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THE EFFECT OF DARAB SALT DOME ON THE QUALITY OF ADJACENT KARSTIC AND ALLUVIUM AQUIFERS (SOUTH OF IRAN)*

VPLIV SOLNE DOME DARAB NA KVALITETO VODE SOSEDNJIH KRAŠKIH IN ALUVIJALNIH VODONOSNIKOV (JUŽNI IRAN)

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Sharafi, A. Raeisi, E. & Farhoodi, G.: Vpliv solne dome Darab na kvaliteto vode sosednjih kraških in aluvijalnih vodonosnikov (Južni Iran)

Zakrasele kraške formacije vsebujejo najpomembnejše vodne vire osrednjih delov jugovzhodnega Irana. Če kraška voda ni onesnažena zaradi slanih dom, je v tem delu Irana njena električna prevodnost pod 500 µS cm^{-1}. Področje raziskav je južno krilo antiklinale Shahneshin-Milk, 200 km vzhodno od Shiraza, ki sodi v narivno cono Zagrosa. Kraška formacija Tarbur (zgornji Campanij-Maastrichtij) izdanja v južnem krilu antiklinale Shahneshin-Milk, pod katero je neprepustna radiolaritna formacija. Solna doma Darab izdanja znotraj zakrasele formacije Tarbur. Iz formacije Tarbur priteka več izvirov. Kvaliteta vode vseh izvirov je v mejah neonesnažene kraške vode razen treh, ki so v bližini solne dome. Električna prevodnost teh treh izvirov je med 1200 in 2000 µS cm^{-1}. Del aluvija okoli solne dome je slano močvirje, ki ga obrobljata dva kanala. Električna prevodnost močvirske vode pod nivojem talne vode je okoli 1400 µS cm^{-1}, v večjih globinah pa se zmanjša na 400 µS cm^{-1}. Odtok s solne dome Darab in prenikanje vode nizke kakovosti iz kanala sta najbrž glavna vzroka za nastanek slanega močvirja. Pomemben delež onesnažene kraške vode iz Tarburja ne teče proti močvirju, saj, prvič, večina kraške vode iz Tarburja priteka na dan skozi izvire, in drugič, na globlje plasti aluvijalnega vodonosnika onesnažena voda ne vpliva.

Ključne besede: kraška hidrologija, vodonosnik, kemizem vode, onesnaževanje voda, solna doma Darab, Jugovzhodni Iran.

Abstract UDC: 556.34(55)

Sharafi A. & Raeisi E. & Farhoodi G.: The Effect of Darab Salt Dome on the Quality of Adjacent Karstic and Alluvium Aquifers (South of Iran)

Karstified carbonate formations are among the most important water resources in the south-central regions of Iran. If the karst water is not contaminated by salt domes, the electrical conductivity of water in the karst aquifer is less than 500 µS cm^{-1} in the south-center of Iran. The study area is located in the southern flank of Shahneshin-Milk anticline, 200 km east of Shiraz. This region is situated in the Zagros Thrust Zone. The Tarbur karstic formation (Late Campanian-Maastrichtian) is outcropped on the southern flank of the Shahneshin-Milk anticline which is underlain by the impermeable Radiolarite formation. The Darab salt dome outcrops inside the karstified Tarbur Formation. Several springs emerge from the Tarbur Formation. The quality of all springs is in the range of unpolluted karst water except for three springs which are located near the Darab salt dome. The electrical conductivity of these springs range from 1200 to 2000 µS cm^{-1}. Part of the alluvium near the Darab salt dome is salt-marsh which is bounded by two channels. The electrical conductivity in the salt-marsh below the water table is about 1400 µS cm^{-1}, and it reduces to 400 µS cm^{-1} at the lower depths. Run-off from the Darab salt dome and seepage from the channel with low quality water are probably the main reasons of salt-marsh development. A considerable amount of polluted Tarbur karst water does not flow towards the marshland because, firstly, most of the Tarbur karst water discharges from the springs, and secondly, the alluvium aquifer is not affected by polluted water at lower depths.

Key words: karst hydrology, aquifer, water chemistry, water pollution, Darab salt dome, Southeastern Iran.

