Investigation of the diapirism effect on increasing salinity and solubility of water resources: a case study in eastern Tehran Province

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Received: 23 June 2020 / Accepted: 21 December 2020 / Published online: 15 January 2021
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Abstract

The water potential in east of Tehran plain is different due to a variety of evaporative formations and the effects of fault structures and diapirism. In this study, the relationship between features of water sources, especially salinity with geologic settings and a structural property, is investigated. A field investigation was performed after determining the study range in the Eyvanekey area to identify the geological formations and distribution there along with the faults and salt domes locations using geological maps. Afterwards, by identifying the wells' location and by using the decomposition results of water samples of the area, the concentration contour maps of chloride, sulphate, and sodium, among others, were plotted. The faults' performance and the plotted maps' interpretation showed that the highest salinity concentration lied in the eastern and southern parts of the plain; their change trend occurred in highlands towards central and western parts of the study range, which is consistent with the main river path. Considering the qualitative results of the water, the eastern and southern parts of the plain are typically of sodium chloride nature, while the water of the area is classified as non-potable in terms of potation and harmful saline with regard to agricultural use. The study findings showed that the high evaporative mass erosion rate, and gypsum and saline sediment transport have developed saline fields in the plain. On the other hand, disorganized exploitation of water sources has considerably reduced the water quality and increased the salinity in the area.

Keywords Diapirism · Water quality · East Tehran · Eyvanekey

1 Introduction

Geological structures play a major role in determining the composition of groundwater. The qualities of groundwater in different areas adjacent to evaporative formations indicate that a large variety of formations, geological structures, and hydrological factors are involved. The geological and hydrochemical analysis, along with decomposition of water well samples, determines that the existence of evaporative formations is greatly effective in determining the quality of water in the best part of such areas. Suitability of water for various uses depends on the types and concentrations of dissolved minerals, with groundwater having

more mineral compositions than surface water [1, 2]. Many researchers have examined the problem of water sources and soil management and accordingly proposed different methods. We will deal with some of those methods below.

Cheragi et al. [3] in their studies on over-exploitation of groundwater and the relevant impact on south-western Abu Dhabi concluded that the tectonics and topography of the area have considerably affected the quantitative and qualitative changes of the water in the area. Hydrochemical features of the groundwater and the governing relationships in Ravar region (Kerman Province) measure the main ion content amount in the waters and calculate the saturation index of different minerals in the river paths.

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From this, it could be concluded that the existing prevailing ions in the geological formations and especially chloride and sulphate are responsible for the presence of high solvent content in the waters. Heydarizadeh et al. [4] determined the layers affecting the chemistry of Kardeh River water and their significance by using stoichiometry and ion ratio methods. They concluded that the presence of carbonated and evaporative units covering the best part of the basin, together with their high dissolution strength, has caused a high concentration of calcium and magnesium cations and bicarbonate and sulphate anions in the river water and constitutes the main portion of the ions in the river. Lashkari et al. [5] in their study, which analysed the groundwater quality of Iranshahr plain, determined the water type by sampling from 22 selected wells in the plain aquifer. They showed that petrology has affected the change trend of the water type in some parts of the aquifer and that the contact between groundwater and adjacent geology formations has increased the soluble solid material content in the water. The reason was the contact of water with anhydrite and lime clay layers of the Gachsaran evaporative formation and frequent faulting. Gasemi et al. [6], in their analyses of the chemical quality of the Shourlaq basin in Sarakhs, Khorasan Razavi Province, concluded that the difference between types of formations in the basin has produced major differences in groundwater quality. Moayeri et al. [7] investigated the diapirism phenomenon and its effect on the contamination of the Dehram saline river, one of the most important sources of surface water in Fars Province of Iran. They concluded that about 95% of salinity of the river emanates from the salt domes as well as from saline evaporative formations and springs, which makes the water inconsumable both for potation and agricultural use. Omar et al. [8] studied on the physicochemical and biological properties of water samples in Shoubak south of Jordan conclude that the ground water salinity resulted from the Halite and gypsum solution from the adjacent formations, sudden increase in the sodium chloride content in some parts of the plain and composition of sodium chloride water which renders the area water as inconsumable. The Amman-Zarqa Basin (AZB), the most vital basin in Jordan, is facing recent groundwater deterioration due to large increases in water demands, quantifying the degree of contamination in the basin by evaluating the characteristics, distribution, and seasonal variations of pollution showing salinity concentrations [9]. The reasons of an increase in groundwater salinity are numerous, including aridity, the nature of the aquifer rocks, groundwater recharge, aquifer thickness and over-pumping, and excessive consuming of groundwater in the Abu Dhabi Emirate, UAE [10, 11]. An example based on a salt dome of the Central European basin system will elucidate the effects of thermal anomalies on oil maturation.

