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Classification of surface waters and groundwater in terms of drinking, agriculture, and industry

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Abstract

In this study, samples were collected from Seydoon River, The Alaa River, Galal Duparan Well, and Seyed Behzad Seepage Well near Seydoon River during the water year 2021-2022 for evaluation by the Khuzestan Water and Power Organization. Following laboratory analysis, Schuler and Wilcox diagrams were created using Aqua and Chemistry software to classify and interpret the water from The Seydoon River, The Alaa River, Duparan Well, and Seyyed Behzad Seepage Well. The objective of this study is to assess and comprehend the water quality of the rivers and wells in the region for drinking, industrial, and agricultural purposes. Overall, the groundwater in the area is deemed to be of medium to unsuitable quality for drinking. The well water is are classified as extremely hard. Furthermore, The Seydoon River and The Alaa River exhibit lower hardness levels compared to the groundwater in the region. in accordance with the Wilcox diagram, both surface and groundwater in the area are suitable in sodium absorption ratio for agricultural use, but they do face salinity issues. The water from The Seydoon River is suitable for industrial purposes, while The Seydoon River, The Alaa River, and Seyyed Behzad Seepage Well water is drinkable, and the water from Duparan Well is prone to forming deposits.

Keywords: River; Groundwater; Software; Schuler; Wilcox

1. Introduction

Water is one of the substantial requirements in planning, developing, protecting, and controlling water resources. Improper and inefficient assessment and management of surface and groundwater could provide essential risks in the fields of human health and well-being, food security, industrial development, and the life of ecosystems [1–4]. During recent years, multiple studies have been presented to evaluate water quality for drinking uses with the Schoeller diagram, water quality indices, and GIS software in different parts of the world [5,6].

Natural processes including the mineral precipitation or dissolution, ionexchange, redox condition, residence time, and mixing between different water type may have a great impact on groundwater quality [7]. Anthropogenic activities such as rapid urbanization, industrialization, and intensive agricultural activities have caused a deterioration in water quality worldwide [8–11]. Groundwater contamination can be persisted a long time due to the low flow rate of groundwater in an aquifer and may involve major ions and trace elements [12].

In recent years, pressure on natural resources due to issues such as rapid population growth, increasing urbanization and industrialization of societies has become one of the basic challenges of human society. Groundwater is one of the important components of natural resources, which is considered a vital resource for the continuation of human survival from the perspective of providing drinking and agricultural water. Groundwater is one of the important sources of water supply in arid and semi-arid regions. Therefore, in addition to the quantity, its quality is also very important. In addition

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to humanity, fresh water, intensive development of agriculture, and underground water are the reasons for the increase in the demand for water supply from limited resources. This demand could, in the short term, lead to urbanization in Iran. Underground water sources make it difficult for Iran to provide adequate and high-quality water. It is worth mentioning that, due to the high dependence of the country on underground water resources, monitoring the quality of underground water resources should be considered as one of the basic steps of water resources management in Iran. In monitoring the quality of water sources, various parameters are checked, and the interpretation of the obtained results requires specialized knowledge. Therefore, in any environmental monitoring program, including water quality monitoring, reporting the results to managers and the general public is one of the important goals of that monitoring. Hydrochemistry is the primary determinant of domestic, irrigation or industrial water use. Groundwater quality is regulated by various variables, including climate, soil characteristics, lithology type, region topography and on-site human operations [13–15]. Surface water and groundwater play a significant role in offering drinking, irrigation and industrial water supply, with approximately 2.5 billion individuals worldwide depending on it [16]. Ashraf et al [17] conducted a study on the effects of groundwater and the quality of agricultural products in a GIS environment. They evaluated the levels of elements such as sodium, magnesium, potassium, chlorine, and electrical conductivity, quantifying them for agricultural use. According to their analysis, the overall condition of these elements in agriculture is desirable, but an increasing trend in their quantity is observed. Baalousha [18] investigated the nitrate monitoring network in the research entitled 'Evaluation of the Groundwater Quality Monitoring Network Using Vulnerability and Geo-statistical Maps'. The results of this research showed that a number of highly vulnerable areas have not been included in the monitoring network. It was also noted that the number of monitoring places and their distribution is insufficient. Some of the sampling places should be removed, and others should be added to the network. Madhu et al [19] conducted a study from 2015 to 2016 on the qualitative and chemical parameters affecting water in the Gujarat region of India. The results of analysis of water samples showed that the amount of lead increased in these areas compared to last year and the pesticides used have an effective role in water quality. Adimalla and Taloor [20] Geographical Information System (GIS) and Groundwater Quality Index (GWQI) method investigated the water quality in the hard formation. In this study, it was found that the concentration of nitrate in 50% of the samples of the water was higher than the World Health Organization standard and this limited the use of groundwater resources in agricultural products and drinking water products. In research by Aravinthasamy and et al [21], the limit of water quality was determined in hard structures for agricultural consumption. In the mentioned research, the traditional parameters of water quality, including pH, TDS and EC, were used. In the completed classification, it was shown that 72 percent of the groundwater samples have medium and high salinity, and in the areas facing salinity, only the cultivation of salinity-resistant products is recommended. Daudpota et al [22] investigated the quality of drinking water for the Sindh region of Pakistan. They examined physical factors such as smell, taste, and color, and chemical factors such as carbonates, magnesium, and potassium. The results of the mentioned research showed that the physical factors, the smell of the water samples were within the standard conditions, but the taste of the water was too much due to the chloride content and, on the other hand, the turbidity was more than acceptable. It was from the World Health Organization. However, in relation to water quality, most factors such as sodium, calcium and hardness were found to be higher than the permitted and determined values.

The HAV hydrogeology is characterized by a high groundwater content favoured by climate conditions. Two different kinds of aquifers are recognized: fissured and/or karstified aquifers in the Apennine units of the substratum and porous multilayer aquifers developed in the Quaternary succession [23]. Both types host high volumes of groundwater storage, with the richest amount located in Pre-Quaternary substratum aquifers usually subdivided in different hydrogeological complexes according to the structural, lithological, and permeability features [24]. These aquifers mainly occur in highly fractured limestones (Carbonate Platform) and in the underlying "Calcari con Selce" Fm (Lagonegro Units), both characterized by high permeability. Porous aquifers occur in gravelly-sandy permeable deposits of the Quaternary succession [25], where the larger groundwater body is recognized in a multilayered and semiconfined aquifer. Carbonate karst and fractured aquifers play a leading role in the overall hydrogeological system, since their groundwater resources supply the detrital-alluvial ones occurring at the valley bottom. Finally, most springs from HAV, generally showing an average flow rate greater than 5 l/s, are at the contact between permeable limestone and dolostone (Lagonegro Units and Carbonate Platform) and impermeable Plio-Pleistocene siliciclastic and recent alluvial-lacustrine deposits [26].

Considering the importance of water resources and the differences in water quality standards in its classification, knowing the quality of river water for drinking, industry, and agriculture is one of the most important measures for water resources management.

2. Materials and methods

2.1. Case Study

Khuzestan province, with an area of about 64236 Km^2, is located between 47 degrees and 41 minutes to 50 degrees and 39 minutes east from the Greenwich Meridian and 29 degrees and 58 minutes to 33 degrees and 4 minutes north from the equator, in the southwest of Iran. In geographical and hydrological conditions, Khuzestan province has the largest share of fresh water in the whole country . The only source of drinking, agricultural, and industrial water supply in the city of The Seydoon is from the two rivers of The Seydoon and Ala River in Baghmalek County.

