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Groundwater quality determination regarding major anions and cations (Case study of an aquifer in the Lut Desert, Iran)

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ABSTRACT: Groundwater quality regarding major anions and cations in the Birjand Plain located in the largest desert in Eastern Iran was monitored in this study. Fifteen boreholes were considered as sampling stations and the parameters pH, TDS, EC and major anions and cations were measured in groundwater samples. The dominant groundwater types can be introduced as sodium-chloride and magnesium-sulphate. The majority of samples were within the not-suitable category for drinking uses. Regarding agricultural use, around 80 and 50 per cent of samples indicated a very high salinity hazard and a very high sodium alkali hazard, respectively. Spatial distribution of salinity was also monitored within the study area. If the study area was considered to be a semicircle, the centre appeared to be the least polluted area, while towards the peripheral surroundings, an increasing behaviour was observed. Intrusion of salt water from eastern and western parts of the study area caused severe groundwater degradation. The relatively better quality of groundwater in southern areas may be attributed to a chain of mountains located along south of the study area. The prevention of uncontrolled groundwater withdrawal must be regarded to cease the salinization trend and to prepare the required infrastructure for implementing the artificial recharge projects.

Key words: Birjand plain, Groundwater, Quality, Salinity

INTRODUCTION

Natural resources have been adversely impacted by daily reinforced industrial and agricultural activities (Sherif et al., 2011; NabiBidhendi et al., 2007; Psychoyou et al., 2007). Ever-increasing pollution discharge into environmental bodies has resulted in vast ecological degradation during recent years (Mohamet et al., 2005; Nasrabadi et al., 2011; Nasrabadi et al., 2010b; Lopez and Vurro, 2008).Water resources have been one of the most significant targets of such industrialization. On the other hand, water is considered as an absolutely major challenge within the structure of sustainable development approach (Manoli et al., 2004). As a remarkable per cent of achievable potable water globally (around 90%) is regarded as groundwater resources, the monitoring of qualitative and quantitative parameters pertained to such resources should be highlighted. Furthermore, considering the bigger pollution exposure potential of surface water compared to groundwater, and consequently higher imposed treatment costs would also justify the groundwater option (Baghvand et al., 2010).

The water demand generated by agricultural, industrial and residential land use has caused an ascending withdrawal of groundwater. This phenomenon is more

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frequently observed in sensitive areas like deserts and coastal environments, where aquifers may suffer from saline water intrusion and upconing, which consequently results in quality degradation (Silva et al., 1998).

Groundwater quality deterioration has occurred in many aquifers around the world for a variety of reasons, among which the issue of salinization is well-recognized (Bear et al., 1999). Compiling the origin and mechanisms of such phenomena has been taken into consideration by many researchers worldwide. Depending on case studies, some major causes include dissolution (Pulido et al., 2003), downward leakage (Aunay et al., 2007), upward flow from deep saline water (Vengosh et al., 1999), fossil seawater (Yamanaka and Kumagai, 2006) or seawater intrusion (Kim et al., 2003) have been introduced.

Iran is a country that is highly threatened by a potential water crisis. A relatively low precipitation rate, as well as its uneven temporal and spatial distribution, is among the major causes of such a potential crisis (Lopez and Vurro, 2008). Water scarcity in areas where inadequate precipitation dominates will cause an overload of groundwater withdrawal. Such phenomena, when applied without the required considerations, may adversely affect aquifer quality due to salinization in areas that are located close to deserts or marine areas. Roughly half of Iran is occupied by vast deserts that can be regarded as a potential risk for groundwater degradation. Lut is the largest desert in Eastern Iran and the second largest in the country. In the present study, groundwater quality of a plain within the desert water basin was considered with regard to major anions and cations.

Study area

Birjand Plain, with an approximate surface area of 1045 square kilometres, is part of the Lut Desert water basin in Eastern Iran. The study area is located at 67° 63/ and 72° 31/ longitude and 36° 33/ and 36° 42/ latitude. With an average altitude of 1400 metres above sea level, the plain stretches westwards in the shape of a bended strip. Being surrounded by mountainous areas like the Baqeran and Shekarab mountains, the plain includes an alluvial aquifer at its centre. The study area, as well as details regarding the sampling stations, is shown in Figure 1.

