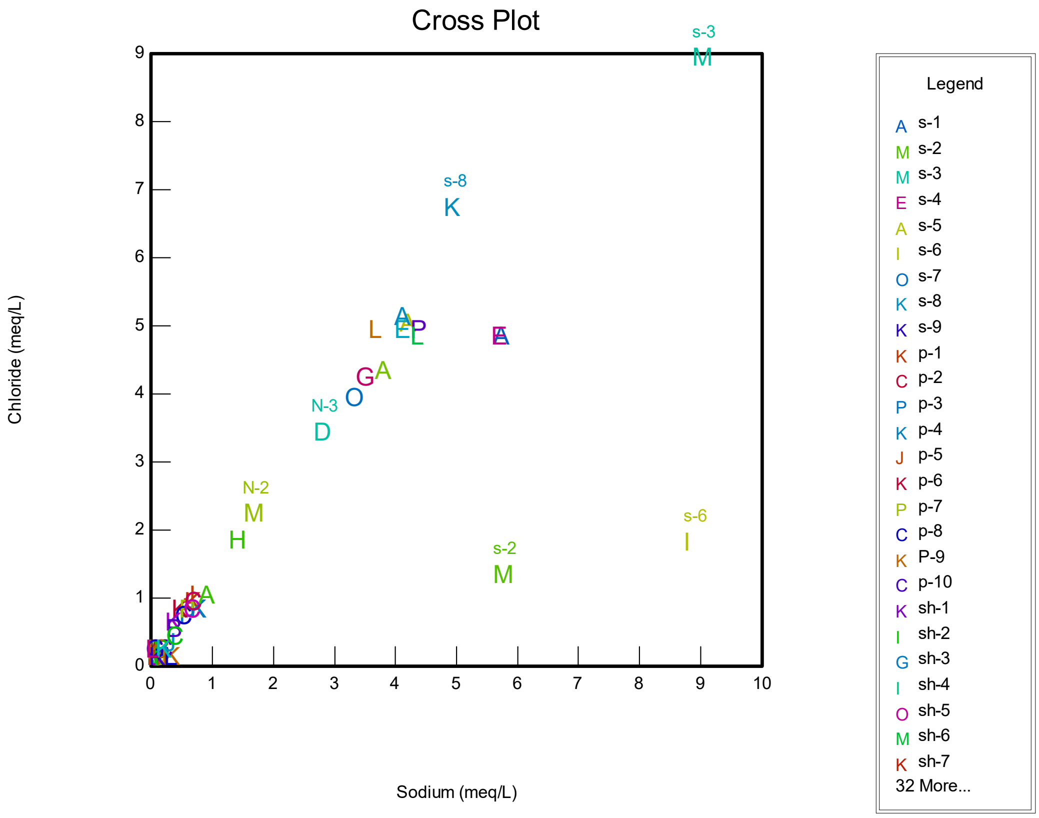

Fig. 17 Cross plot for Sodium and Chloride

TABLE VI
COMPARISON OF MAJOR IONS IN THE QARE-SOU RIVERS AND OTHER STANDARDS (IN PPM)

source	EC	TDS	pH	HCO_3	SO_4	Cl	Mg	Ca	Na+K
Global average [16]	-	-	-	30.5	4.8	3.9	2.4	8	4.4
Qaresou (this study)	1310	942	7.18-8.09	314	199	153	54	92	130
Chinese State Standard	-	1000	6.5–8.5	-	250	250	-	-	200
Max permissible [23]	1500	1000	6.5–9.2	600	600	600	150	250	450
Averages of world rivers [21]	-	-	-	58.4	11.2	7.8	4.1	15	8.6
Yellow River [13]	-	460	-	205	66.8	54.7	20.6	47	58.6
Amazon-Upper [14]	-	122	-	68	7	6.5	2.3	19.1	7.5

TABLE VII
COMPARISON OF IONS PRESENT IN THE GORGAN GULF AND THE OTHER SEAS (IN PPM)

SO_4	Cl	Mg	Ca	K	Na	pH	
2721	19353	1292	412	399	10768	8.2	Ocean [22]
3530	22043	1434	444	413	12589	7.9	Mediterranean [20]
3982	23911	2859	497	439	11274	8.1	Red Sea [20]
2721	27898	2142	636	661	14284	8	Persian Gulf [20]
1933	10733	479	251	60	2273	8.3	Gorgan gulf (this study)