2.1.1. Structural and tectonic geology

In terms of geological divisions, the studied area is located in the folded Zagros zone. On the other hand, the studied area based on the divisions made by the National Iranian Oil Company is located on a part called Izeh zone, which is a part of the folded belt of Zagros and from the north to the southern limit of the trusts, in the south to the northern limit of Dezful subsidence, in the east It is limited to the Kazaron fault and in the west along the assumed fault line, which is responsible for the bending of the upper river. The northern part of Izeh zone (Chaharmahal and Bakhtiari mountains) has structural differences from its southern part (Kahgiliyeh mountains), but it is not easy to separate them. In terms of its structural features, Izeh zone can be divided into 2 parts, the north-west of Izeh zone and the south-east of Izeh zone.

2.1.2. Geology and hydrogeology

Alaa River originates in the mountainous region located 70 Km east and northeast of Ramhormoz. This mountain mass includes Sard and Fon mountains (height 2939 meters), Mangesht (3613 m). The Seydoon River is one of the branches of the Alaa River, which originates from the eastern slopes of the 2598-meter mountain in the northeast of Ramhormoz. Then, by passing through a deep and mountainous valley, it reaches the city of Seydoon and joins Alaa in the village of Talaver. The catchment area of this river is mountainous and almost half of the area is covered by forest trees. The area of its catchment area is about 130 km^2.

Determination of the actual thickness of aquifer is important for calculation of groundwater flow discharge and aquifer transferability. The thickness of alluvium varies between 20 and 100 meters in different parts of the plain. The highest alluvial thickness is observed in Benshvar area and in the south of Seydoon with a depth of 100-75 meters. And the lowest in the Duparan area is about 25-35 meters. In general, along the river Seydoon towards the center of the plain, as well as from the Duparan area towards the center of the plain, the depth of the floor rock and the alluvial thickness increases. Due to the lack of a piezometric network, not much information is available in this field, but according to the geophysical information and exploitation wells (at the location of Galal Duparan and Seyed Behzad well), the depth of underground water in the area is between 20 and 35 meters. Therefore, the stagnation level in the region is lower than the evaporation range.

2.2. The Alaa River

It is one of the two important branches of the Jarahi river and originates from the mountainous area located 70 km east and northeast of Ramhormoz. This mountain mass includes Sard and Fon mountains (height 2939 meters), Mangesht (3613 meters). The first branch of the river is called Lirab, and after passing through a place called Tang La, it is named The Alaa River. In the village, the Yellow River meets the Yellow River, which is one of its important branches (from this point on, it is called Allah). Then it flows to the south and meets with the bitter river and enters Ramhormoz plain. The area of the upstream watershed before the confluence with the Yellow River is about 1385 km^2.

2.3. Seydoon River

The Seydoon River is one of the branches of the The Alaa River, which originates from the eastern slopes of the 2598-meter mountain in the northeast of Ramhormoz. Then, by passing through a deep and mountainous valley, it reaches the city of The Seydoon and joins The Alaa in the village of Talaver. The catchment area of this river is mountainous and almost half of the area is covered by forest trees. The area of its catchment area is about 130 km^2. Figure 1 shows the study area.

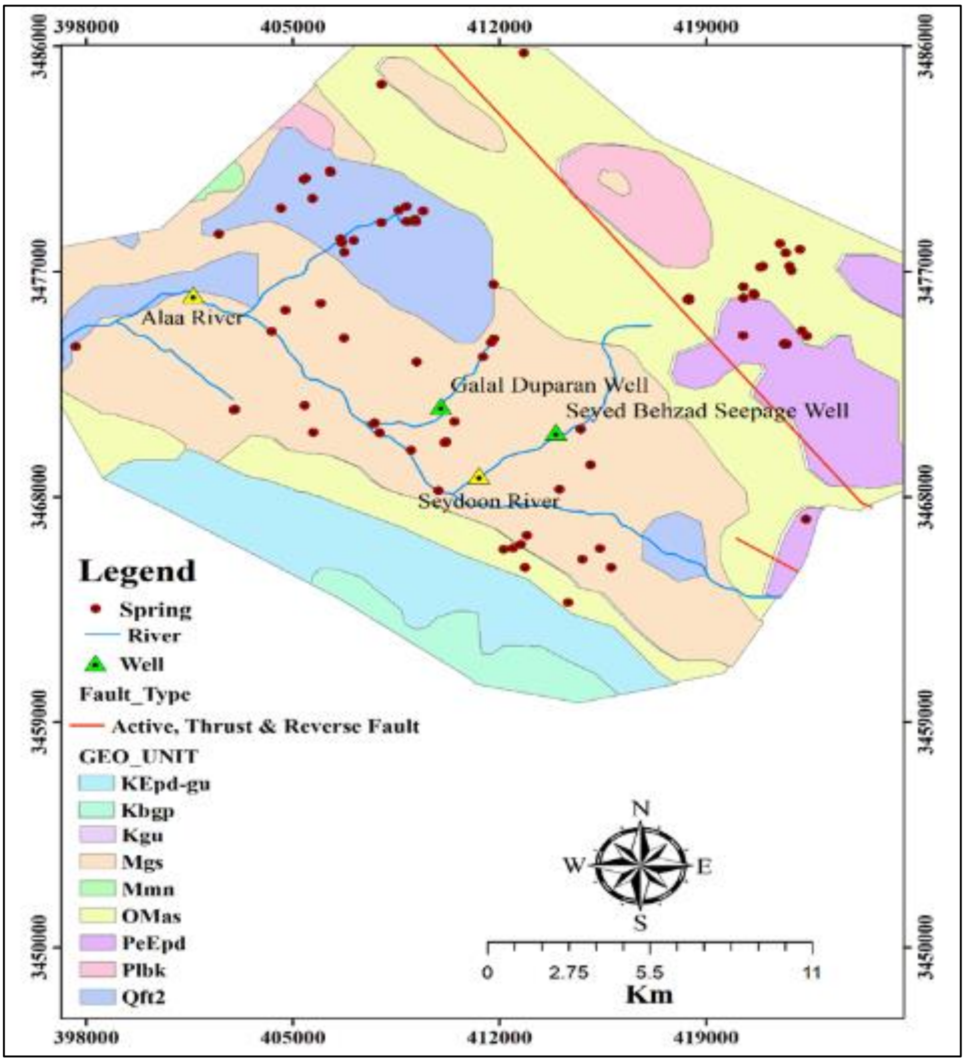

Figure 1 Location of the study area

2.4. Seyed Behzad Seepage Well

Seyed Behzad Seepage Well is drilled at X=413928 and Y=3470582 coordinates with a depth of 50 meters. The well is pumped with a discharge of about 9 to 11 l/s. The problems of this well are the relatively low chemical quality of water (about 1300 EC) and lack of water in part of the year. Due to the poor irrigation and three times increase in salinity of well water compared to river water, the hydraulic relationship between these two sources is questionable. By simultaneous investigation of water level fluctuations and changes in river discharge and also co-analysis of concentration of soluble elements in well water and river water, the degree of communication and the amount of flow to the river through well can be determined.

2.5. Galal Duparan Well

The Gulal Duparan well is located 5 km away and at the coordinates of X=410025 and Y=3471608 in the city of Seydoon. It is 217 meters deep. The depth of water in the well is about 20 meters above the ground when the silent pump is in operation, and with a discharge of 28 l/s, it is pumped at a depth of 40 meters. The well has a relatively good flow rate, but the number of soluble substances in the water is very high, bringing the electrical conductivity (EC) to about 2,500 to 3,000 micromhos. The relatively significant flow rate of this well can be attributed to its great depth and flow from the permeable conglomerate formation nearby. However, most of the water in this well is supplied by the Gachsaran Formation, which is the cause of its quality deterioration. The infiltrating water in the well, while passing through the joints and small cracks of this formation, dissolves a large amount of calcium sulphate in itself, and the mixing of these waters with the infiltrating water from the conglomerate formation causes a decrease in the quality and an increase in the salinity of the well water.