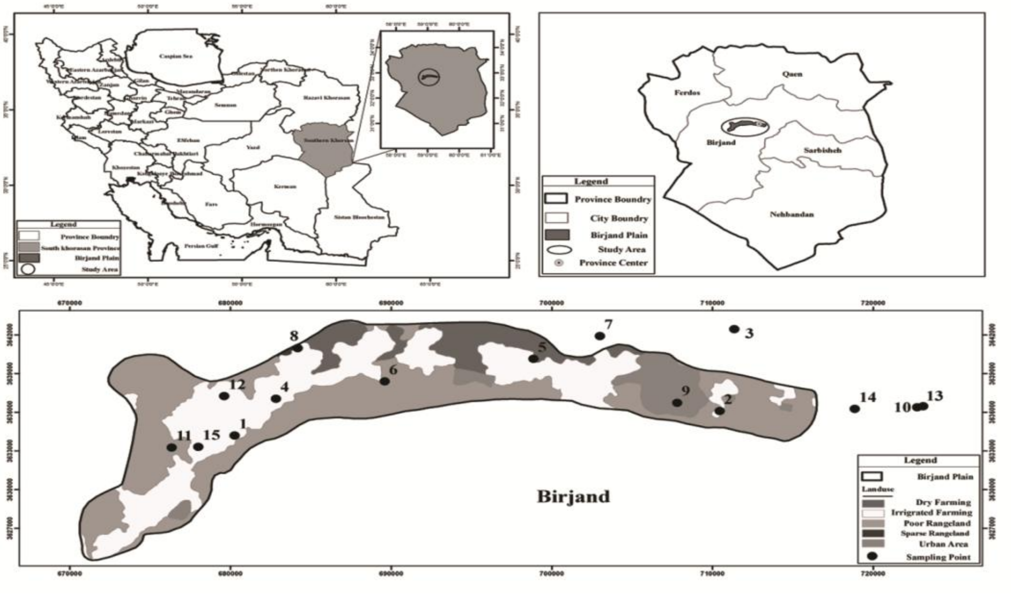

Fig.1. Study area and sampling stations

MATERIALS & METHODS

Fifteen boreholes were considered for the sampling campaign within the study area (Fig. 1). in order to gain in-depth knowledge about the quality of regional groundwater parameters like pH, electrical conductivity, total dissolved solids, sodium, calcium, potassium, magnesium, carbonate and bicarbonate, sulphate and chloride were analysed in water samples. Electrical conductivity and pH were measured in situ. TDS was determined gravimetrically at between 105 to 110°C (Kazi et al., 2009). Bottles for metal analysis were immediately acidified with 1% Merck quality nitric acid, while those for the anions' analysis were treated with no acidification. Anion concentrations were measured using HACH DR/2000, while cations were measured using ICP-MS according to the EPA 3005 method. Data processes were rendered using software such as AqQa, SPSS 15, Excel and Surfer.

RESULTS & DISCUSSION

The values for the parameters pH, EC and TDS, as well as major anions and cations are shown in Table 1.

Table 1. Hydrochemical analysis of the studied aquifer

Station	Water resources coordination		TDS mg/L	EC µS/cm	pH	meq/L							
	X	Y				CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
1	3634205	680252	2079.1	3420	8.15	--	7.44	12.52	15.27	4.96	13.98	15.97	0.08
2	3636107	710442	1504.3	2490	8.33	1.25	5.49	9.76	9.25	3.35	9.86	11.92	0.17
3	3642451	711354	4000.4	6590	8.12	--	3.15	42.40	22.25	13.60	14.83	34.79	0.25
4	3637060	682830	1969.3	3270	8.80	0.49	3.82	15.15	14.83	4.25	16.42	12.78	0.12
5	3640150	698850	620.1	1072	7.53	--	3.82	3.88	3.85	1.80	5.38	4.32	0.14
6	3638400	689600	845.2	1456	8.40	0.49	4.81	6.23	3.85	1.94	7.30	5.41	0.11
7	3641911	702989	3635.6	6240	8.66	1.15	3.25	43.28	15.51	3.69	14.79	43.82	0.18
8	3640985	684178	5130.5	8440	7.50	--	3.15	48.50	38.86	10.80	16.10	58.63	0.40
9	3636741	707795	670.6	1131	8.10	--	5.25	3.29	3.31	1.94	5.62	3.91	0.05
10	3636393	722737	3690.6	6021	8.28	--	3.25	40.42	17.50	4.81	9.97	46.10	0.15
11	3633268	676332	2992.3	4940	7.84	--	4.60	32.73	14.00	3.82	5.83	40.37	0.13
12	3637260	679606	4820.1	7960	7.95	--	3.25	49.79	29.00	2.81	13.47	65.00	0.27
13	3636480	723103	1920.8	3280	8.61	--	4.15	20.21	8.41	5.39	5.97	23.00	0.08
14	3636269	718845	3715.4	5960	7.99	--	2.84	39.34	17.8	8.24	13.84	36.97	0.15
15	3633326	677997	2510.8	3960	8.46	--	5.98	23.86	9.72	5.84	13.71	20.38	0.22

As was observed, a concentration of carbonate was not detected in most of the samples, while that of potassium was also negligible. Generally, within the study area, chloride and sulphate may have been introduced as the first and second dominant anions, while in case of cations, sodium and magnesium were remarkable, in a descending order. In order to investigate the spatial distribution of the studied parameters, isoconcentration contours were generated within the study area (Figs. 2 to 9).