In the second part, an example of fluid flow inside salt structures is given, and particular focus will be placed on the effects of salt-induced temperature disturbances on groundwater flow processes. Numerical examples of thermally driven brine flow based on the north-east German basin are subsequently described [12]. Karimi et al. [13] examined the chemical properties of Eyvanekey plain groundwater in terms of drinking as well as industrial and agricultural use. The analysis results showed that along the east–west direction and with the change in the geological formations' nature, together with the expansion of Gachsaran evaporative formation, the quality of water severely declined. The studies on the groundwater quality of the Dashte-Abbas plain located south-east of Ilam and north-west of Khouzestan Provinces, the chemical analysis of the samples showed that the dissolution of materials constituting aquifer-feeding formations like gypsum and anhydrite as well as factors like evaporation, drop of the hydrostatic level, and possibly the penetration of oil saltwater from the oil-field adjoining the southern borders of the plain contributing to the salinity of the plain groundwater [14]. Accordingly, some studies have applied both methods in determining the main probable source of pollution (MPSP) of groundwater [15]. Ionic ratios and statistical analyses, particularly principal components factor analysis (PCFA), have been used in several studies to determine the MPSP of water resource systems or individual water bodies [16], while some studies have determined the MPSP of ground water using only ionic ratios [17].

2 Materials and methods

Initially by collecting the geological and hydrogeological data, along with field studies, the location of evaporative masses and clastic rocks were determined. Hence, the formations effective in the water sources' quality were identified, and, besides, the tectonics and geological structures for specifying the quantitative changes of water were studied. In the next stage, water wells in the area were identified and their locations were mapped, and all the relevant basic data were entered into the geographical information system (GIS). Based on water sampling from selected wells, chemical analysis and water quality was performed Semnan Regional Water Company. The alluvium and aquifer status of Garmsar and Eyvanekey was determined and the static water table, the discharge rate, and the annual exploitation underground water level of the plain were investigated by preparing the required maps in GIS software environment. Also, the existing data of 22 exploitation water wells and the Eyvanekey plain Piezometer were used for plotting the water quality maps and different quality graphs, which were used for quality

interpretation of the groundwater sources. After plotting the water quality and concentration contour maps of the relevant elements, especially of sodium and chloride, the relationship between the solvents and the salinity rate with evaporative masses, and the salt dome location effect were evaluated. Accordingly, this paper evaluates the water sources and the relationship between the aquifers located in the above-mentioned range with tectonic structures and petrology.