This study examined data on various parameters such as electrical conductivity (EC), total dissolved solids (TDS), pH, calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), hydrogen carbonate (HCO3), carbonate (CO3), chlorine (Cl), sulphate (SO4), temperature, and discharge from sampling sites near The Seydoon River in 2022. The analysis was carried out by the Khuzestan Water and Power Organization Laboratory to evaluate water quality. The findings were further interpreted using Schuller and Wilcox diagrams via AqQa and Chemistry software to classify the water quality of Seydoon, Alaa, Seyed Behzad Seepage Well and Galal Duparan Well.

2.6. AqQa software

The water analysis and reporting software from the American company Rockware is widely recognized as one of the most popular and extensively used tools in various industries. This software, known for its user-friendly graphical interface, enables users to conduct precise and comprehensive water analyses and reports effectively. In this research, version 1.1 of the software, released by Rockware in 2006, has been utilized. This particular version of the software, incorporating advanced and precise technologies, allows users to perform more accurate and detailed water analyses. The use of this software empowers users to precisely analyse water-related issues and needs, identify them comprehensively, and suggest suitable solutions in a graphical format. Given the unique features and capabilities of this software, its utilization by users in water analysis and reporting proves to be highly effective and beneficial. This software enables users to perform water analyses more accurately and comprehensively, and effortlessly generate graphical reports.

2.7. Chemistry software

The Chemistry program, developed in Visual Basic within the Microsoft Excel environment, is a powerful tool for evaluating water quality. This program allows users to share data and water quality information with other software, enabling the transfer of chemical analysis data to other programs and leveraging their capabilities. One of the features of this program is the analysis of water chemical quality. Using this program, users can thoroughly and comprehensively examine information related to various types of chemical analysis of water. This information includes parameters such as pH value, salt content, heavy metal concentrations, and other chemical substances present in the water. Furthermore, this program also facilitates the transfer of information to other software. In this way, users can easily and quickly transfer their required information to other programs and use them for various operations. Ultimately, using the Chemistry program to assess water quality is of great importance. This program enables users to accurately assess the chemical quality of water with high precision and use the resulting information for various purposes. Therefore, the use of this program can significantly contribute to improving the quality of life and environmental protection.

2.8. Wilcox Diagram

The Wilcox diagram categorizes water into different classes based on the values of electrical conductivity of salts dissolved in water and the sodium adsorption ratio. In total, there are 14 different classes that can be identified for water quality according to the Wilcox classification. The classification is important for understanding the suitability of water for various purposes such as irrigation, industrial use, and domestic consumption. By categorizing water into different classes, it becomes easier to assess its quality and determine the appropriate treatment or management measures. The Wilcox diagram provides a visual representation of the relationship between the electrical conductivity of water and the sodium adsorption ratio. This allows for a quick and easy interpretation of water quality based on these parameters. Understanding the classification of water according to the Wilcox diagram is essential for making informed decisions regarding its usage. It helps in identifying potential issues related to salinity, sodicity, and overall suitability for different applications. By using the Wilcox diagram, water resource managers, agricultural professionals, and other stakeholders can make informed choices about the management and utilization of water resources. It provides a systematic approach to assessing water quality and determining the necessary actions to maintain its suitability for various purposes. The Wilcox classification system serves as a valuable tool for evaluating water quality in diverse settings, including agricultural areas, industrial facilities, and municipal water supplies. It offers a standardized method for assessing water quality that can be applied across different regions and contexts. In conclusion, the Wilcox diagram plays a crucial role in classifying water quality based on electrical conductivity of salts and sodium adsorption ratio. Its systematic approach provides a valuable framework for understanding and managing water. Table 1 shows the Wilcox classification for agricultural waters (Asadinia, 2013).

Table 1 Wilcox classification for agricultural waters

Water Class	Water quality for irrigation
C_1S_1	Sweet-ineffective for agriculture
C_1S_2-C_2S_2-C_2S_1	Slightly salty - fairly suitable for agriculture
C_2S_3-C_3S_1-C_3S_2-C_3S_3-C_1S_3	Salt- with the necessary arrangements, suitable for agriculture
C_4S_1-C_1S_4-C_1S_4-C_2S_4-C_3S_4-C_4S_4-C_4S_3-C_4S_2	Too salty - harmful to agriculture

2.9. The Schuler's diagram

Schuler's diagram is a semi-logarithmic diagram that shows the concentration of main ions in meq/L. This chart classifies water according to five chemical parameters: sodium, chlorine, sulphate, dry residue and water hardness in drinking consumption. One of the quality indicators of drinking water is its hardness, which is measured based on calcium carbonate. In this research, semi-logarithmic Schuler's diagram was used to determine the alkalinity of water. In table number 2, the water used for drinking is divided into six groups based on quality: good, acceptable, unsuitable, average, drinkable in emergency situations, and non-drinkable.

2.10. The Water hardness

Hardness is mainly based on calcium and magnesium cations. In general, the elements aluminium, iron, and manganese are effective in water hardness, but calcium and magnesium are highly effective in water hardness, and other cations either do not exist or exist in very small amounts, which can be overlooked. Total hardness (TH) is the total amount of calcium (Ca) magnesium (Mg). Permanent hardness or non-carbonate hardness includes hardness without bicarbonate salts (such as chloride, sulphate, etc. Temporary hardness or carbonate hardness includes calcium and magnesium bicarbonate and is obtained from the difference in total hardness (TH) and permanent hardness. The water hardness is related to calcium and magnesium ions, and the total hardness in Mg/l is obtained from the relation (1).

$$TH = 2.497ca + 4.115$$,,,,,,,,,,,,,,,,,,,, Relation (1)

3. Discussion and Results

3.1. Drinking ability

Schuller's division is one of the criteria for classification of drinking water. According to this table and the results of analysis of water samples, the groundwater in the area is not of good quality in terms of drinking, so that the samples of the Seyed Behzad effluent well are in the inappropriate category and the deep well samples of Galal Duparan are in the bad and potable category in emergency conditions. Conversely, the chemical quality of the surface waters of the region is suitable for drinking, and the water of both The Seydoon and The Alaa rivers are considered acceptable for drinking (Table 3).

Table 2 Standard parameters of drinking water quality according to Shuler's table

Row	Water Quality	TDS (mg/l)	T.H (mg/l caco^3)	Na(mg/l)	Cl(mg/l)	SO4(mg/l)
1	Good	<500	<250	<115	<175	<145
2	Acceptable	500-1000	250-500	115-230	175-350	145-280
3	Inappropriate	1000-2000	500-1000	230-460	350-700	280-580
4	Bad	2000-4000	1000-2000	460-920	700-1400	580-1150
5	Drinking in an emergency	4000-8000	2000-4000	920-1840	1400-2800	1150-2240
6	Non-drinkable.	>8000	>4000	>1840	>2800	>2240

Table 3 Water sample quality in the Seydoon catchment area for drinking purposes

Row	Sampling location	TDS	TH	Na	Cl	SO4	Water quality
1	Alaa River	1	2	1	1	1	2
2	Alaa River	1	2	1	1	1	2
3	Alaa River	1	2	1	1	1	2
4	Alaa River	1	2	1	1	1	2
5	Duparan Well	4	4	1	1	5	5
6	Duparan Well	3	4	1	1	4	4
7	Downstream stream of the Seydoon river	2	2	1	1	2	2
8	Downstream stream of the Seydoon river	1	2	1	1	2	2
9	Downstream stream of the Seydoon river	1	2	1	1	1	2
10	Upper stream of the Seydoon river	1	2	1	1	1	2
11	Upper stream of the Seydoon river	1	2	1	1	2	2
12	Upper stream of the Seydoon river	1	2	1	1	2	2
13	Upper stream of the Seydoon river	1	2	1	1	1	2
14	Seyed Behzad Well	2	3	1	1	3	2
15	Seyed Behzad Well	2	3	1	1	3	3
16	Seyed Behzad Well	2	3	1	1	3	3
17	Seyed Behzad Well	2	3	1	1	3	3
1: Good 2: Acceptable 3: Inappropriate 4: Bad 5: Drinkable in an Emergency 6: Undrinkable							