INTRODUCTION

There are about 200 salt plugs in the southern part of the Zagros Mountain Range and the Persian Gulf, Iran (Kent 1970). The salt dome of Infra-Cambrian age (Hormuz Formation) protrudes through younger formations. It moves upward due to the buoyancy, the lateral pressure resulting from the opening of the Red Sea to the southwest, and the weight of several thousand meters of overlying sediments. It emerges like a mushroom and its movement is facilitated where the area is more fractured. Karstified carbonate rocks outcrop on about 23 per cent of the south central region of Iran (Raeisi and Kowsar 1997). In this region, karst waters which are not in direct contact with salt domes or gypsum evaporite formations have good quality, usually with electrical conductivities of less than 500 µS cm^{-1} (Raeisi and Moore 1993). In some parts of the Fars Province, the salt protrusions are adjacent to the carbonate karst formations or alluvium, reducing the quality of adjacent aquifers (Raeisi et al. 1996; Sharafi et al. 1996). The Tarbur karstic formation (Late Campanian-Maastrichtian) outcrops in the southern flank of the Shahneshin-Milk anticline which is underlain by the impermeable Radiolarite formation. The Darab salt dome outcrops inside the karstified Tarbur Formation. The water qualities of the three springs and adjacent alluvium which are located near the Darab salt dome are not in the range of karst water. The objective of this study is to determine the source of salinity in the study area.

GEOLOGICAL SETTING

The study area is located 200 km east of Shiraz, southern Iran. This region is situated in the Zagros Thrust Zone. The Thrust Zone represents the deepest part of the Zagros geosyncline. Marine deposits accumulated up to 5300 m in the Mesozoic and Early Tertiary times (James and Wynd 1965). In this zone, older Mesozoic rocks and the Paleozoic platform cover were thrust on the younger Mesozoic. The stratigraphy and structural characteristics of the Zagros sedimentary sequence have been described by James and Wynd (1965) and Falcon (1974). The outcropped geological formations in decreasing order of age are the Paleozoic Hormuz salt dome, Cretaceous Bangestan Group (marl and karstified limestone), Cretaceous Radiolarite, Tertiary Tarbur limestone, and Tertiary Jahrum limestone and dolomite formations. The study area is located in the southern flank of the Shahneshin - Milk anticline. The Darab salt dome is outcropped in the southern flank of this anticline and it is surrounded by the Tarbur karstified Milk aquifer, impermeable Radiolarite, and an alluvium plain (Fig. 1). The largest and smallest diameters of the Darab salt dome are 1.3 and 0.3 km respectively. The Darab salt dome is covered by gypsum, limestone, and algal dolomites of the Hormoz formation. The height of its summit is about 1316 m above sea level, and about 300 m above the surrounding plain.

Two Tarbur karstic aquifers, Milk and Shahneshin, are located in the eastern and western part of the Darab salt plug respectively. The Tarbur Formation is underlain by the Radiolarite formation which has low permeability and prevents vertical movement of water. An alluvial zone is located in the western part of the salt dome, which is probably underlain by a Radiolarite unit.

