CONTAMINATION OF THE KONAR SIAH KARST SPRING BY SALTDOME

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Abstract There are about 200 salt plugs in the southern part of the Zagros Mountain Ranges and the Persian Gulf in Iran (Kent, 1970). The salt comes from the Hormuz salt Formation at the base of the Phanerozoic zone. It moves upward due to the buoyancy, the latteral pressure resulting from the opening of the Red Sea to the southwest, and the weight of several thousand meters of overlying sediments. It merges like a mushroom and its movement faciliated where the area is more fractured. Outcrops of geological formations subject to karst are found in about 23% of the surface area in the middle of southern Iran. They form aquifers of good water quality, especially in Fars province. In general, the electrical conductivity is less than 500 micosiemens per centimeter. In some parts of Fars province, the salt piercements are adjacent to the carbonatic rocks; hence, the karstic waters are of poor quality. The Konar Siah spring, located in the vicinity of Firoozabad, flows out from the Sarvak Limestone Formation. This spring is adjacent to the saltdome; thus, its water is very contaminated. A geologic map on a scale of 1: 50000 is prepared. In addition, the concentration of the following ions: Ca, Na, Mg, K, SO_4, HCO_3, and Cl; PH, EC and the temperature, and also the discharge of the Konar Siah spring have been determined tri-weekly for a duration of 9 months. The discharge of a few seasonal springs issuing from the saltdome has been measured as well. Based on the observations, the study concludes that the saltdome is the source of water contamination.

Key Words Karst Water, Spring, Water Contamination, Salt Dome

چکیده در جنوب ایران در قسمتی از کوههای زاگرس و خلیج فارس در حدود دویست بیرون زدگی نمکی (Salt-Plug) وجود دارد. این نمکها مربوط به سری هرمز می باشند که در قاعده ستون چینه شناسی زاگرس قرار دارد بعلت کمتر بودن وزن مخصوص نمک نسبت به سنگهای مجاور و فشار جانبی که از طرف جنوب غرب، بعلت بازشدگی دریای سرخ به عربستان و از آنجا به ایران وارد می آید و همچنین وزن طبقاتی که بر روی نمک قرار دارند، نمک بشکل قارچ بخصوص از لابلای شکستگیها به بالا رانده شده و به سطح زمین می رسد. ۲۳ درصد جنوب مرکزی ایران تشکیلات کارستی رخنمون دارند و در استان فارس این تشکیلات لایه های آبدار کارستی با کیفیت خوبی را تشکیل می دهند و عموماً هدایت الکتریکی چاهها و چشمه هایی که از این تشکیلات تخلیه می گردند کمتر از ۵۰۰ میکروموس بر سانتیمتر می باشد. در بعضی از مناطق فارس بیرون زدگی نمکی در مجاورت تشکیلات کارستی است در نتیجه بعلت مجاورت گنبد نمکی، تشکیلات کارستی، کیفیت آبهای کارستی کاهش می یابد. چشمه کنار سیاه در منطقه فیروز آباد از تشکیلات آهکی سروک خارج می گردد ولی تشکیلات سروک در مجاورت گنبد نمکی قرار گرفته است. در نتیجه کیفیت چشمه کنار سیاه به مقدار قابل ملاحظه ای کاهش می یابد. به منظور بررسی علل کاهش کیفیت آبهای کارستی نقشه ۱/۵۰۰۰۰ زمین شناسی منطقه تهیه گردید و یونهای عمده (کلسیم، سدیم، منیزیم، پتاسیم، سولفات، بی کربنات، کلر) PH، هدایت الکتریکی، درجه حرارت، بده چشمه کنار سیاه هر سه هفته یکبار بمدت ۹ ماه به روشهای استاندارد اندازه گیری گردید. نوع آب چشمه ها، کلروره بود. تغییرات زمانی پارامترهای فوق مشخص گردید. در پایان علل کلروره شدن آب تشکیلات سروک مورد بررسی قرار می گیرد.