In general, the deterioration of groundwater chemical quality in the region is strongly affected by sulphate ion. Dissolution of calcium sulphate in the water of the region has increased Ca and SO_4 ions in surface and groundwater and made them unsuitable for drinking. The presence of high amounts of sulphate ion causes bitter taste in water. Conversely, the amount of chlorine and sodium ions in groundwater is very low. This can be attributed to the absence and dissolution of the halite mineral (NaCl) in the rocks and sediments of the area. In general, the groundwater in the area is classified as moderate to unsuitable for drinking. In addition, surface water in the region has a better chemical quality than groundwater for drinking use.

Figure 2 shows the Schuler diagram of groundwater in the area of the plains of The Seydoon and Figure 3 shows the Schuler diagram of The Alaa and The Seydoon rivers. As the trend of the charts shows, all of the water in the region follows a specific trend and the most important factors reducing water quality in drinking terms include hardness (TH) and high concentration of sulphate and calcium ions.

Table 4 shows the surface and underground waters of the region based on total hardness, permanent hardness and temporary hardness. In general, the underground waters of the region and the water of the Seydoon River are classified as hard to very hard.

Among the collected samples, Galal Duparan well with a total hardness of about 1283 mg CaCO3/l had the highest hardness and then Behzad Seyed Behzad well with a mean total hardness of 547.5 mg CaCO3/l is classified as completely hard water. The Seydoon River water with a hardness of about 339.5 mg CaCO3/l although it has less hardness than groundwater in the region, but is considered a completely hard water. The Alaa River water is classified as hard water with an average total hardness of 226.6 mg CaCO3/l, However, it has the lowest hardness in the region.

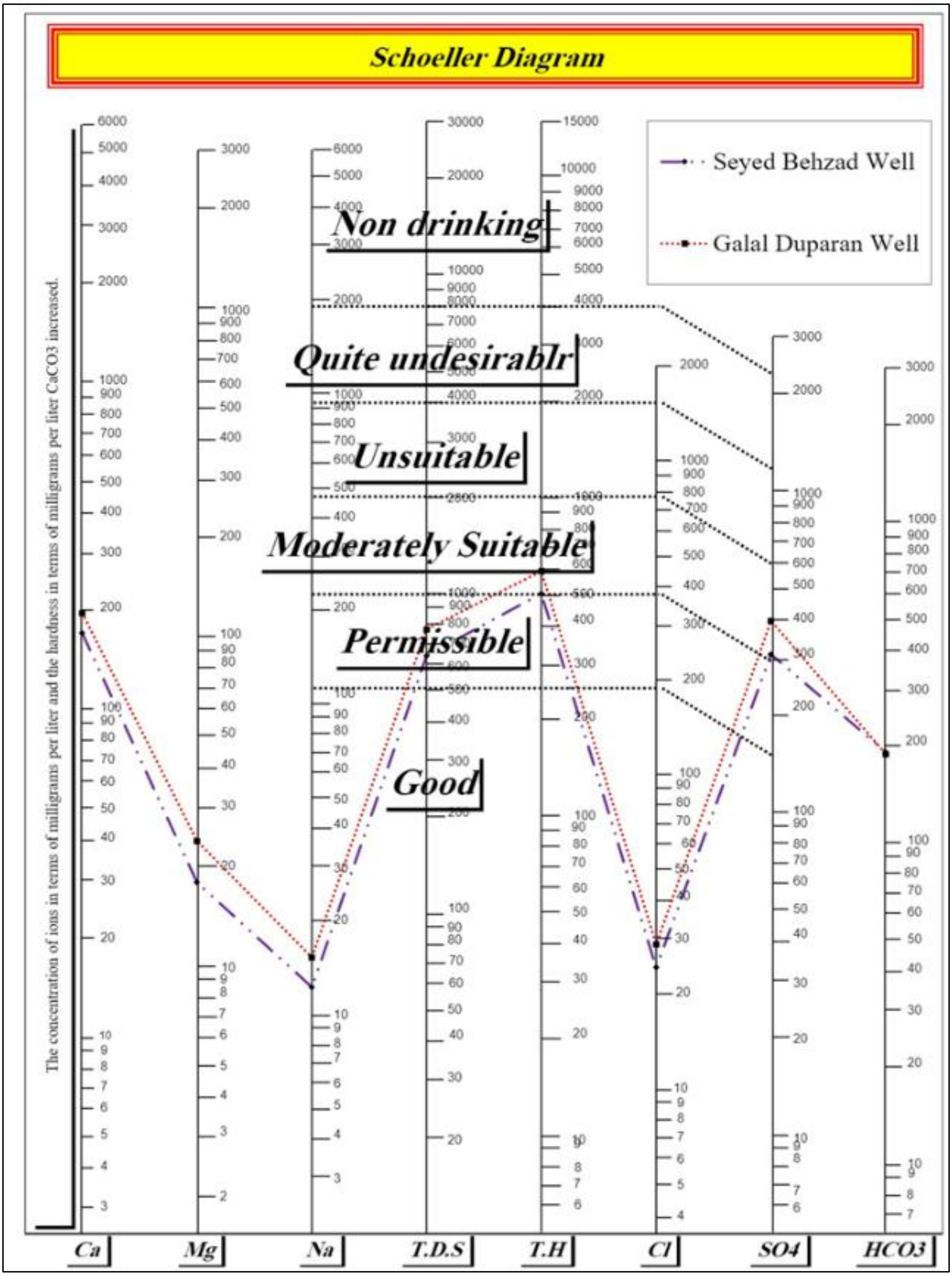

Figure 2 Schuler diagram of the groundwater samples from Seyed Behzad and Galal Duparan