2.1 Geomorphology and geological setting

Eyvanekey Township is located 60 km from south-eastern Tehran and 25 km west of Garmsar Township. The average height of the plain is about 1020 m from sea level, and it lies in the geographical range between 51°, 20'–51°, 50' eastern longitude and 35°, 15'–35°, 23' northern latitude. The Eyvanekey drainage basin is limited northwards to Tar and Eynvarzan lake heights, westwards to the heights overhanging the Damavand River, eastwards to the heights overhanging the Hablehrood River, and southwards to Kouhesorkh gypsum and salt formation. The ruling general slop trend of the plain is north to south, with two partial west–east slopes [18]. Garmsar plain is one of the most important ranges located in the central Iran drainage basin in terms of water sources, which is significantly crucial for supplying potable and agricultural water of the area, especially west of Semnan Province. The plain is often classified as belonging to cold dry to semidry climatic regions of the northern areas. Climatic precipitation is one of the most important as well as most variable climatic factors; its type, amount, and severity vary for different regions and month of the year. Based on the statistics gathered by the Eyvanekey pluviometry station, the average amount of precipitation during the past 23 years was equal to 145 mm per year the wet and dry periods recorded 205 and 78.5 mm for the highest and lowest annual precipitations, respectively. The oldest rocks' outcrop in the area belongs to Eocene and Oligocene. Nowhere a regular sedimentary layer is seen to enable the researcher to identify and compare the relationship between. The oldest rocks of the region with the outcropped rocks include the evaporative set accompanied by the volcanic rocks as well as the relationship between the foregoing set with the younger rocks of the Qom formation and the upper red formation [19]. Although disorder resulting from the salt movements, together with young tectonic of the region, prevents from specifying a very clear sedimentary layer, it could still be possible to segregate specific petrology units. In the understudy area, in addition to diapirism, the upper red formation and the young sediments have the highest expansion. Generally, the area formations include the lower clastic and evaporative formation, Qom limestone

formation, upper red clastic and evaporative formation, Hezardarreh conglomerate and the present era sediments [20]. In Garmsar zone (Kalarz Mountain), the Qom formation has been divided into two parts, separated from each other by a gypsum layer of lower Miocene. Also, the lime outcrops of Qom formation towards north of the area (north of Bonehkooh) has outstanding outcrop.

2.2 Structural geology

The tectonic of Eyvanekey–Garmsar region and the surrounding areas indicates that the diapirism of the area is in direct relationship with the regional faults' trend and is considered a contributory factor in salt surface movements in the area [21]. This movement, among others, is one of the significant properties of the salt, produced by the gravity and height difference of the diapirs with the adjoining plains, causing downward movement of the salt. The most important faults of the area are described as follows:

2.2.1 Garmsar fault

This fault, 90 km in length, is located north of Garmsar and with west–east direction reaches the Pishva fault that lies to the south of Varamin.

2.2.2 Pishva fault

This fault with the north–west–south–east direction begins from Pishva and continues for 30 km. It is finally buried under the alluviums in the west.

2.2.3 Eyvanekey fault

This fault with a length of 75–80 km continues from south–west Tehran (Mesgarabad) to east Eyvanekey. It seems likely that this fault initiates many of the major and minor earthquakes taking place in Tehran range, which are usually attributed to the set of sheer faults.

2.2.4 Kalarz fault

This fault lies 31 km from Garmsar city with the east–west direction. The western end of this fault could be considered to be in relation with the Parchin fault, causing the positioning of the lower part of the upper red formation on the intermediate section of this formation; Qom formation has over thrust on the upper red formation in each intermediate section of the fault; it interrupts the Pliocene deposits on the western part [22].

It should be noted that the drainage basin ending in the Eyvanekey plain joins Mosha–Fasham from the north over

thrust, the desert margin trust fault (Pishva fault) from the south, and Fasham-Kahrizak from north-west and south-east directions. The Eyvanekey plain lies on the east–west axis primarily has taken a syncline form due to the destructive flow of great floods and then has been filled with new sediments resulting from the destruction of the heights by the surface flows, thereby creating the Eyvanekey groundwater table. The presence of lower quaternary alluvial terraces in the south-west of the plain and on the hillside of the Jajrood and Varamin alluvial cone has probably been the initial bed of the Jajrood River in previous eras. The contact between south-east formations of siltstone and the marl drainage basin with gypsum and salt formation is often faulted and into different directions.