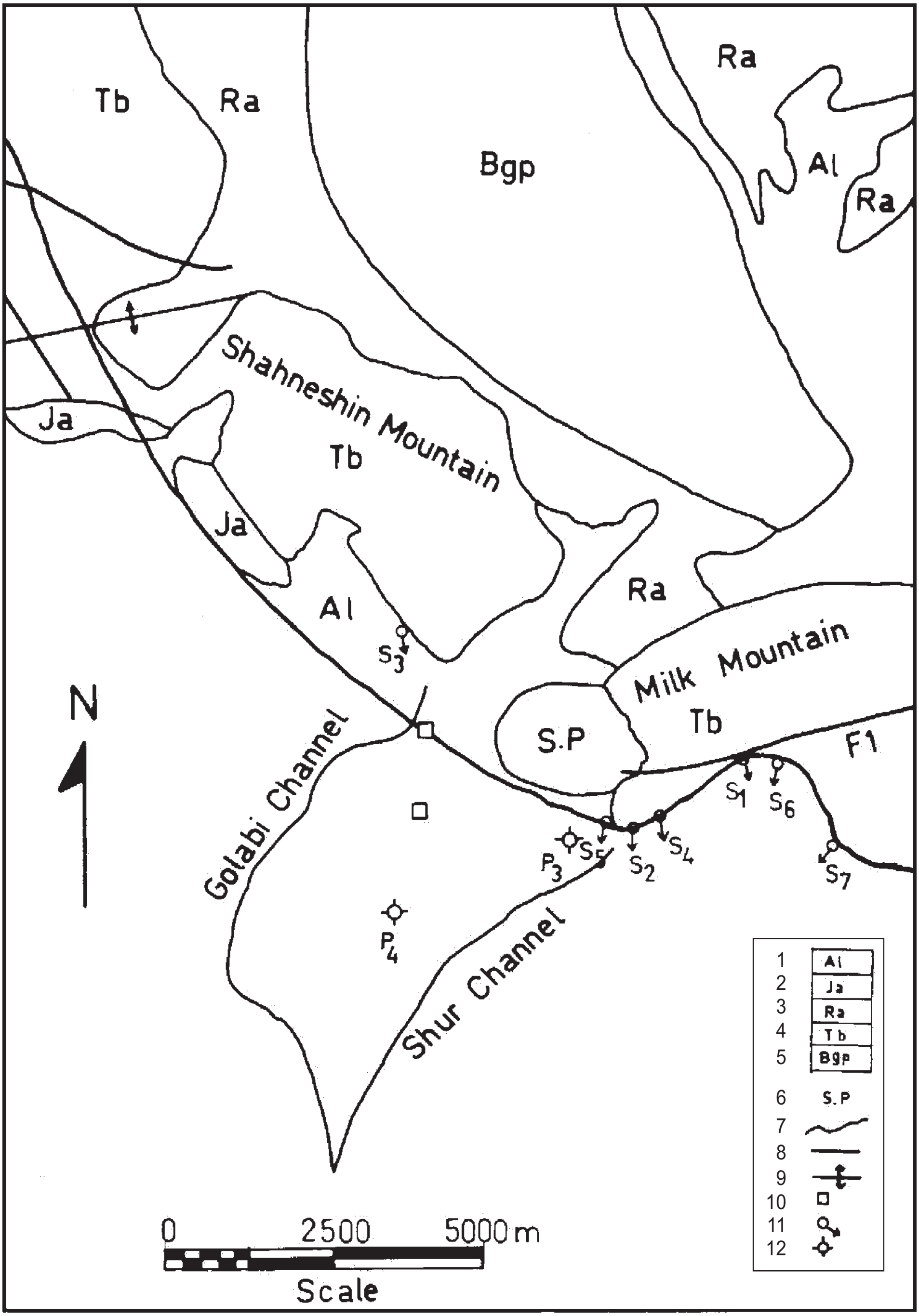

Fig. 1: Geological map of the study area (legend on page 109).

THE EFFECT OF THE SALT DOME ON THE ADJACENT KARSTIC AQUIFERS

Groundwater from the Milk aquifer discharges from 6 springs, namely the S7 spring, Tizab spring (S6), Shahijan spring (S1), Bonaki spring (S4A, S4B), Shur spring (S2), Hamami spring (S5). The Golabi springs (S3) emerges from the Shahneshin aquifer. The spring locations are shown in Fig. 1. Discharges of some of the springs are presented in Table 1.

Table 1: The discharge of main springs in the study area (lit/sec).

Year	1958	1974	1976	1987	1990	1992
Shahijan Spring	315	380	250	195	175	338
S7, S5 and S1 spring	336	318	230	164	164	363
Golabi Spring	333	515	260	790	773	1073

Table 2: Chemical analysis of Darab salt dome springs.

Sample	T	No. on Fig. 1	EC	PH	CO_3	HCO_3	CL	SO_4	Na	Ca	K	Mg
S7	26	S7	390	7.2	?	3.95	0.65	0.75	1.02	2.7	0.03	1.3
Golabi A	26.1	S3	520	7.3	_	3.8	1.35	1	1.93	3.3	0.03	1.5
Golabi B	26.1	S3	520	7.3	_	3.8	1.35	0.92	1.93	3.2	0.03	1.3
Shahijan	26.2	S1	410	7.4	_	3.4	0.7	0.69	1.14	2.7	0.03	1.3
Shur	26.4	S2	1490	7.7	_	3.45	13.9	1.46	16.7	2.5	0.06	1.5
Hamami	26.3	S5	1240	7.7	_	3.35	11.6	1.38	13.38	2.5	0.05	1.4
Bonaki A	26.1	S4	1480	7.8	_	3.5	13.1	1.55	16.14	2.6	0.07	1.6
Bonaki B	25.4	S4	1970	8.1	_	3.4	20	2.17	22.4	2.2	0.08	2.3
Tizab	26.1	S6	410	7.9	_	3.4	1	0.85	1.26	2.2	0.05	1.8

Legend to Fig. 1 (on page 108): 1 - Alluvium; 2 - Jahrum Fm.; 3 - Radiolarit; 4 - Tarbur Fm.; 5 - Bangeslan group; 6 - Salt Plug; 7 - Formation Boundary; 8 - Fault; 9 - Anticlinal axis; 10 - Village; 11 - Spring; 12 - Piezometer.