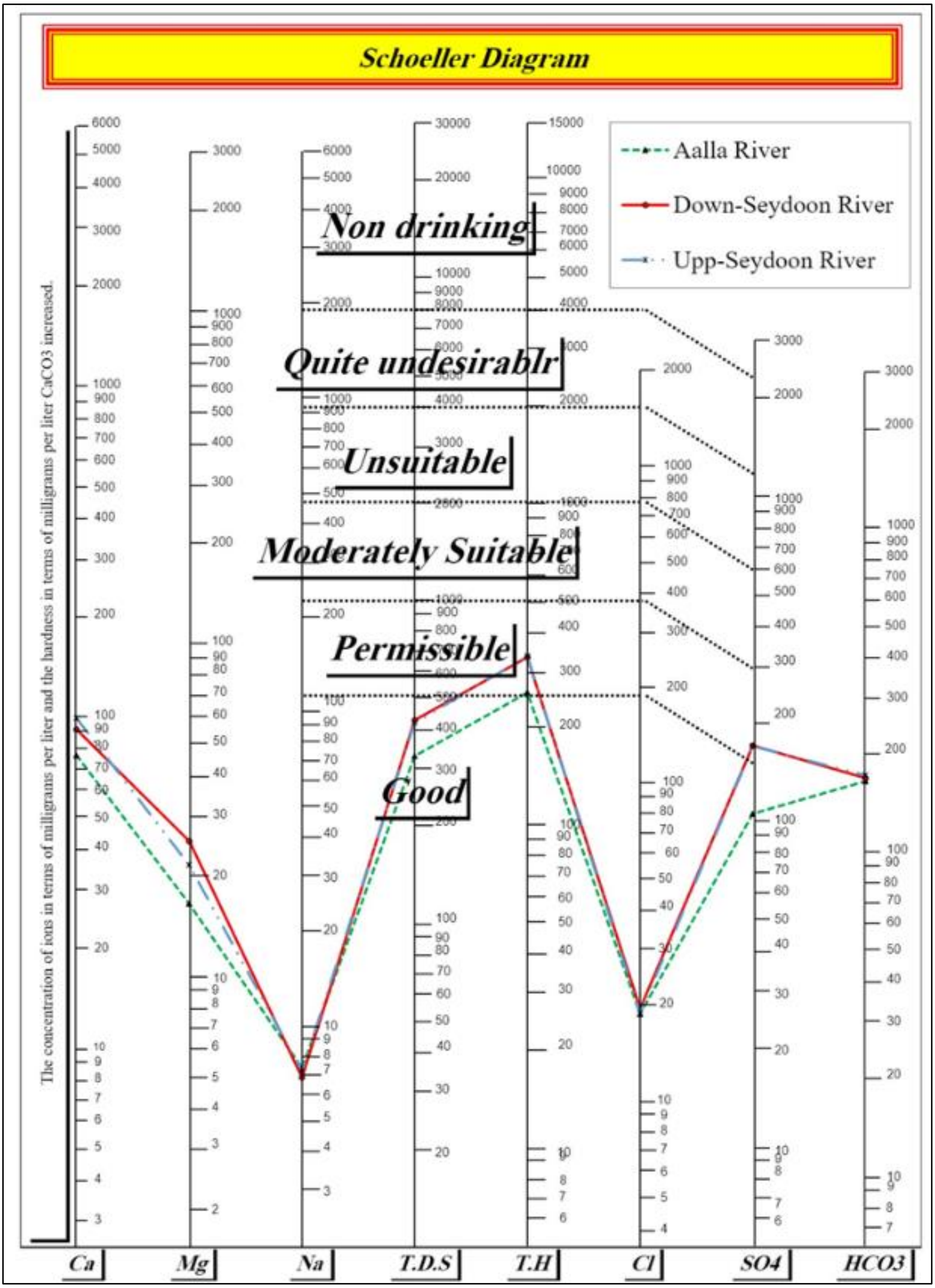

Figure 3 Schuler diagram of water samples from the Seydoon River and the Alaa River

Table 4 Total hardness, permanent hardness, and temporary hardness of surface and groundwater samples in the Seydoon Plain

Row	Sampling location	Permanent Difficulty	Temporary Difficulty	Total Difficulty	Water type based on hardness
1	Alaa River	275.7	270	5.7	hard
2	Alaa River	263.34	263.34	0	hard
3	Alaa River	258.29	258.29	0	hard
4	Alaa River	269.06	269.06	0	hard
5	Duparan Well	1476.9	268.03	1208.87	quite hard
6	Duparan Well	1089.17	196.77	892.34	quite hard
7	Downstream stream of the Seydoon river	417.54	280	137.54	quite hard
8	Downstream stream of the Seydoon river	383.36	280	103.36	quite hard
9	Downstream stream of the Seydoon river	264.12	264.12	0	hard
10	Upper stream of the Seydoon river	275.7	275.7	0	hard
11	Upper stream of the Seydoon river	382.86	280	102.86	quite hard
12	Upper stream of the Seydoon river	383.53	270	113.53	quite hard
13	Upper stream of the Seydoon river	269.28	269.28	0	hard
14	Seyed Behzad Well	679.98	356.06	323.91	quite hard
15	Seyed Behzad Well	517.92	340	177.92	quite hard
16	Seyed Behzad Well	518.48	350	168.48	quite hard
17	Seyed Behzad Well	473.81	290	183.81	quite hard

3.2. Agricultural consumption capability

Wilcox classification (1955) is one of the most important agricultural water quality classifications. The basis of this classification is electrical conductivity (EC) and sodium absorption ratio (SAR) and divides irrigation water into 16 categories, Table 5. The sodium absorption ratio or sodium risk of irrigation water is calculated by the following equation. In this regard, the concentrations are in meq/l.

$$SAR = \frac{rNa^{+2}}{\sqrt{\frac{r(Ca^{+2}+mg^{2})}{2}}} \text{.................. Relation (2)}$$

The different groups of water in Wilcox classification for Agriculture are classified as follows:

- Class C1S1 Very good waters
- C1S2, C2S2, C2S1 Good Water Grades and Classes
- Class C1S3, C2S3, C3S1, C3S2 Medium Water
- C1S4, C2S4, C3S4, C4S4, C4S1, C4S2, C4S3, C4S3 Unsuitable Waters for Agriculture.

The ability to use the waters of the Sedoon area for agricultural purposes has been investigated based on the above materials and presented in Table 6. Also, the Wilcox diagram of harvested water samples in figure 4 shows that surface and groundwater in the area have excellent quality for irrigation purposes in sodium adsorption ratio, but in salinity, it has a problem. Seyed Behzad well water with C3 class is salinity suitable for agriculture, but Galal Duparan well water is not suitable for agriculture due to high salinity. The water of the Upper River in the C2 category is suitable for agriculture and the Sidon River water in C2 to C3 is suitable for agriculture in the appropriate to usable category.

Table 5 Electrical conductivity values and sodium absorption ratio in Wilcox classification

Water Quality	Electrical Conductivity	Rate	sodium absorption ratio (SAR)	Rate	Affectivity
Higher	EC<250	C1	SAR <10	S1	No harmful effects
good	250<EC<750	C2	10<SAR<18	S2	Harmful to sensitive plants
Medium	750<EC<2250	C3	18<SAR<26	S3	Harmful to most plants
Inappropriate	2250<EC	C4	26<SAR	S4	Only suitable for resistant plants

Table 6 Usability of regional waters for agricultural use

Row	Sampling location	SAR	EC	Water Class	Water quality for agriculture
1	Alaa River	0.19	466	C2-S1	A little salty - suitable for agriculture
2	Alaa River	0.06	544	C2-S1	A little salty - suitable for agriculture
3	Alaa River	0.05	537	C2-S1	A little salty - suitable for agriculture
4	Alaa River	0.26	597	C2-S1	A little salty - suitable for agriculture
5	Duparan Well	0.33	2816	C4-S1	A little salty - suitable for agriculture
6	Duparan Well	0.35	2200	C3-S1	Too salty - unsuitable for agriculture
7	Downstream stream of the Seydoon river	0.04	856	C3-S1	Salt - can be used for agriculture
8	Downstream stream of the Seydoon river	0.14	809	C3-S1	Salt - can be used for agriculture
9	Downstream stream of the Seydoon river	0.26	584	C2-S1	Salt - can be used for agriculture
10	Upper stream of the Seydoon river	0.14	460	C2-S1	A little salty - suitable for agriculture
11	Upper stream of the Seydoon river	0.05	785	C3-S1	A little salty - suitable for agriculture
12	Upper stream of the Seydoon river	0.14	806	C3-S1	Salt - can be used for agriculture
13	Upper stream of the Seydoon river	0.26	595	C2-S1	Salt - can be used for agriculture
14	Seyed Behzad Well	0.28	1300	C3-S1	A little salty - suitable for agriculture
15	Seyed Behzad Well	0.17	1085	C3-S1	Salt - can be used for agriculture
16	Seyed Behzad Well	0.13	1076	C3-S1	Salt - can be used for agriculture
17	Seyed Behzad Well	0.22	1004	C3-S1	Salt - can be used for agriculture

3.3. Industrial consumption capability

In the field of industrial use of water resources, corrosion or sedimentation is one of the most important issues that are considered. Water with high hardness due to heating and separating some of the soluble carbon gas deposits in the pipe wall and reduces the transmission capacity and increases energy consumption in the network. Waters with low hardness, low pH and high CO_2 content tend to corrosion, which causes perforation of concrete and metal beds. Table 7 shows the chemical quality of samples of harvested water from corrosion and sedimentation.