2.2.5 Diapirism

Salt domes (diapirs) are common geological features of sedimentary basins. Owing to their physical and structural properties, salt diapirs strongly influence the temperature field of sedimentary basins. Temperature disturbances in the vicinity of salt domes strongly control groundwater transport processes since they provide the coupling between hydraulic and thermally driven forces. [12]. The worse conditions and presence of degraded lands in the area are related to more natural causes like arid climate and geological formations such as salt domes [23]. Sometimes, in the study area, small and scattered blocks of limestone are seen on the salt domes, which, in terms of petrological features, are similar to Qom formation with the difference that the mentioned limestone has been totally tectonized and crushed under the effect of diapiric movements of salt. Considering the presence of Qom limestones on the salt domes, the diapiric sedimentation age in this area is older than Qom limestones. Towards the east and south of the Eyvanekey region, the diapirism includes the large masses of evaporative (gypsum and salt), purple red clay, shale, and scattered volcanic stones that are a bit higher than the adjacent grounds and broad faults interrupt the upper red formation, Qom formation, and the younger formations (including Hezardarreh conglomerate); this diapirism has caused cluttering of the structural and stratigraphy order of the area. There are scattered masses of volcanic rocks inside the area. The area's diapirs level is almost flat or in the form of small hills and has Karst-like topography in some parts. The best part of diapirs comprises salt, although no further information is available concerning the base. But there is purple-coloured marl above salt. And it is traceable almost everywhere. The existing salt outcrops inside the diapirs smaller in height compared with other diapiric parts and along the faults and valleys with washed cap rock. The salt outcrop on the surface is covered almost everywhere with a thin

layer of clay. The upper part of salt masses mainly includes clay and silt layers, and alternatively green, red, cream, and white to smoky layers are seen in the Eocene–Oligocene transition. The alluvial units of the Eyvanekey plain containing the main groundwater sources of the area have been formed by the transport of materials resulting from the destruction of conglomerate, sandstone, tuffs, and other old rocks that have been put in their places by the Namrood River and other flood ways in the area. The bedrock of the plain is from Hezardarreh conglomerates that have been covered by Nemarm alluvial fans' sediments and other flood ways. The thickness of the alluvium is different, and this thickness reaches up to 300 and 50 m in northern and southern parts of the plain, respectively. These alluviums belong to quaternary. The erosion of conglomerate and sandstone formations in the north and centre of the plain has a high permeability degree, and, hence, the concentration of wells is high in this part of the plain and the wells feature higher yield. In the ending part of the plain, the permeability is low due to the alluvium type originating from the marl, clay, and gypsum of the southern mountains. The Eyvanekey plain is a hollow of a syncline with the west–east axis having been filled with alluvial fan sediments.

2.3 Hydrology

2.3.1 Hablehroud drainage basin

The Hablehroud River is the most important river ending in the Eyvanekey aquifer; it is the main source of surface and groundwater flows of the Garmsar plain. This basin with an area of 3119 km² annually discharge about 250 mill/m³ of surface flows together with solvents sedimentary load into the plain. The best part of the flows in the form of river base discharge is used for agricultural consumption. The measured average base discharge in the water at the Bonekouh hydrometer station was 9.6 m³/s during 2012–2013. It shows the relative increase of such discharge compared with past years. A part of the surplus streams is between Bonekouh station and Garmsar diversion dam, which is mainly flood flows penetrating between the two points, while another part is injected into the groundwater tables by the artificial feeding basins. The rest flows into the mainly open natural flood ways.

2.3.2 Rameh drainage basin

The Rameh River originates from this basin and flows inside it. The basin's area, until the end of entry strait, is equal to 171 km². The area of the Rameh drainage basin set is about 203 km², which is dividable into two sub-basins due to topographic reasons.

2.3.3 Khoshabroud basin

The waters resulting from precipitation flow over this basin (area: 32 km²) in the Khoushabroud valley. And outside the Rameh strait in northern heights of Sarasiyab joins the Rameh River.