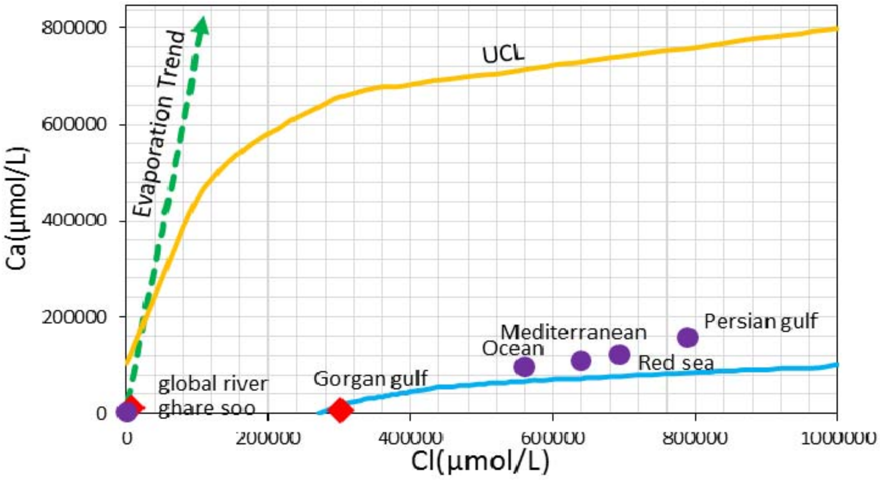

Fig. 18 Behavior of Gorgan gulf and Qare-sou River in the relationship between Calcium and the Chlorine in natural water

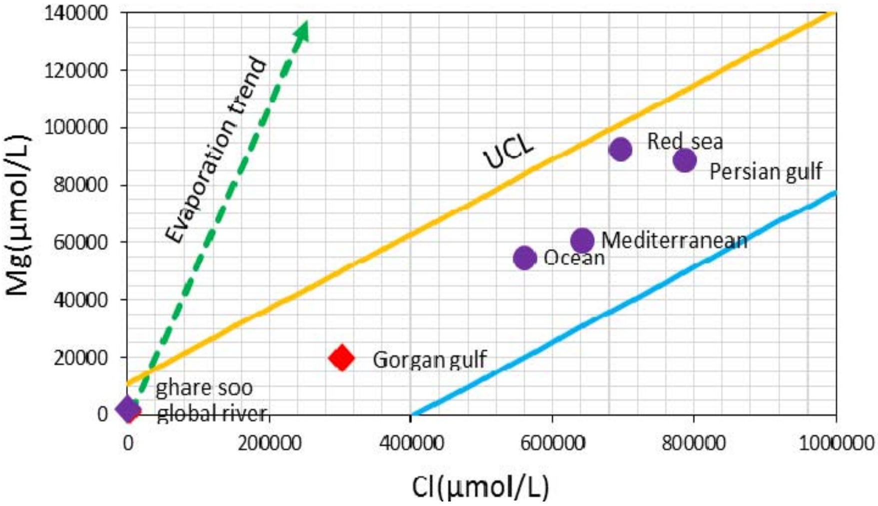

Fig. 19 Behavior of Gorgan gulf and Qare-sou River in the relationship between Magnesium and the Chlorine in natural water

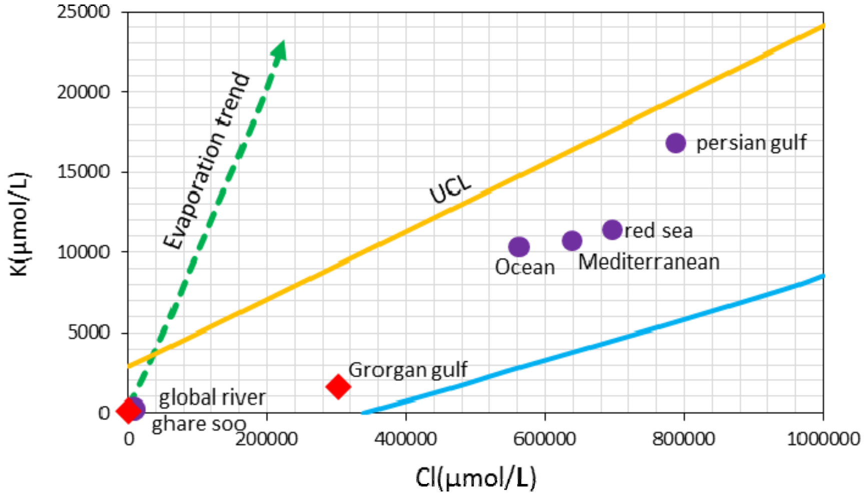

Fig. 20 Behavior of Gorgan gulf and Qare-sou River in the relationship between Potassium and the Chlorine in natural water