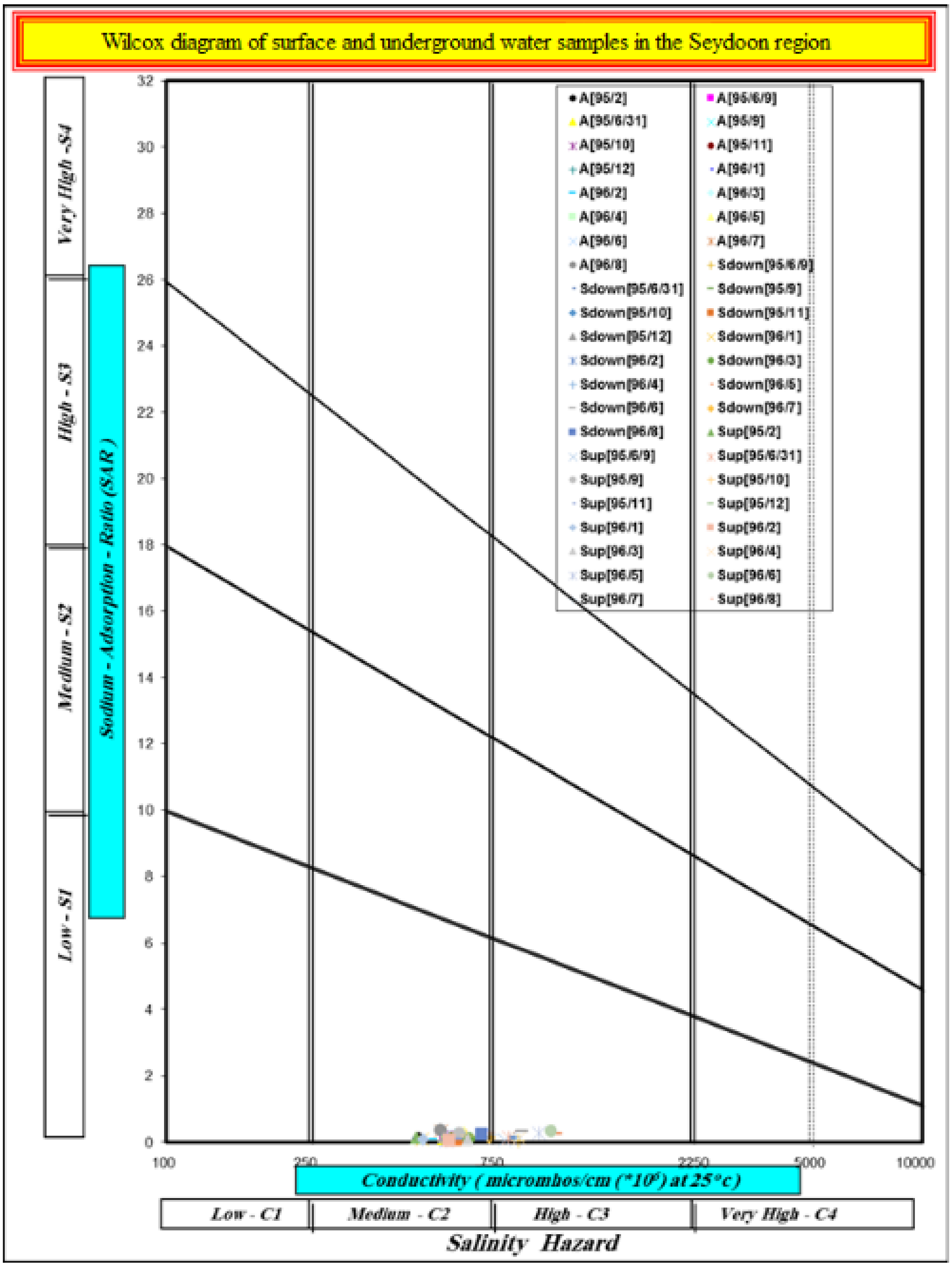

Figure 4 Wilcox diagram of surface and underground water samples in the Seydoon region

Table 7 Surface and groundwater quality of Sidon plain in terms of industrial use

Row	Sampling location	Alkalinity in CaO	Ca (mg/l)	Coefficient C	PHs	PH	PHs-PH	Water quality for industrial
1	Alaa River	8.53	100.2	11.28	8.3	7.3	1	Corrosive
2	Alaa River	3.24	58	11.28	9	7.76	1.24	Corrosive
3	Alaa River	3.01	54	11.28	9.1	7.87	1.23	Corrosive
4	Alaa River	11.06	86	11.28	8.3	7.8	0.5	Corrosive
5	Duparan Well	34.283	460.9	11.33	7.1	7.2	-0.1	Deposit Maker
6	Duparan Well	31.55	400	11.32	7.2	7.4	-0.2	Deposit Maker
7	Downstream stream of the Seydoon river	3.24	98	11.29	8.8	7.79	1.01	Corrosive
8	Downstream stream of the Seydoon river	7.38	112	11.29	8.4	7.92	0.48	Corrosive
9	Downstream stream of the Seydoon river	11.06	86	11.28	8.3	7.87	0.43	Corrosive
10	Upper stream of the Seydoon river	6.691	100.2	11.27	8.4	7.5	0.9	Corrosive
11	Upper stream of the Seydoon river	3.24	94	11.29	8.8	7.84	0.96	Corrosive
12	Upper stream of the Seydoon river	7.38	118	11.29	8.4	7.83	0.57	Corrosive
13	Upper stream of the Seydoon river	11.06	94	11.28	8.3	7.7	0.6	Corrosive
14	Seyed Behzad Well	18.505	257.3	11.31	7.6	7.6	0	Balanced
15	Seyed Behzad Well	11.31	156	11.3	8.1	7.62	0.48	Corrosive
16	Seyed Behzad Well	7.84	176	11.3	8.2	7.67	0.53	Corrosive
17	Seyed Behzad Well	11.98	168	11.3	8	7.46	0.54	Corrosive

3.4. Descriptive graphs of water quality

3.4.1. Stiff Diagram

Steff diagrams show the differences in hadrochemical facies and total solids concentration of water samples. In Figures 5,6 and 7 the Steff diagram of groundwater samples and the Alaa and Seydoon rivers are depicted. Based on the Steff diagram, all samples taken from the water of Seyed Behzad Efflux well and Gulal Duparan well follow a pattern in which anion sulphate is dominant and calcium cation is dominant. However, the total concentration of soluble elements in Galal Duparan well is higher than that of Seyyed Behzad's efflux well (Figure 5). Also, the relative concentration of sulphate ion (SO_4) in the samples of Galal Duparan wells is much higher than other anions.

According to Figure 5 in samples harvested from Seydoon River, concentrations of sulphate and bicarbonate (HCO_3) do not differ much. The relative concentration of these two ions in the water of this river varies in different seasons, this difference may be due to rainfall and runoff entering the river water. The dominance of bicarbonate anion in the water samples of Seydoon River indicates the source of water from the limestone-marl area upstream. In the samples taken from the water of the Alaa River, the concentration of two ions of sulphate and bicarbonate is almost equal and the bicarbonate ion is slightly predominant.