This basin has a common limb with the Abdolabad River basin in the east.

2.3.4 Ghalibaf drainage basin

Its area is about 49 km² and the waters result from the precipitation flow in the Ghalibaf basin in a valley with the same name. After passing by Ghalibaf village and Dashtak farm, they join the Rameh River in Dorandarreh. The penetration waters of the basin, originating from the shale rocks' openings (Talkhab spring), appear in the downstream of Emamzadeh Esmaeil of Ghalibaf village.

2.3.5 Tarkehdar basin

This basin with an area of 24 km² has been covered with evaporative formations and shale in some parts; the penetration waters from precipitation appear in the form of springs across the basin and the resulting stream, after irrigating the agricultural lands in Dichool farm, flows into the strait and joins the Rameh River in Baghdan District.

In general, the length of the groundwater streams and the duration of the contact between water and soil particles, inadequate feeding of the aquifer, and immethodical exploitation, among others, are the most significant factors in the amount of solvents, changing, and inappropriateness of the quality of the water sources. The solvents' amounts in the analysed waters in the wells of the area show values between 517 and 1345 mg/l as well as an average amount of 931 mg/l, all of which indicate the high rate of solvents in the water.

2.4 Analysing the salinity quality status of the plain groundwater

2.4.1 Electrical conductivity (EC)

Examination of the maps shows that the increasing trend of the EC starts from the northern entry of the groundwater towards the central and southern parts of the plain. Also, the penetration of the relatively saline fronts' water from the north western areas and the outlet of the Eyvanekey plain heighten the EC of the water in the plain central region. Altogether, the water electrical conductivity in entry sections has the lowest value due to the feeding of the marginal formations; it increases in the exit sections of groundwater owing to decreases in the grain

diameter and expansion of fine-grained clay depositions. Accordingly, the longer to contact time of water with the gypsum and clay layers, this can increase the EC. However, the mean electrical conductivity of 4357 Micro mhos for the Eyvanekey plain is indicative of the plain's unsuitable quality of water as well as the effect of gypsum contaminating factors in the salt and the groundwater table (Table 2) (Figs. 1 and 2).

2.4.2 Chloride

Cl⁻ in water and ambient temperature changes causes gradual solution of different ions in the water, thereby increasing the soluble minerals' concentration in it. The salt would diffuse to the lower part of soil column after several numbers of cyclical freeze thaw [24]. The chloride amount in the water is one of the important and decisive factors of water quality especially for drinking consumptions and its increase will increase the water salinity. This element is mainly affected by the bedrock nature and marginal formations of the plain; the salt and Cl⁻ ion amount also increases in evaporative draining zones. Figure 3 represents the Cl⁻ ion value in the Eyvanekey plain. Based on the map of Fig. 3, the chloride ion change trend is consistent with the electrical conductivity changes. Hence, in northern entry areas the concentration of groundwater (around Eyvanekey) is about 500 mg/l, while the parameter's value in north-western and western areas of the plain reaches up to 4000 mg/l under the effect of contaminating geological units.

2.4.3 Sodium

Na, in addition to its abundance in the nature, is mostly found in the natural water resources due to its high solubility. The Na content varies from 1 to 100 mg/l in salty water. The taste threshold of Na in potable water depends on several factors, as the main anions exist in the water and the water temperature. The international standard of World Health Organization (WHO) has declared less than 20 mg/l as the normal amount of Na [25].

2.4.4 Sulphate

The SO₄ concentration in natural water is variable from several mg/l to several thousandth mg/l. In fact, SO₄ can penetrate from different resources into surface and groundwater, e.g. solution of gypsum or other mineral sediments containing SO₄. Owing to the presence of alternating layers of gypsum and anhydride in lower red formation outcrops, the SO₄ content in the best part of the study area range and the sampling wells is higher than the permissible level (Fig. 4).