INTRODUCTION

Outcrops of karst formations are found in about 23% of the surface area in the middle of southern Iran [1]. In general, the electrical conductivity is less than 500 micromhos per centimeter [2]. Because water quantity and quality affect the agricultural products (in Fars province), the study of the nearly 200 salt plugs in

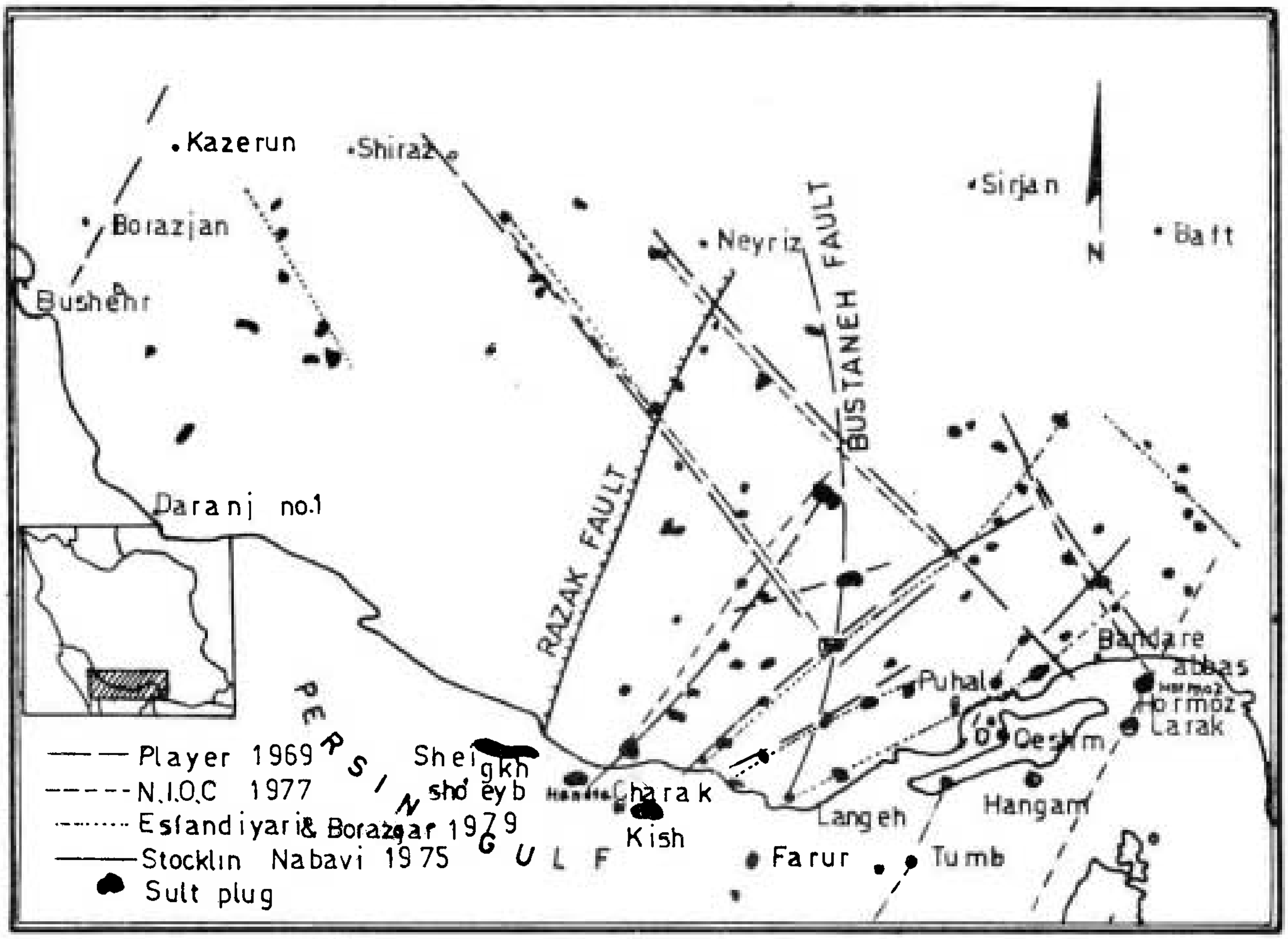

Figure 1. Different arrangement of Salt plugs/domes in central south of Iran (Ahmadzadeh Heravi, M. et al. 1990).

southern Iran becomes very important [3]. The salt plugs are scattered in the middle of southern Iran including Persian Gulf (Figure 1). Some of the islands in the Persian Gulf (e.g. the Tomb, Hormuz, Larak and Hangam islands) have been orginated from salt plugs.