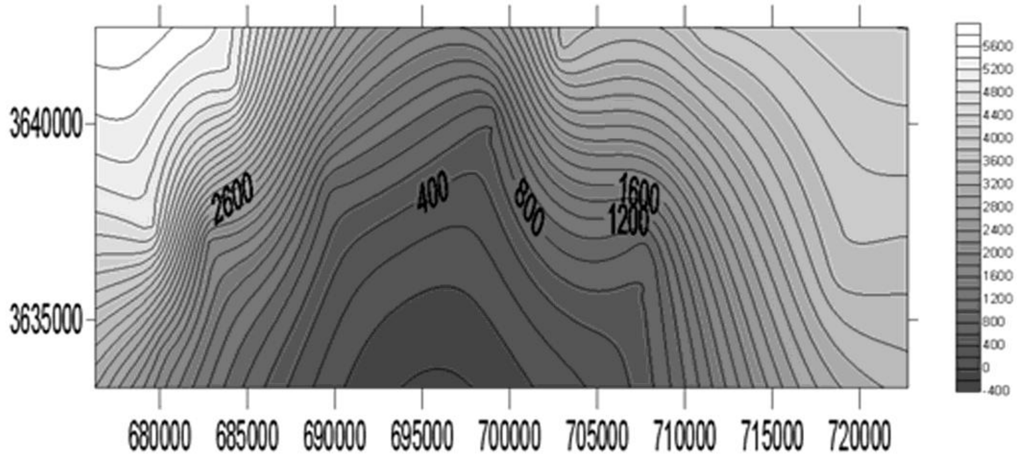

Fig. 2. Spatial distribution of TDS within the study area

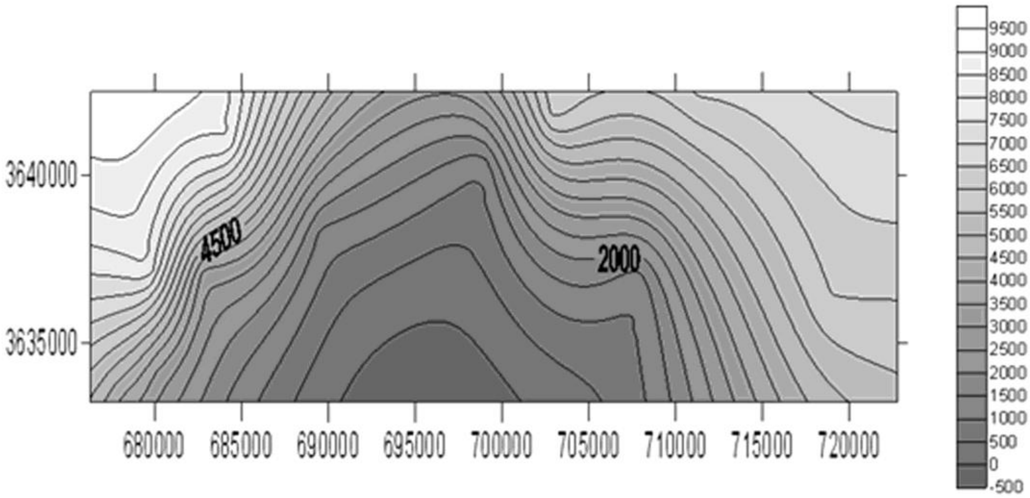

Fig. 3. Spatial distribution of EC within the study area

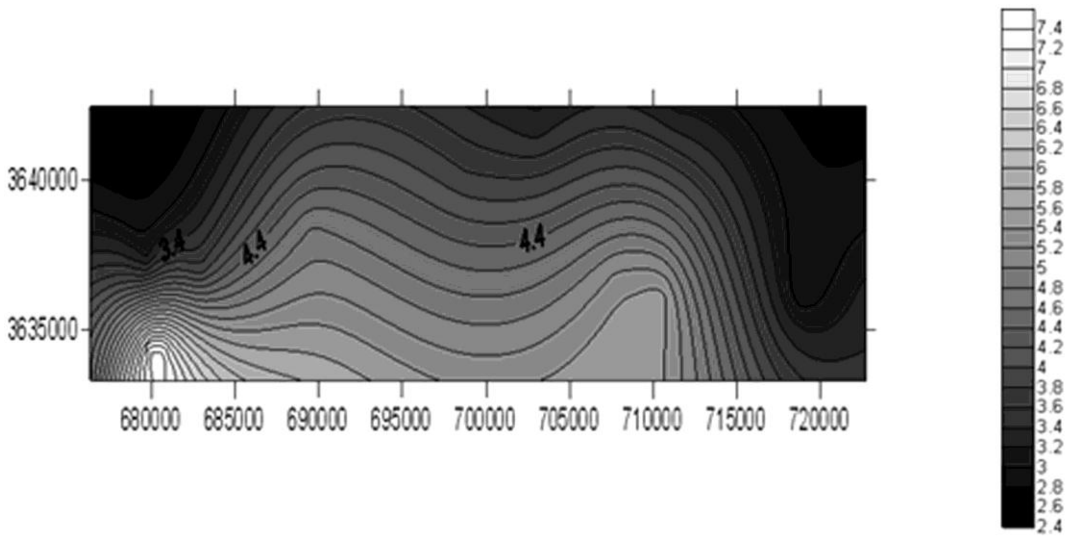

Fig. 4. Spatial distribution of bicarbonate within the study area

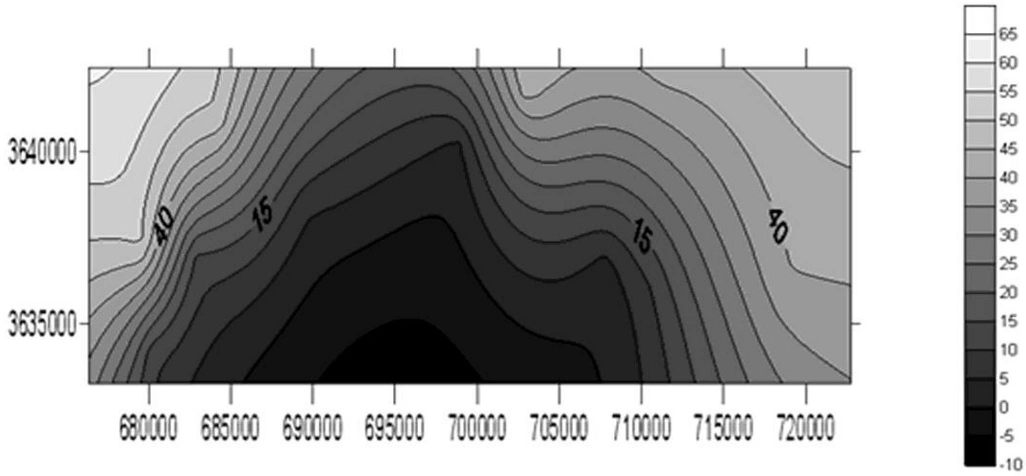

Fig. 5. Spatial distribution of chloride within the study area

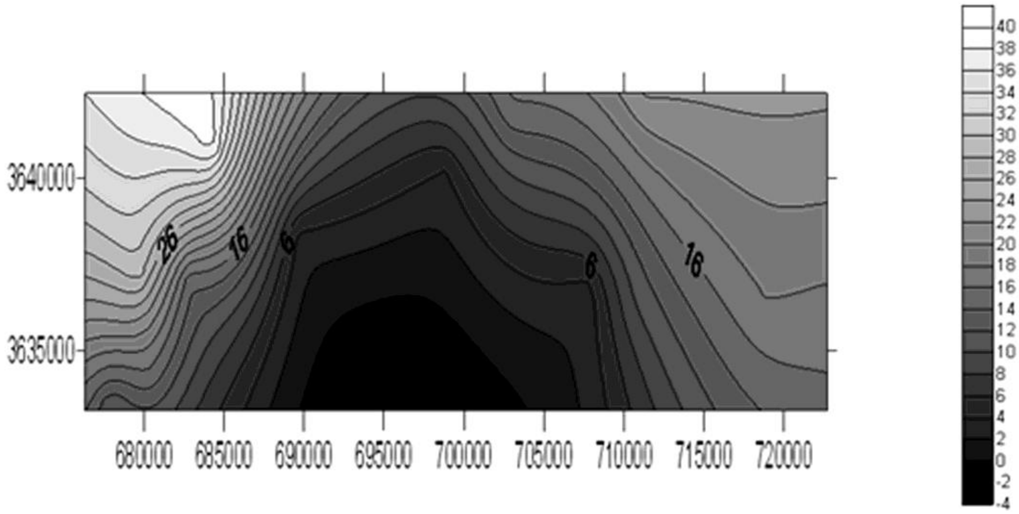

Fig. 6. Spatial distribution of sulphate within the study area

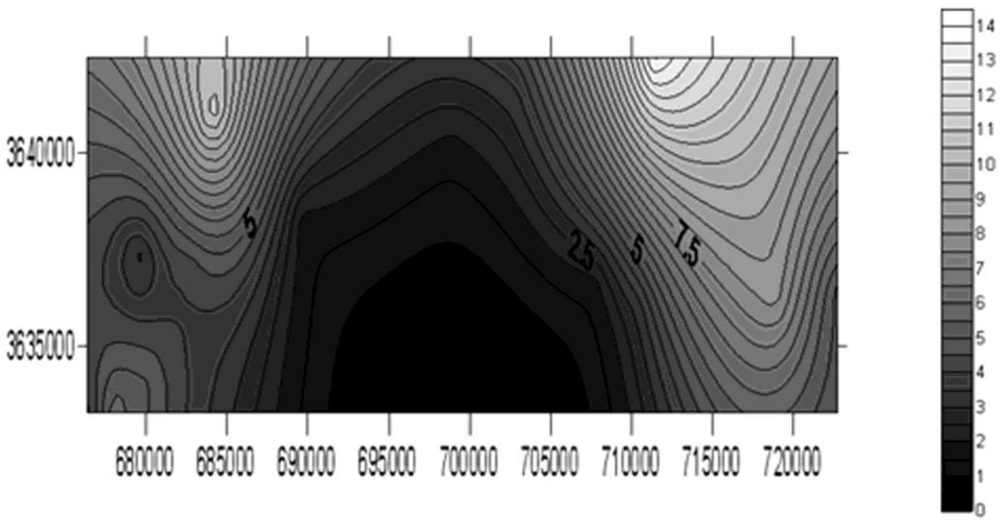

Fig. 7. Spatial distribution of calcium within the study area

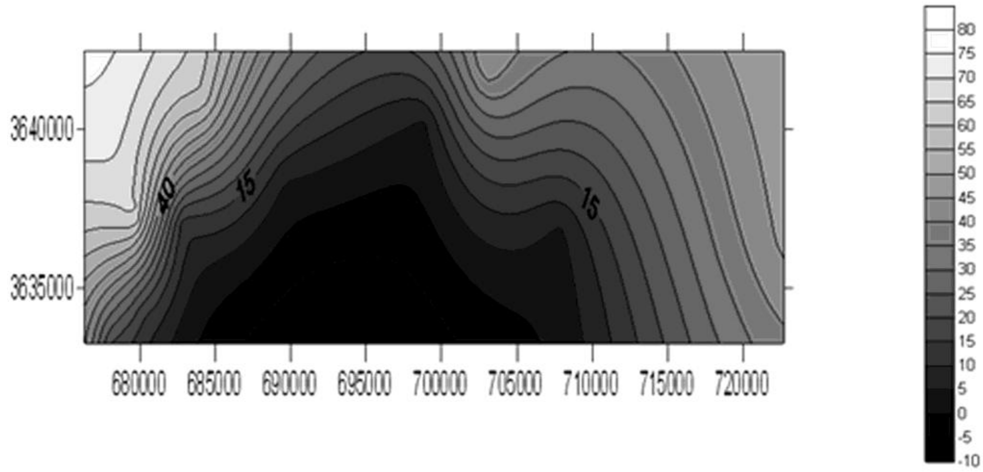