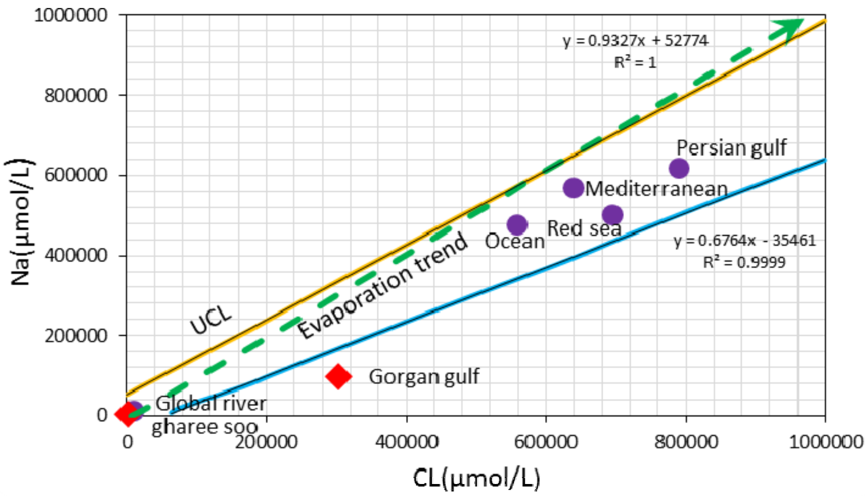

Fig. 21 Behavior of Gorgan gulf and Qare-sou River in the relationship between Sodium and the Chlorine in natural water

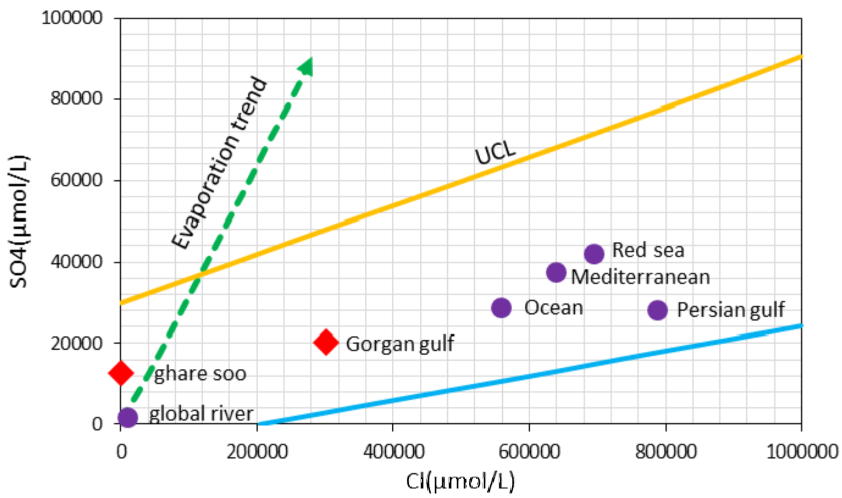

Fig. 22 Behavior of Gorgan gulf and Qare-sou River in the relationship between Sulfate and the Chlorine in natural water

IV. Conclusion

This study examined Qare-sou catchment and Gorgan Gulf as sensitive ecological areas environmental aspect. The change of similar in trends of calcium, magnesium, and bicarbonate ions, which were more than the others and trend of chloride, sulfate, sodium and potassium ions followed EC and TDS trends. In Nahar khoran and Siah Ab stations, the number of soluble solids and concentration of ions are higher than other stations. Siah Ab station showed significant difference in TDS and the rate of ions than other stations as a result of being near Gorgan Gulf and the return of water from the gulf to Qare-suo River. Nahar khoran station showed a higher concentration because of human activities and the role of geology of the region. Gibbs diagram for Qare-sou showed that the data of this river is placed in stone range and is more affected by weathering reaction between water and stone and less affected by evaporation and crystallization. Examination of the water quality of the river by using graphical methods with the help of AQ.qA showed the type of water as Ca-HCO_3-Mg. Results of Qare-sou water quality examination for agriculture and irrigation showed that water in Siah Ab and Nahar khoran stations is not useful for agriculture. However, in other stations the rate of damage was less and could be used for agricultural purposes, but in the long run it might cause damage to farmlands.

In examination of ions, chloride and sodium ions showed a relatively good correlation and this can be a reason for the high salinity of water of Qare-sou and its inappropriateness for agricultural usages. Concentration of major ions in Qare-sou was more than the universal average; however, it was less than the permitted range determined by the World Health Organization and China Standard Organization. A comparison of ions presented in Gorgan Gulf and other seas and oceans illustrated that the rate of pH in Gorgan Gulf is higher than other seas; however, the rate of Anion and Cation presented in it is less than other seas.

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