The electrical conductivity of karst springs emerging from the Sarvak Formation that have an apparant connection with the adjacent evaporitic formation is below 500 µmhos/cm [2]. The Konar Siah spring emerges from Sarvak Formation, but the average electrical conductivity is 5432 µmhos/cm. The adjacent Konar Siah sattdome deteriorates the quality of karst springs. The objective of this study is to determine the contamination mechanism of Konar Siah spring.

LOCALITY AND GEOLGICAL SETTING OF THE AREA

The area under study is located at a distance of 90 km to the southeast of Shiraz and 20 km to the southwest of firoozabad. The outcropped formations taken from the descriptions in their type sections [4] are:

Palaeozoic Hormuz Salt Fm.
Cretaceous Kazhdumi Fm.: mainly marly and shaly.
Cretaceous Sarvak Limestone Fm.
Cretaceous Gurpi Fm.: mainly shaly and marly.
Tertiay Pabdeh Fm: mainly shaly and marly.
Tertiay Asmari-Jahrom Fm.: mainly carbonatic.

Tertiay Gachsaran Fm.: mainly marly and evaporitic.

The Gachsaran Fm. has been divided into 3 members which are from top to bottom as follows:

Mol Member: dominantly gypseous marls.

Champeh Member: mainly chalky-gypseous limestones and dolomites.

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Chehel Member: mainly anhydrite and gypsum.

Tertiay Mishan Fm.: The limestone Guri Member at the base changes to grey marls.

Tertiary AghaJari Fm.: predominatly sandy-marly.

Quaternay Bakhtyari Fm.: mainly conglomeritic.

The Hormuz Salt Formation has been outcropped only in the form of pierced saltdomes. Although it appears as mixed aggregates of sedimentary, igneous and metamorphic rocks, according to Ahmmadzadeh Heravi[5], it can be divided into 4 distinct units (Figure 2):

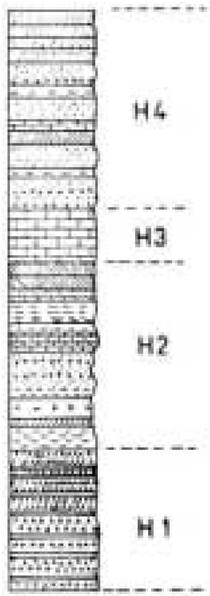
Horizon 1) This is the lowest unit of the Hormuz Formation. Its lower contact have not been identified. The main part of this unit consists of salt layers interbedded with thin layers containing tuffs, marls, carbonates and iron oxides.

Horizon 2) Alternation of marls, anhydrites, tuffs, ignimbrites, ironstones with some intercalations of fine laminated algal limestones.

Horizon 3) Foetid algal limestones.

Horizon 4) Alternations of tuffs, sandstones, with some intercaltations of anhydrites and black algal limestones.

Many geologists studying the salt in the region have considered the buoyancy of the salt together with the vertical pressure of several thousand meter sedimentary cover and the latteral pressure resulting from the opening of the Red Sea to be the reason for the salt diapiric intrusion. The upward movement of salt has been faciliated by faults. Some geologists believe that 25% of the outcropped saltplugs in southern Iran can be traced along Razak and Bostaneh faults as shown in Figure 1 [5]. Nabavi and Sabzei [5] believe that 70% of the saltdomes are located on faults parallel to the two faults.



H_4. Alternation of tuffs, sandstones, marls with some intercalations, of anhydrites and black algal limestones.

H_3. Laminated black footid algal limestones.

H_2. Alternation of marls, anhydrites, tuffs, ignimbrites, ironstones with some intercalations of fine laminated algal limestones.

H_1. Salt beds with fine intercalations of tuff, marls, limestones, iron oxides and sulfides.

Figure 2. Schematic stratigraphic column of Hormoz Formation. (Ahmadzadeh Heravi, M. et al. 1990).