Fig. 8. Spatial distribution of sodium within the study area

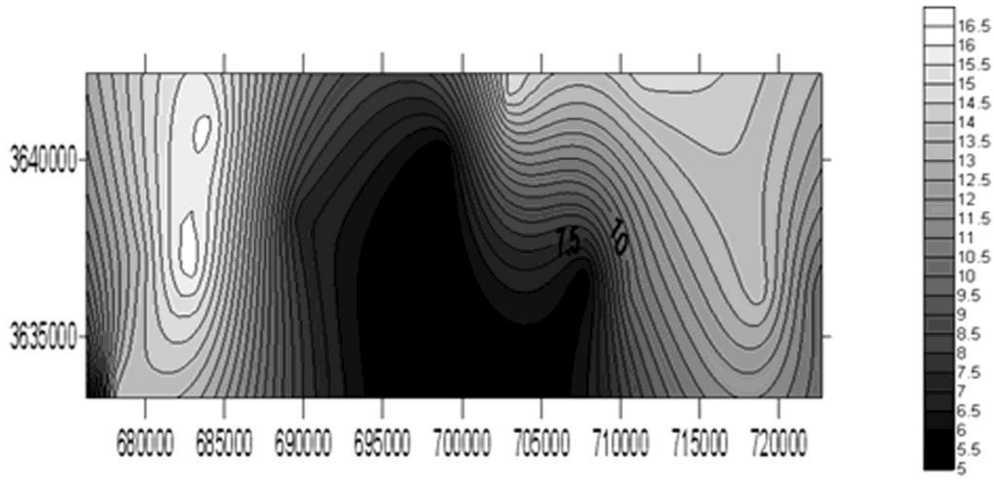

Fig. 9. Spatial distribution of magnesium within the study area

As can be seen, a remarkable similarity was observed between the distribution pattern of TDS (or EC) (Figs. 2 or 3) and that of chloride (Fig. 5) and sulphate (Fig. 6) in anions, as well as sodium (Fig. 8) and magnesium (Fig. 9) in cations. Conversely, calcium and bicarbonate showed a completely different pattern compared to TDS.

Water type is dependent on factors such as the lithological characteristics of aquifers, retention time and the pattern of groundwater flow (Lopez and Vurro, 2008). In order to distinguish the regional groundwater type, a piper diagram is presented in Figure 10.

As is shown in Figure 10, the major water types can to some extent be identified as Na- Cl and Mg- sulphate. Regarding potable water, a Schoeller diagram was generated for all water samples (Fig. 11).

According to the Schoeller diagram, except for stations 5, 6 and 9, no water samples met the necessary criteria to be used as drinking water. In order to monitor the water quality for agricultural use, the Wilcox diagram was also considered (Fig. 12).

Figure 12 indicates that the majority of water samples showed very high and high risks concerning both salinity and sodium alkali hazards for agricultural use.