The electrical conductivities of Shahijan, Tizab and S7 springs are less than 410 µS cm^{-1} and the type of water is calcium bicarbonate. The electrical conductivity of Bonaki springs, Shur spring and Hamami spring range from 1240 to 1970 µS cm^{-1} and the type of water is chloride (Table 2). The waters of these springs are directed into a Shur channel and they are collectively called the Korsiah springs. The chemical analysis of these springs (Table 2) reveals that S7, S6 and S1 are not affected by the Darab salt dome, while the Korsiah springs (S5, S4 and S2) are polluted by it. The following justifies the good quality of S7, S6 and S1 springs.

1. The general direction of flow is from the eastern part of the Milk aquifer toward the Darab salt dome. The F1 fault may have a positive effect on canalizing the karst water. Therefore the Darab salt dome is located near the outlet part of the Milk aquifer.
2. The impermeable Radiolarite formation is located beneath the Milk aquifer, and the Darab salt dome is not extended to the region of high quality springs. The distance between S4 and S1 is about 1.5 km, which confirms the lack of extension of the salt dome beneath the Milk aquifer.
3. The groundwater level around S1 is at least 20 m higher than around S4, (Ab-Niroo Consulting Engineers 1993) such that it can prevent the intrusion of saline water beneath the Milk aquifer.

The following justify that the Darab salt dome is the main source responsible for decreasing the quality of the Korsiah (S5, S4 and S2) karst springs:

1. There are no formations having halite mineral in the catchment area of Korsiah springs, and the Darab salt dome may be extended beneath the area of these springs.
2. The saline water of the Darab salt dome may mix with the karst water near the emergence points of low quality springs.
3. The quality of Korsiah karst springs may be reduced due to dispersion or intrusion of salt dome saline water.

The electrical conductivity of Golabi spring (S3) is about 520 µS cm^{-1} and the type of water is calcium bicarbonate. The quality of this spring is not affected by the Darab salt dome. All the discussions mentioned about springs S7, S6, and S1 are also valid for the lack of effect of the Darab salt dome on this spring. In addition, there is no direct contact between Shahneshin and the Darab salt dome. The Radiolarite Formation is most probably located beneath the adjacent alluvium, preventing the intrusion and/or dispersion of saline water into the Shahneshin aquifer.

THE EFFECT OF THE SALT DOME UPON THE ADJACENT ALLUVIUM

The area which is surrounded by the Golabi and Korsiah channels is salt-marsh, and it is not suitable for agricultural uses (Figure 1). The hydrogeology of the marsh area is reported by Ab-Niroo Consulting Engineers (1993). Piezometer No.3 which is located at a distance of 750 m south of the salt dome, had an initial water table of 8 m at the start of drilling and 5.5 m at the end of the drilling. The lithology of Piezometer 3 was mostly fluvial sand. The electrical conductivity at the depth of 10 m below the ground surface is from 1286 to 1448 µS cm^{-1} and it decreases to 504 µS cm^{-1} at a depth of 54 m. Electrical conductivity varies from 830 to 960 µS cm^{-1} up to the depth of 96 m. This implies that the effect of the salt dome on the ground water is limited to the top part of the alluvium aquifer and the depths are much less polluted by the salt dome. The low quality of groundwater at the top part of the alluvium aquifer may be due to the infiltration of salt dome runoff into the alluvium aquifer. The salt deposit is observed on the surface of the marsh region. The causes for such small effects of the salt dome on the adjacent alluvium need to be investigated through more research; however, they may be due to following reasons:

1. Ground water of the salt dome has been mostly directed toward the adjacent Tarbur formation and it emerges mostly from S4, S2 and S5 springs because the hydraulic gradient is much lower in the karstified limestone than in the alluvium aquifer.
2. An impermeable layer may be located between the salt dome and the alluvium. This could be confirmed by drilling a borehole near the salt dome.
3. The main source of the alluvium aquifer is generally from the adjacent limestone formations, and the amount of water from the salt dome is not enough to reduce the quality of alluvium aquifer prominently.

CONCLUSION AND RECOMMENDATION

The Darab salt dome does not have a considerable role in reducing groundwater quality of the adjacent karstic aquifer and alluvium. The salt dome is located downstream of the resurgence points of Milk and Shahneshin aquifers, therefore firstly preventing mixing of saline water and karst water, and secondly reducing the dispersion and intrusion of saline water into the karst water. The Radiolarite formation partially disconnects the hydro-geological relationship of the salt dome and alluvium and karst aquifers. If groundwater quality needs to be increased, the direction and discharge of groundwater flow in the salt dome should be determined. The salt dome water may be drained by pumping wells or qanats. The drained salt water could be evaporated in evaporates basins. The effect of the salt dome on the adjacent alluvium aquifer may be reduced by the following methods.