GEOLOGICAL SETTING

The Konar Siah saltdome breaches across the Aghar anticline (Figure 3). Thus, the Sarvak Formation, as the core of the anticline, and all other outcropped formations have been cut and are discontinous, and offset by a transcurrent fault, on both sides of the salt plug. The saltdome contains considerable amounts of salt in the form of salt crystals and redeposited salts, in some of the drainages and flood plains, as well. Temporal spring discharging among the saltdome contains a great deal of chloride and sodium compounds.

The Sarvak Formation to the southeast of the saltdome has been subject of the regional and saltdome pressure, the transcurrent fault and several other normal faults. Therefore, it is intensively tectonised. This is clearly indicated in the closely jointed rocks

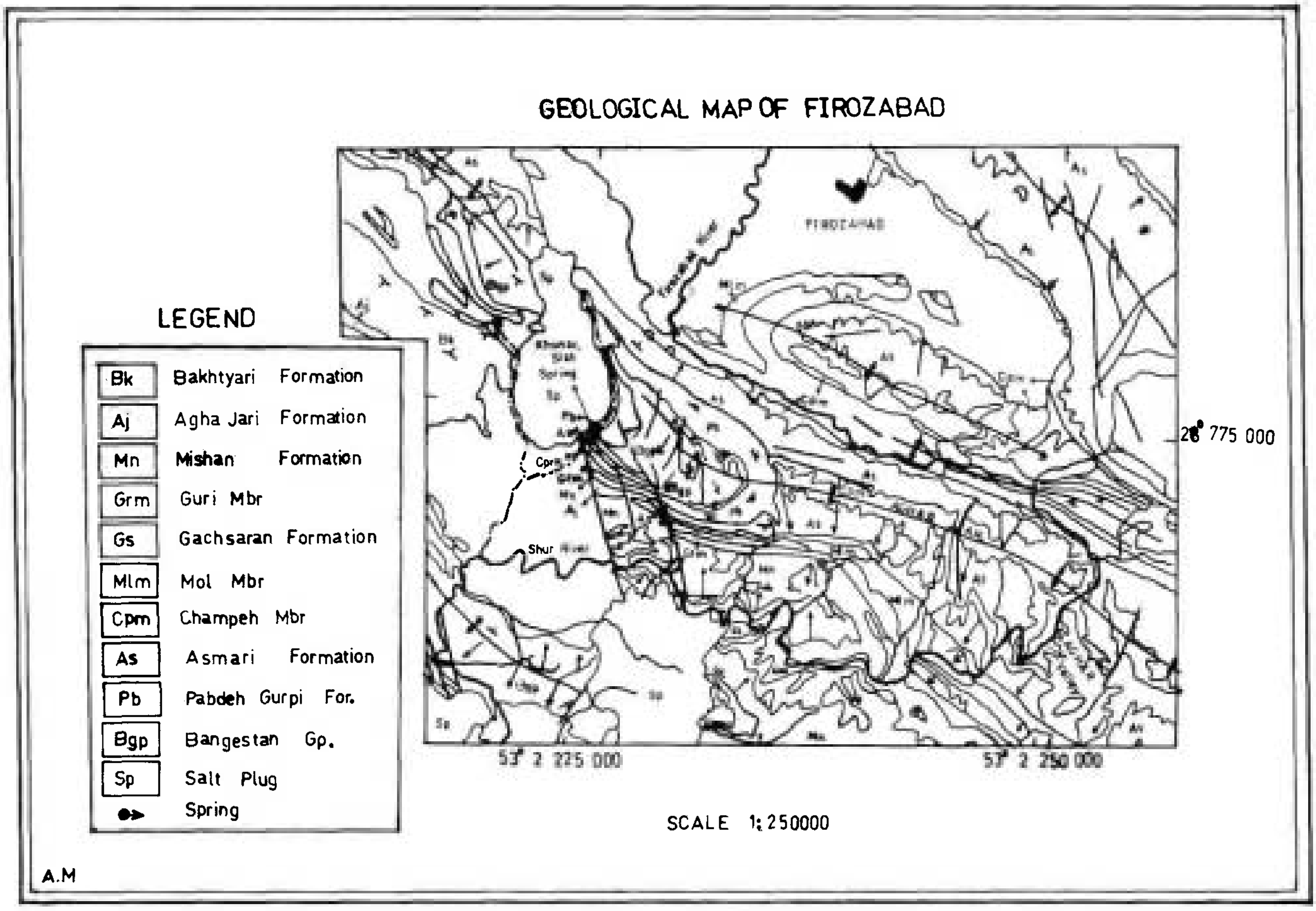


Figure 3. Geological map of Firoozabad.

and numerous subsidence structures.