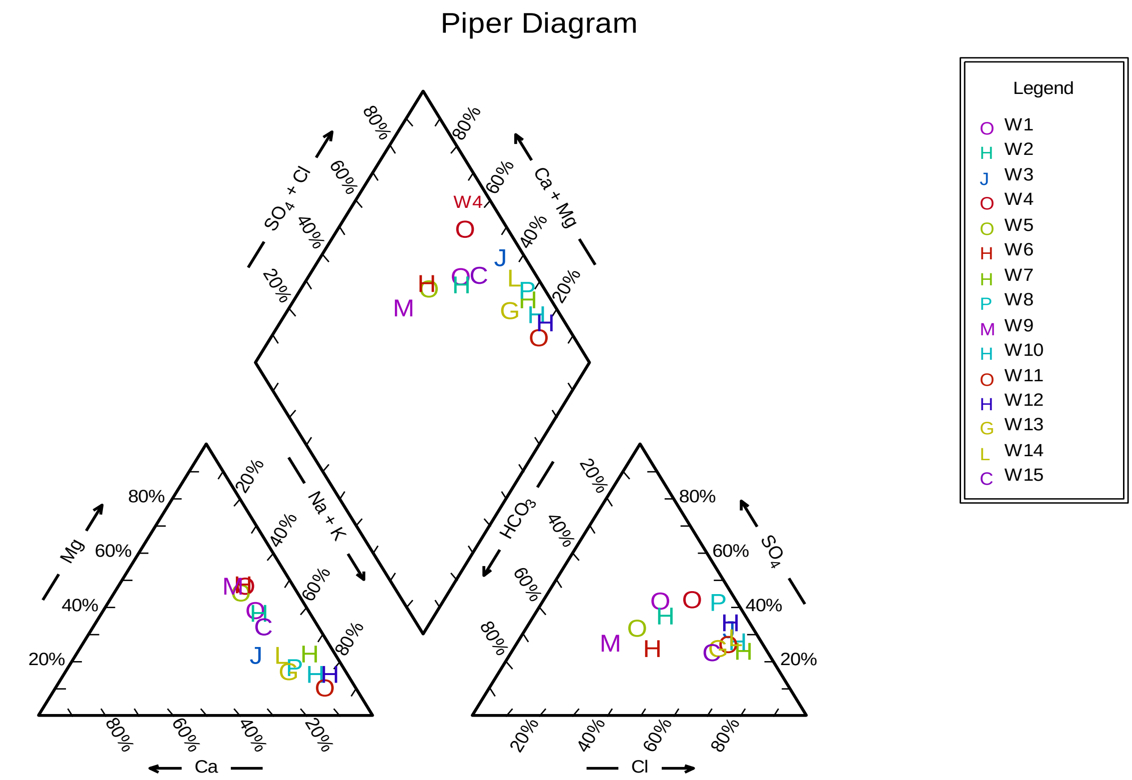

Fig. 10. Piper diagram showing regional groundwater type

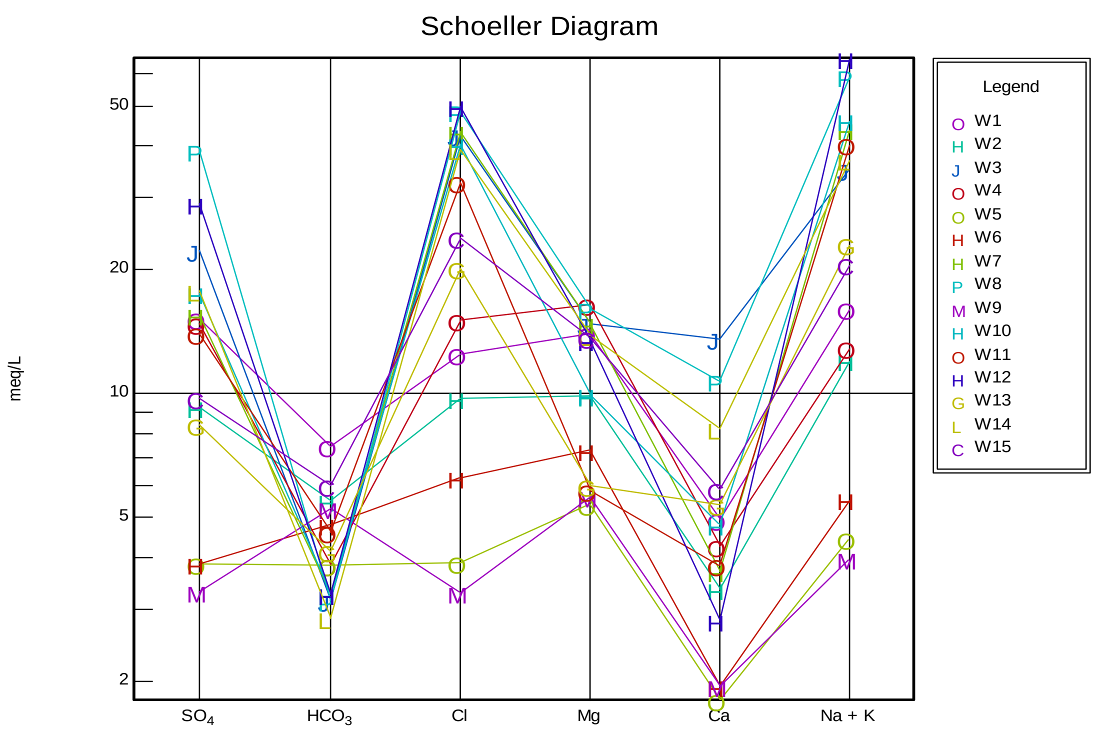

Fig. 11. Schoeller diagram showing the regional groundwater suitability for drinking uses