In surface and groundwater samples, bicarbonate and magnesium had moderate levels and chlorine and sodium had the lowest values. This is due to the absence of chloride-sodic salts in sediments and rocks in the region. The high concentration of calcium and sulphate ions in the sample of Galal Dopran well indicates the penetration of sulphated waters from Gachsaran Formation origin in this well.

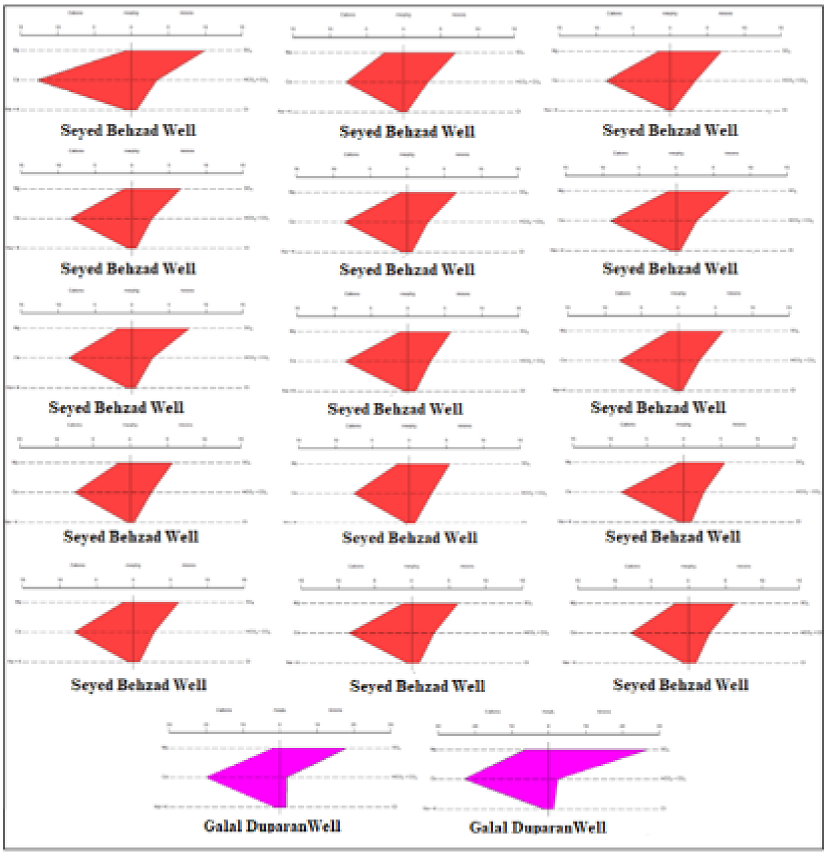

Figure 5 Stiff Diagram of Groundwater Samples of Seyyed Behzad Well and Galal Dopran well