THE CATCHMET AREA OF THE KONAR SIAH SPRING

The Konar Siah spring flows out from the Sarvak Formation in the contact zone of the Pabdeh-Gurpi Formation and the konar Siah saltdome. The following indications show that the sarvak Formation southeast of the saltdome is the only catchment area for the Konar Siah spring:

1) The Sarvak Formation is hydrologically disconnected from the lower and upper karstic formations, since the Gurpi Formation to the top and the Kazhdumi Formation to the bottom are hydrological barriers.

2) There is no hydrologic connection between the two parts of the Sarvak Formation on either side of the saltdome since the numerous sinkholes in the saltdome drain the water into the valleys around it. In fact, there are numerous small springs which discharge into the valleys.

3) It appears that the transcurrent fault, separating the Sarvak Formation from the southeast part of the saltdome, has crushed the limestone in a way that the fault acts as a barrier to the ground water flow.

4) Part of the contact of the saltdome and the Sarvak Limestone Formation to its southeast consist of consolidated conglomerate. Groundwater flows more easily in limestone than in conglomerate.

5) The Pabdeh and Gurpi Formations act as hydrogeological barriers. They separate the Asmari-

Jahrom Formation from the Sarvak Formation. The Asmari-Jahrom Formation to the northwest part of the slatdome discharges its ground water into the Firoozabad river, while in the southeast they discharge into the Narak and some other smaller springs.

HYDROCHEMISTRY AND HYDROGEOLOGY OF THE KONAR SIAH SPRING

The discharge of the konar Siah spring has been measured monthly (Figure 4). Although a device for daily measuring of the discharge was installed directly at the spring, the data are not reliable due to the changes of the water surface profile in response to the downstream tributary. The daily comparison of the precipitation histogram and the discharge curve are not possible due to lack of daily reliable discharge data. Therefore, the seasonal trends are considered only. Comparison of seasonal changes of discharge and the rain histogram (Figure 5) show that the discharge doesn't change considerably in the wet, 267 l/sec, and dry, 204 l/sec, seasons. This means a relative change of 1.3 and indicates that the karst porosity in the Sarvak Formation is not highly developed. It indicats that the groundwaters have been retarded first in small joint aquifers before joining gradually larger channels. In the high develop karst the groundwaters flow rapidly into major channels.

The spring temperature has been measured regularly (Table 1). It shows that the minimum (24.5°C) varies only slightly from the maximum (26.5 °C). The average temperature is 24.36°C and the coefficient of variation is 0.6°C. The average, maximum and minimum values of atmospheric temperatures are 19°C, 41°C and -1°C respectively. The comparison of spring temperatures and atmospheric temperatures suggests no correlation between the two. Thus, the temperature is rather stable and independent of the air temperature. This implies that the spring temperature is rather dependent on the geothermal gradient. On the other hand, the little changes of the temperature indicates ground water laminar flow [6-8].

Samples have been taken and analyzed at least once a month from February 1991 to March 1992. Major ions like chloride, bicarbonate, calcium, sulphate, sodium, magnesium, potassium magnesium and potassium have been analyzed by standard methods. Electrical conductivity and water temperature were also recorded (Table 1). The results show

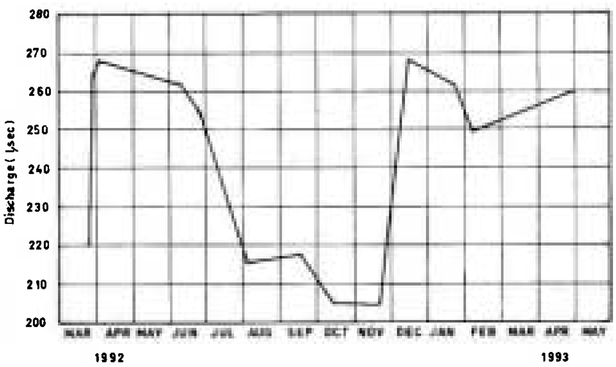


Figure 4. Time variation of discharge in Konar Siah spring in period 1992-1993.