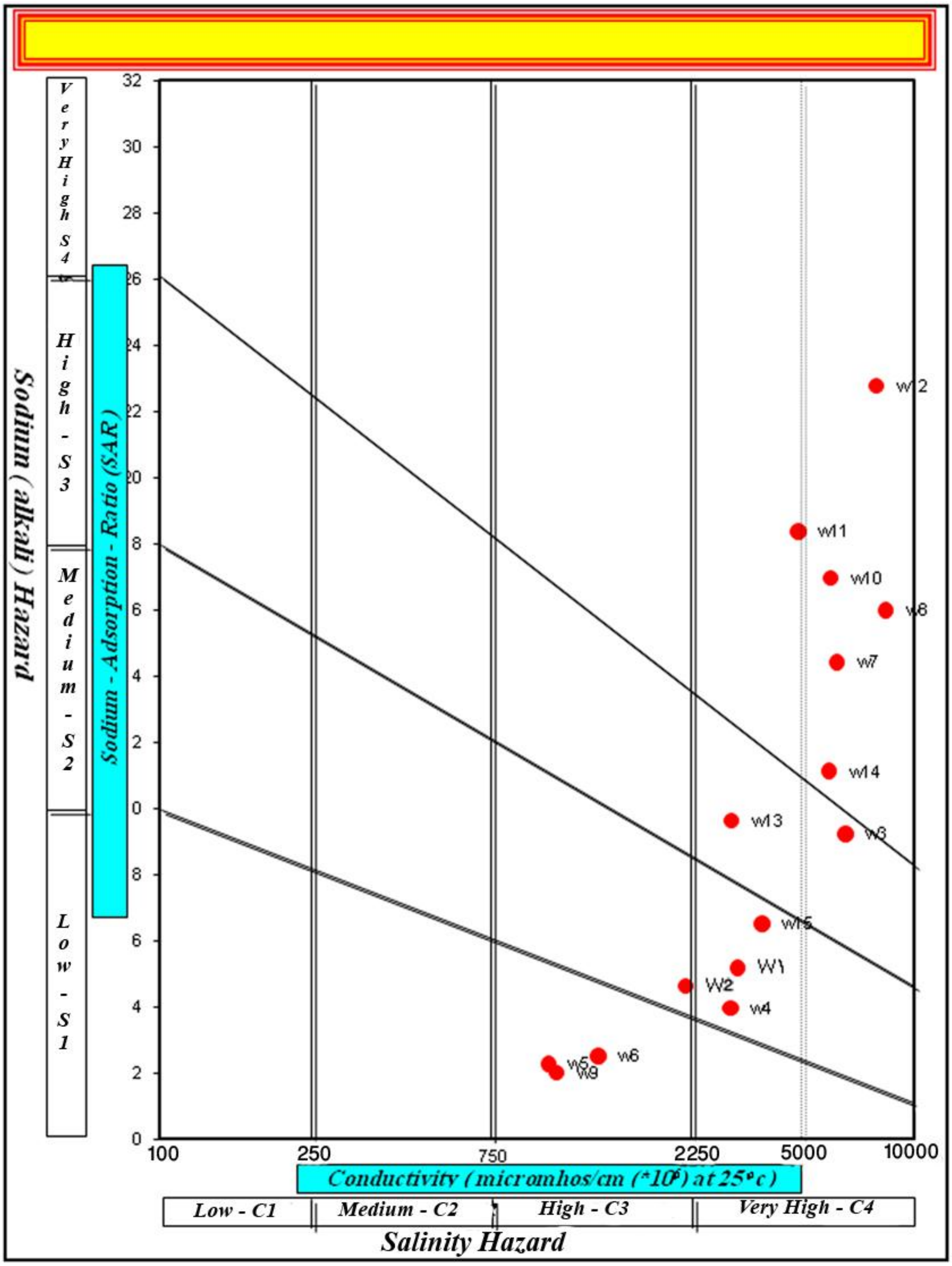

Fig. 12. Wilcox diagram showing the regional groundwater suitability for agricultural uses

CONCLUSION

The groundwater quality regarding major anions and cations in the Birjand Plain, located in the largest desert in Eastern Iran, was monitored in this study. Fifteen boreholes were considered as sampling stations and the parameters pH, TDS, EC and major anions and cations were measured in groundwater samples. The first and second dominant anions and cations were introduced as chloride, sulphate and sodium, and magnesium, respectively. In other words, Na- Cl and Mg- SO_4 will be to some extent the major groundwater types in the study area.

A case such as the current study is relatively distinguished among aquifers that are normally applied to drinking and agricultural uses with Ca- HCO_3 type (Lopez and Vurro, 2008; Baghvand et al., 2010a; Nasrabadi et al., 2009). From a drinking use point of view, except for three samples from the central part of study area, which showed good quality, the majority of samples located within the not-suitable category. Such a result is interesting when considering that the main drinking water supply for Birjand city (the capital of South Khorasan Province) is groundwater. The case will be even more dramatic when considering the water's agricultural uses; while around 80 per cent of water samples indicated a very high salinity hazard and the rest 20 per cent remained in the high risk category. The same held true for sodium alkali hazards, while more than half of the water samples fitted the high and very high risk classes. Similar groundwater quality degradation in Iranian aquifers adjacent to deserts and marine areas has been reported in recent years (Baghvand et al., 2010). Spatial distribution of salinity has also been monitored within the study area regarding TDS or EC as indexes. If the study area was considered a semicircle, the centre appeared to be the least polluted area, while towards the peripheral surroundings, an increase in pollution was observed; however, the degradation severity northwards was less compared to the east and westwards. The relatively better quality of groundwater in southern areas may be attributed to the Baqeran mountain chain located along the south of the study area. A similar justification is suggested for northern areas, where some mountains enclose the study area. Finally, most polluted areas were located in the eastern and western parts of the study area, where intrusion had occurred due to an overload groundwater discharge. The adjacency of the Lut Desert, the second largest in Iran, serves as a potential risk exposure that must be considered in the context of regional groundwater withdrawal. The prevention of uncontrolled groundwater withdrawal must be regarded as curtailing the salinization trend and preparing the required infrastructure for implementing artificial recharge projects.

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