Fig.1 Geological map of study area and sampling locations

Fig.2 Satellite image shows fault activity and displacement of Pliocene formations: M3a member includes sandstone, shale, marl, and silt-clay, and M3c member includes periodicity of marl shale,

gypsum clay, clay, sandstone, and conglomerate (The arrow for the fault extension and the trend of fault fractures are shown in the rose diagram)

3 Result and discussion

To analyse the development of anions existing in groundwater sources, the identification of feeding

sources and controlling the flow direction of ground-water is considered in certain areas. Salt redistribution in soil occurs as a result of the integrated effects of convection, diffusion, and numerous chemical and physicochemical processes [26]. The TDS, EC, and major ions

Fig. 3 Map of contour line and frequency of Cl^- ion in the groundwater

Fig. 4 Map of contour line and frequency of SO_4 ion in the groundwater

in east Tehran Plain groundwater most likely originated from saltwater intrusion and the study area's geologic structure [27]. The groundwater type in feeding zones is full of bicarbonates, which during movement through permeable layers. And combination with the existing minerals and ions exchanges into sulphated water, and finally, in clastic areas changes to water with high chloride concentration. The results of the chemical analysis of the samples taken from the Eyvanekey plain, as shown by the groundwater type in entry regions (around Eyvanekey), show the sulphated type, which, owing to movement and mixing with the waters flowing through eastern, southern, and north-west parts, changes into water with a high chloride concentration.

3.1 Water classification in terms of potation

Considering the chemical analysis and based on the Schöeller diagram, six selected samples and five samples from potable water sources from the selected villages Cheshmeh Nadi and Eyvanekey Township, among others, were analysed, and it was observed that the quality of drinking water in Eyvanekey Township was desirable and Shourgazi drinking water was of good quality. Based on the Schöeller diagram, most of the above-mentioned water samples belong to acceptable to improper classification in terms of potation: the quality of water in northern parts of the plain lies between good to acceptable; it is acceptable to

improper in central part; and it changes from improper to unsuitable in western and south-western regions.

3.2 Classification of water in terms of agricultural

The most important determinant in agricultural consumption of water is the sodium absorption ratio to EC [28, 29]. Table 1 shows the agricultural water classification (Wilcox diagram) in the Eyvanekey plain. Accordingly, the water samples taken from the northern and central Eyvanekey plain generally belong to the C_3S_1 class having an EC of about 750–2250 and highly saline category. However, if the ground is suitable in terms of grading and soil penetration ability, this water can be used for agricultural consumption. Also, waters from the eastern and southern parts of the plain mainly belong to Class C_4S_1 , which is improper for drinking. In these waters, the higher the S index, the more the salinity of the water, which makes it unsuitable for agricultural irrigation use, save under specific conditions. An analysis shows that according to Table 2, more than 56.5% of the exploited waters from the selected wells of the plain for agricultural use lie in the suspicious to improper category, while 21.7% belong to good to acceptable and 17.2% are of the improper category. In order to investigate the groundwater quality of the Eyvanekey plain for agricultural use, the sodium absorption ratio (SAR) map was provided.

From the above map it can be seen that in most of the eastern and southern margins, and especially in the