1. The surface of the salt dome can be mulched to prevent the precipitation infiltration into the salt dome.
2. The salt dome run-off can be directed into an impermeable channel. This channel can join a large river downstream, with a flow rate high enough to diminish the effect of salt dome run-off.
3. The Korsiah channel along the marsh region can be lined by an impermeable cover, preventing the seepage of low quality water of the Korsiah springs into the alluvial aquifer.
4. The water table is high near the ground surface in some parts of the marsh region. A drainage system could reduce evaporation from groundwater and consequently salt concentration on the surface.
5. The exploitation of karst water is recently increasing due to the construction of pumping wells. It reduces the share of karst water in the Korsiah springs, therefore the salinity of these springs may increase in the future. In addition, it may decrease the level of karst water, increasing the dispersion and intrusion of saline water into the karst aquifer.

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VPLIV SOLNE DOME (DIAPIRJA) DARAB NA KVALITETO VODE SOSEDNJIH KRAŠKIH IN ALUVIJALNIH VODONOSNIKOV (JUŽNI IRAN)

Povzetek

Zakrasele kraške formacije vsebujejo najpomembnejše vodne vire osrednjih delov jugo-vzhodnega Irana. Če kraška voda ni onesnažena zaradi slanih dom, je v tem delu Irana njena električna prevodnost pod 500 µS cm^{-1}.

V južnem delu gorovja Zagros je okoli 200 solnih dom - diapirjev. V celotnem južnem delu osrednjega Irana predstavlja kras 23 % površja. Področje raziskav, opisanih v tem prispevku, je južno krilo antiklinale Shahneshin-Milk, 200 km vzhodno od Shiraza. Sodi v narivno cono Zagrosa. Kraška formacija Tarbur (zgornji Campanij-Maastrichtij) izdanja v južnem krilu antiklinale Shahneshin-Milk, pod katero je neprepustna radiolaritna formacija. Solna doma Darab izdanja

(1,3 × 0,3 km, 300 m nad okoliško ravnino) znotraj zakrasele formacije Tarbur. Iz formacije Tarbur priteka več izvirov. V prispevki avtor ugotavlja vzrok zaslanjenosti nekaterih izvirov.

Voda iz vodonosnika Milk izteka skozi šest izvirov. Kvaliteta vode treh izvirov je v mejah neonesnažene kraške vode. Trije, ki so v bližini solne dome, pa imajo večjo vsebnost soli oziroma povečano specifično električno prevodnost, med 1200 in 2000 µS cm^{-1}. Zaradi usmerjenosti kraške talne vode, zaradi neprepustne radiolaritne plasti, ki loči solno domo od kraškega vodonosnika in zaradi relativno višje gladine talne vode v krasu, prvi trije izviri niso zaslanjeni. Zaslanjeni izviri pa so bliže solni domi in v njihovem zaledju ni drugih plasti, ki bi vsebovale halitne minerale.

Del aluvija okoli solne dome je slano močvirje, ki ga obrobljata dva kanala. Električna prevodnost močvirske vode pod nivojem talne vode je okoli 1400 µS cm^{-1}, v večjih globinah pa se zmanjša na 400 µS cm^{-1}. Odtok s solne dome Darab in prenikanje vode nizke kakovosti iz kanala sta najbrž glavna vzroka za nastanek slanega močvirja. Pomemben delež onesnažene kraške vode iz Tarburja ne teče proti močvirju, saj, prvič, večina kraške vode iz Tarburja priteka na dan skozi izvire, in drugič, na globlje plasti aluvijalnega vodonosnika onesnažena voda ne vpliva.

K sanaciji zaslanjenih izvirov bi lahko pomagali naslednji ukrepi:

- površje solne dome bi lahko prekrili (mulčili), da vanjo ne bi prenikale padavine;
- odtok z dome bi lahko speljali v neprepusten kanal in napeljali niže v reko, kjer bi se slanost dovolj razredčila;
- kanal vzdolž močvirja bi morali zatesniti, da ne bi voda iz zaslanjenega izvira zatekala v aluvijalni vodonosnik;
- z ustreznim drenažnim sistemom bi bilo mogoče zmanjšati evaporacijo in s tem koncentracijo soli na površju;
- zaradi povečanega črpanja priteka v zaslanjene izvire manj neoporečne vode in je zato koncentracija soli še višja.