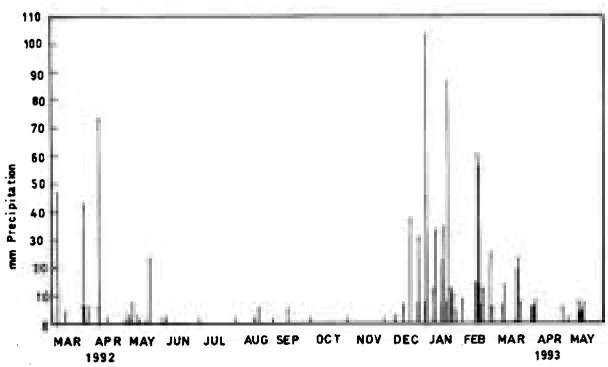


Figure 5. Rainfall histogram in Firoozabad station in period 1992-1993.

TABLE 1. Physical and chemical parameters of Konar Siah spring in period 1992-1993.

Date of water Sampling	Temp. °C	T. D. S. mg/li	E. C. mhos/s	Milliequivalent per liter						
				Ca	Mg	Na	K	Hco	Cl	So
16.3.92		5558.52		6.87	1.90	35.13	0.17	3.73	35.67	1.87
14.4.92		5073.29		6.77	3.47	66.47	5.82	2.87	72.50	8.17
28.4.92		3572.41		6.97	2.15	49.73	0.14	4.90	46.67	6.72
10.5.92		3714.74		5.73	3.16	53.40	0.16	5.00	55.00	1.46
31.5.92		3211.35		6.17	3.47	43.07	0.12	5.00	43.33	4.33
16.6.92		3310.92		2.58	3.25	47.90	0.16	4.77	45.83	4.06
28.6.92		3104.63		2.62	2.42	45.80	0.16	4.03	44.17	3.46
10.8.92		2429.51	5473.3	6.44	2.87	29.97	0.17	4.27	32.97	2.91
22.10.92	24.6	2795.26	5473.3	5.97	3.37	35.30	0.20	5.22	38.17	2.97
8.11.92	24.5	3031.02	5476.6	5.33	3.67	39.03	0.24	6.50	39.50	3.63
21.11.92	24.5	3139.20	5583.3	5.37	4.11	40.97	0.18	6.57	41.03	3.67
7.12.92	24.6	2913.26	5490.0	2.70	3.54	42.10	0.16	4.80	38.96	3.53
24.11.92	24.5	2957.49	5466.6	2.95	2.34	43.15	0.19	4.75	40.00	3.35
11.1.93	25.7	2974.05	5416.6	4.10	1.93	42.37	0.18	4.76	40.33	3.43
30.1.93	24.5	3104.07	5410.0	6.07	2.75	41.83	0.17	4.96	43.17	3.03
22.2.93	24.2	3169.37	5420.0	6.40	3.77	41.93	0.17	5.03	44.33	3.00
7.3.93	26.5	4086.78	5408.3	6.29	2.86	58.83	0.17	4.80	59.23	3.56
6.4.93	26.0		5450.0	4.43	2.30	41.90	0.16	5.05	38.50	
24.4.93	25.5	2871.04	5330.0	4.40	2.96	39.90	0.16	5.06	38.33	3.20
X	24.86	3227.95	5433.2	5.14	2.97	44.10	0.48	4.85	44.15	3.687
SD	00.6	0662.34	0080.6	1.89	30.80	69.70	1.34	0.91	9.92	32.180

that the chloride content of water during the time of observation is very high. The percentage of ions are:

Chloride	44.4%
Sodium	44.1%
Calcium	5.14%
Bicarbonate	4.85%
Sulfate	3.68%
Magnesium	2.97%

Although the Sarvak Limestone Formation is the source area for the Konar Siah spring, the water is not carbonatic like the water of usual karst springs in limestones. The electrical conductivity (EC) is high and averages to 5432 microsiemens, indicating the effect of the contiguous saltdome. Figure 6 shows the seasonal amount of the major ions. Ions of calcium, magnesium, potasium, bicarbonate and sulfate do not change a great deal in the wet (end of the autumn to begining of the spring) and dry seasons (end of the spring to begining of the autumn), while the ions of sodium and chloride show considerable changes. The reason for this phenomenon is the penetration of the saltdome compounds in the Sarvak Limestone Formation. The penetration is only near the contact zone and involves a limited area of the Sarvak Formation, here called the penetration zone. Since the groundwater inside the Sarvak Formation cannot flow downward due to the underlying Kazhdumi Shale Formation, it flows to the regionally lower located Konar Siah spring.