Table 1 Chemical analysis of the selected water wells

Sample	X	Y	EC	T.D.S	Ca2+	Mg2+	Na+	K+	HCO3-	Cl-	SO42-
W1	683,850	4,052,750	5000	704	102	30	69	2.73	378.2	60.35	120
W2	687,500	4,053,750	1000	650	94	33.6	59.8	2.34	372.1	49.7	124.8
W3	696,400	4,061,400	1300	806	128	42	59.8	3.12	457.5	67.45	153.6
W4	691,600	4,051,400	1400	854	130	48	71.3	3.12	433.1	85.2	192
W5	701,100	4,052,650	1020	651	82	26.4	82.8	2.34	457.5	31.95	72
W6	690,900	4,048,650	1100	704	70	42	82.8	3.12	359.9	56.8	148.8
W7	677,500	4,053,250	1190	751	90	43.2	64.4	3.12	396.5	74.55	110.4
W8	686,900	4,049,100	1020	650	84	42	52.9	3.12	353.8	42.6	148.8
W9	685,450	4,054,350	1210	756	98	42	87.4	3.12	408.7	78.1	148.8
W10	677,810	4,054,750	1520	906	88	42	149.5	2.73	518.5	53.25	206.4
W11	696,850	4,056,350	1310	816	100	51.6	69	3.12	518.5	49.7	124.8
W12	707,860	4,057,160	800	536	62	28.8	62.1	1.95	366	24.85	72
W13	685,350	4,057,700	975	632	70	36	75.9	1.95	341.6	46.15	134.4
W14	682,750	4,058,600	1720	996	158	52.8	89.7	4.29	347.7	85.2	379.2
W15	697,250	4,058,700	2000	1150	144	78	259.9	4.29	616.1	230.75	412.8
W16	706,150	4,058,750	950	653	78	37.2	71.3	2.73	427	53.25	76.8
W17	692,950	4,058,760	1980	1135	162	36	184	4.68	481.9	241.4	220.8
W18	688,350	4,061,350	1800	1026	82	48	213.9	2.34	579.5	88.75	268.8
W19	687,000	4,065,500	1300	806	100	37.2	96.6	3.12	481.9	67.45	134.4
W20	691,400	4,062,000	2800	1400	98	37.2	441.6	5.85	823.5	230.75	350.4

Table 2 Classification of agricultural waters of the selected wells in Eyvanekey

Class	Number	Percentage	EC _{μm/cm}	SAR ratio	Quality
C1S1	0	0	100–250	SAR < 10	Very good
C2S1†	1	4.3	250–750	< 10	Good
C3S1†	5	21.7	750–2250	< 10	Good to acceptable
C4S2†	13	56.5	2250 > EC	10–18	Suspicious to unsuitable
C4S3	2	8.6	2250 > EC	18–26	Unsuitable
C4S4†	2	6.8	2250 > EC	SA > 26	Unsuitable

regions affected by Chandab and Krous flood ways, this value is higher and inadequate for green plants, and the land's soils are also not [30]. The above-mentioned value in central parts of the plain, where the Namarak basin feeds the lands, is lower and accordingly agricultural crops in such regions display higher efficiency.

4 Conclusions

The quality of most of the water samples can be classified into the moderate to totally disagreeable class. The waters have more suitable status in terms of bicarbonate and magnesium contents compared with other ions. The best water quality belongs to the western areas, while the worst belongs to the eastern and southern regions due to being closer to the evaporative masses. An analysis of the Wilcox graph revealed that the eastern and southern regions belong to the worst Wilcox class and are unsuitable for agricultural consumption; the central plain waters have lower salinity and EC, which makes them more suitable for agricultural use. The main factors involved in the decrease of the water quality in the area are given in the following:

1. Salt tectonics, expansion of salt domes, and geological formations in the area, with the best part of them being evaporative, including gyps and salt. The most significant layers comprise the vast salt fields in the eastern and southern parts; they have been effective in increasing the solvents and salinity of the water resources.
2. The presence of the saline river in the area and the northern streams of the area having hydraulic relationship with the aquifer. By drainage of the pyroclastic and evaporative units in the upstream of the area and by depositing the solvents in the sediments of the region, this river heightens the anion and cation concentration in the aquifer of the area.
3. Low feeding of the area along with excessive exploitation of the groundwater has decreased the hydraulic slope of the groundwater, making the aquifer incapable of effective discharging of the solvents.

Acknowledgements I would like to express our sincere thanks to the respected management of department of Quality Control of Tehran Water and Sewage Company for facilitating the ground for this study and Islamic Azad University, Islamshahr branch compilation and support of this research.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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