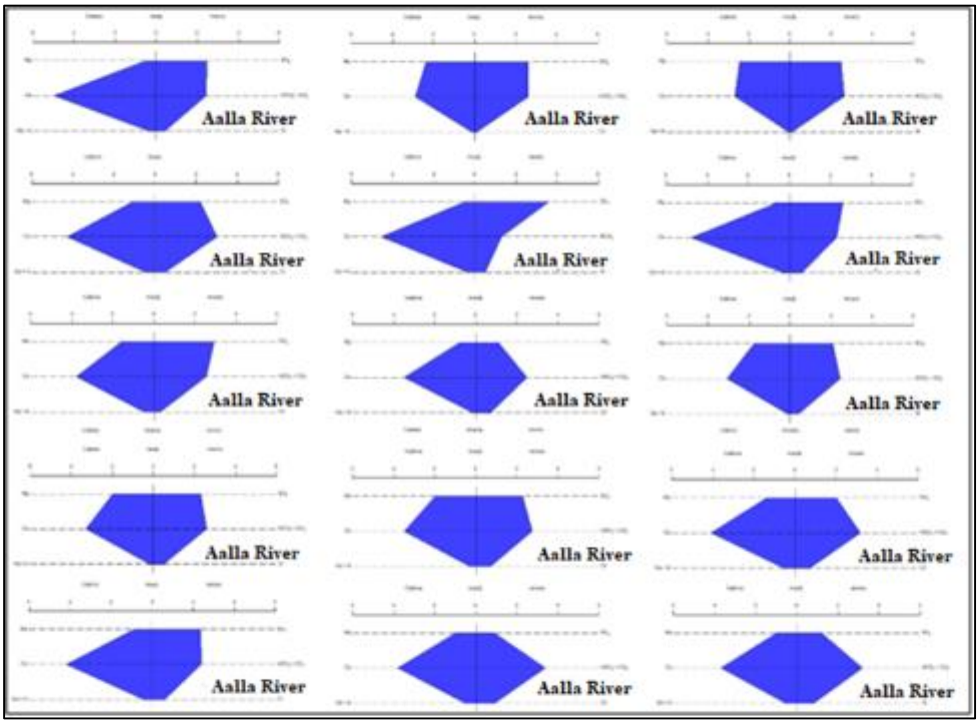

Figure 6 Stiff diagram of the examples of the Alaa River

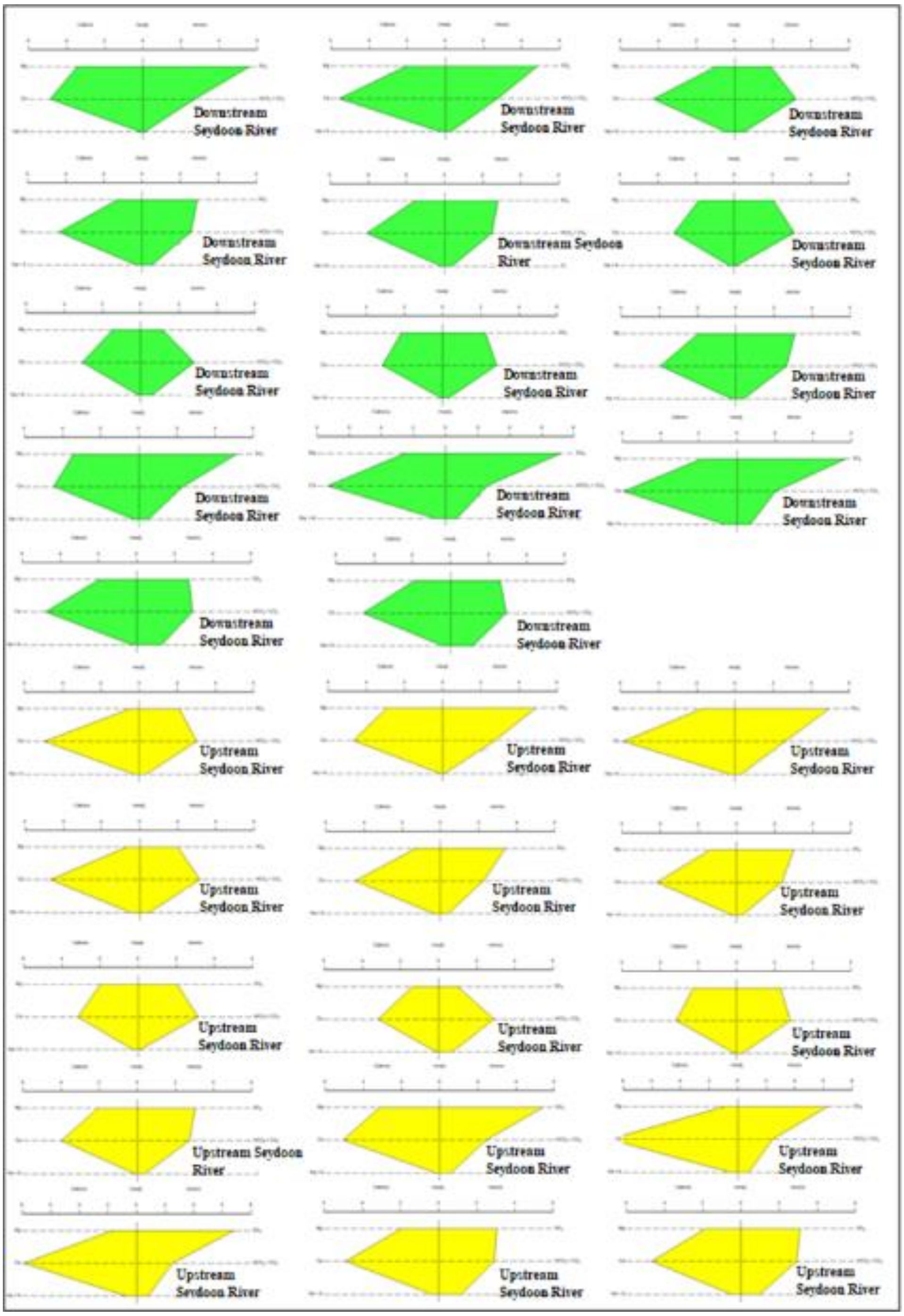

Figure 7 Stiff diagram of samples upstream and downstream of the Seydoon River

3.4.2. Piper diagram

Piper diagram of groundwater samples shows that sulfate anions and calcium cations are dominant in the aquifers (Figure 8). According to these diagrams, it is determined that alkaline earth elements are more than alkaline elements in groundwater samples, and the samples are located in a part of the Piper diagram which generally have Ca (Mg)-SO4 type waters. Based on the Piper diagram and table 8-7, the type and facies of all samples taken from the water of the Alaa River is bicarbonate-calcic, and in the case of Seydoon River, in some months of the year, it is bicarbonate-calcic, and in others, sulfate-calcic. As explained earlier, the decarbonate of the water of the Seydoon River during the high water can be attributed to the high effect of upstream carbonate formations on the chemistry of the river water during rainfall and during the high discharge period.

Table 8 Type and facies and arrangement of cations and anions based on concentration in water samples of Sidon plain

Row	Sampling location	The concentration of anions	The concentration of cations	Type and facies
1	Duparan Well	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
2	Duparan Well	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
3	Seyed Behzad Well	SO4 > HCO3 > Cl	Ca > Na+K > Mg	Classic sulphate
4	Seyed Behzad Well	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
5	Seyed Behzad Well	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
6	Seyed Behzad Well	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
7	Seyed Behzad Well	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
8	Alaa River	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
9	Alaa River	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
10	Alaa River	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
11	Alaa River	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
12	Alaa River	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
13	Alaa River	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
14	Alaa River	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
15	Downstream stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
16	Downstream stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
17	Downstream stream of the Seydoon river	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
18	Downstream stream of the Seydoon river	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
19	Downstream stream of the Seydoon river	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
20	Downstream stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
21	Downstream stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
22	Downstream stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
23	Downstream stream of the Seydoon river	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
24	Upper stream of the Seydoon river	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
25	Upper stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate

26	Upper stream of the Seydoon river	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
27	Upper stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
28	Upper stream of the Seydoon river	HCO3 > SO4 > Cl	Ca > Mg > Na+K	Calcium bicarbonate
29	Upper stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate
30	Upper stream of the Seydoon river	SO4 > HCO3 > Cl	Ca > Mg > Na+K	Classic sulphate

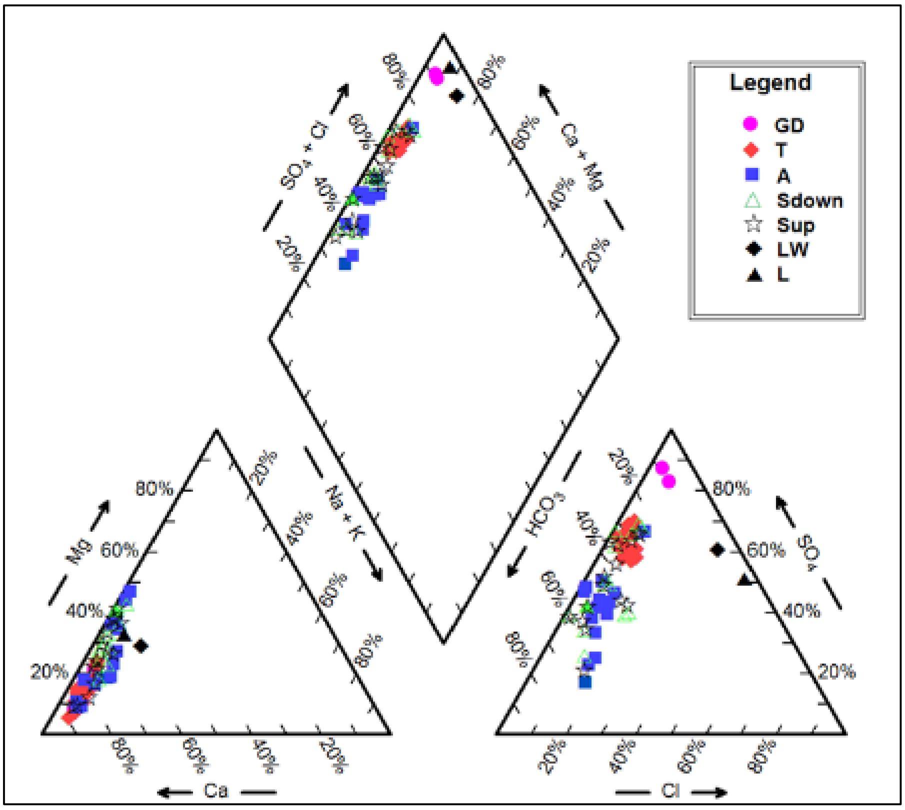

Figure 8 Piper diagram of groundwater samples and rivers in Sidon region

4. Conclusion

Rivers and underground water are among the most important sources of water that play a significant role in providing water needed for various activities such as drinking, agriculture, and industry. Knowing the quality of water resources is vital for their classification and management. Therefore, this research focuses on the classification of the quality of water from the Seydoon River, the Alaa River, and the wells of Galal Duparan and Seyed Behzad, which are located near the Seydoon River, using the Aqua and Chemistry software. According to the Schuler table and the results of water sample analysis, the water samples of the Seyed Behzad well are classified as unsuitable, and the water samples of the deep well of Galal Duparan are classified as poor and suitable for drinking in emergency conditions. Conversely, the chemical quality of the surface water in the region is suitable for drinking, and the water of both the Alaa River and the Seydoon River is classified as acceptable for drinking. The most critical factors affecting the quality of water, especially for drinking, are hardness (TH) and high concentrations of sulphate and calcium ions. Generally, the groundwater of the region and the water of the Seydoon River are classified as hard to very hard, and the Seydoon River and the Alaa River have less hardness than the groundwater of the region but are still classified as completely hard. The use of surface and groundwater in the region for agricultural purposes is of high-quality regarding sodium absorption according to the

Wilcox diagram, but it is not suitable for irrigation due to its high salinity. The water of the Seyed Behzad well is suitable for irrigation in salinity, but the water of the Galal Duparan well is not suitable for irrigation due to its high salinity. The water of the Alaa River is suitable for irrigation, and the water of the Seydoon River is suitable for irrigation, with a classification of C2 to C3. In the potential for using water resources in the Seydoon region for industrial purposes, the water of the Seydoon River, the Alaa River, and the Seyed Behzad well are of the consumer type, and the water of the Galal Duparan well is of the sediment-forming type.

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