In the wet season, the rainwater which infiltrates through the vadose zone in the penetration area dissolves more saltdome compounds compared to the rainwater passing through uncontaminated area. The dissolution of saltdome compound in the penetration during the dry season, because the stored water in the penetration zone with a low residence

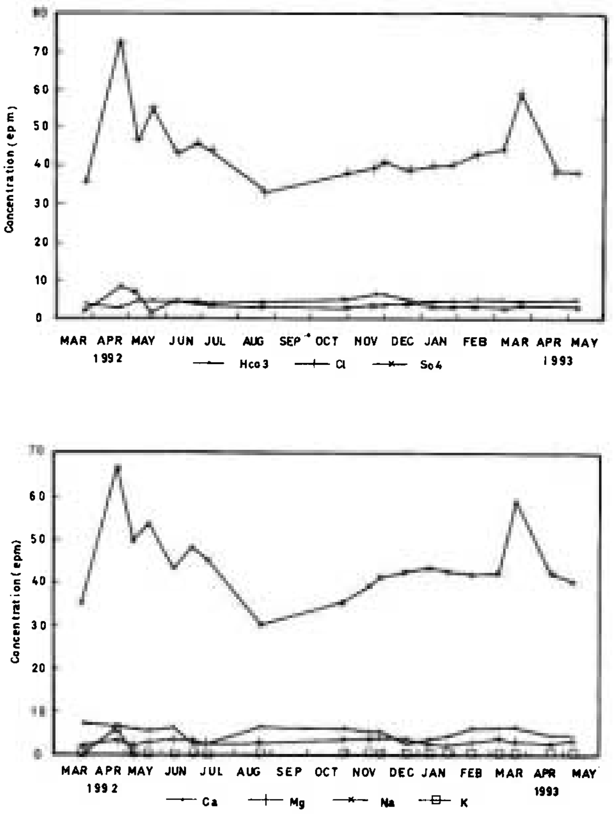


Figure 6. Time variation of chemical parameters of Konar Siah spring in period 1992-1993.

time, discharges quickly at the early stages of the dry seoson. Therefore the groundwater flows only through larger karst channels having longer distances beyond the Penetration Zone. As a result, the water contains less saltdome cotnpounds.

A MODEL FOR THE GROUNDWATER FLOW OF THE KONAR SIAH SPRING

The source area of the Konar Siah spring is the Sarvak Limestone Formation to the southeast of the saltdome. The limestone is covered by soil to a considerable extent. The rainwater which is infiltrated into the soil, passes gradually through the pores and fissures of the underlying limestone. Accordingly the joint density on the outcropped patches of the limestone, due to tectonic activities, is very high. Therefore, the rain water is distributed through the whole bulk of the limestone. Major channels and large caves have not been formed. Probably only near the Konar Siah spring, the water drains into larger drainages before discharging. The karst water flows predominantly laminar in the bulk of the Sarvak Formation. When it reaches the Penetration Zone near the saltdome, it becomes contaminated and its quality deteriorates rapidly. Near the spring, it breaks down to turbulent flow.

The water of the Konar Siah spring is, due to its high electrical conductivity, of limited value for agricultural purposes. By geophysical methods the Penetration Zone must be outlined, and the water tapped before reaching it.

ACKNOWLEDGMENT

This study has been supported by the Research Council of Shiraz University. Mr. M. M. Rasuli, head of the Protectional Office of the Water Resources in Firoozabad, and his collegues Mr. Parvar and Mr. Moradi helped with the field work and provided data. Students Nuri, Moradi, Tavana and Karami also helped with the field work.

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