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Evaluation of Hydrogeochemical Processes and Groundwater Table Decline Caused by Overexploitation on the Groundwater Quality in Iranshahr Aquifer, Iran

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ABSTRACT

The main objective of this study is to examine the effect of hydrogeochemical processes on the groundwater quality in aquifer of Iranshahr. The maximum ionic concentration is detected for sodium-potassium, chloride, and sulfate, respectively, which are the main cause of salinity of groundwater in this aquifer. The existence of evaporate facies of Miocene era, along with the effect of grain size forming plain alluvium on hydrodynamic coefficient of aquifer and also groundwater decline can be the main reasons of alteration in groundwater quality of the aquifer.

KEYWORDS: Groundwater quality, Groundwater table decline, Hydrogeochemical process, Geological formation, Hydrogeology.

INTRODUCTION

Groundwater resources are said to be among the finest natural resources of earth planet. The protection of such natural resource is vitally important because of the importance of it in different sectors such as agriculture, industry, domestic and drinking purposes. Chemical quality of groundwater depends on chemical and biological reactions taking place through the soil zones of anthropogenic and affected layers [15]. Moreover hydrogeological features of rocks [6], human activities including percolation of polluted water into sweet water [6,1], and declining groundwater level play important roles in decreasing the quality of groundwater [8,10,11,12]. Herein we discuss how hydrogeological factors cause to a drop in groundwater quality of Iranshahr aquifer.

Physiographic of the plain

The aquifer is located in the Iranshahr plain, 345 km toward south of Zahedan city, in the center of Sistan & Baluchistan province, southeast of Iran (Figure 1). The aquifer with an area of about 370 square kilometer is located in a region where lies between longitudes 60^0 33´ and 60^0 52´ east, and latitudes 27^0 6´ to 27^0 18´ north.

The climate of the area is arid and the average precipitation, based on the three local stations in the aquifer, is 103.5 mm (recording period of 1989-2007). High temperature in the aquifer causes a high evaporation. Average annual evaporation of the plain is 3295 mm (recording period of 1982-2007). Most of the rainfall is during January and February [13].

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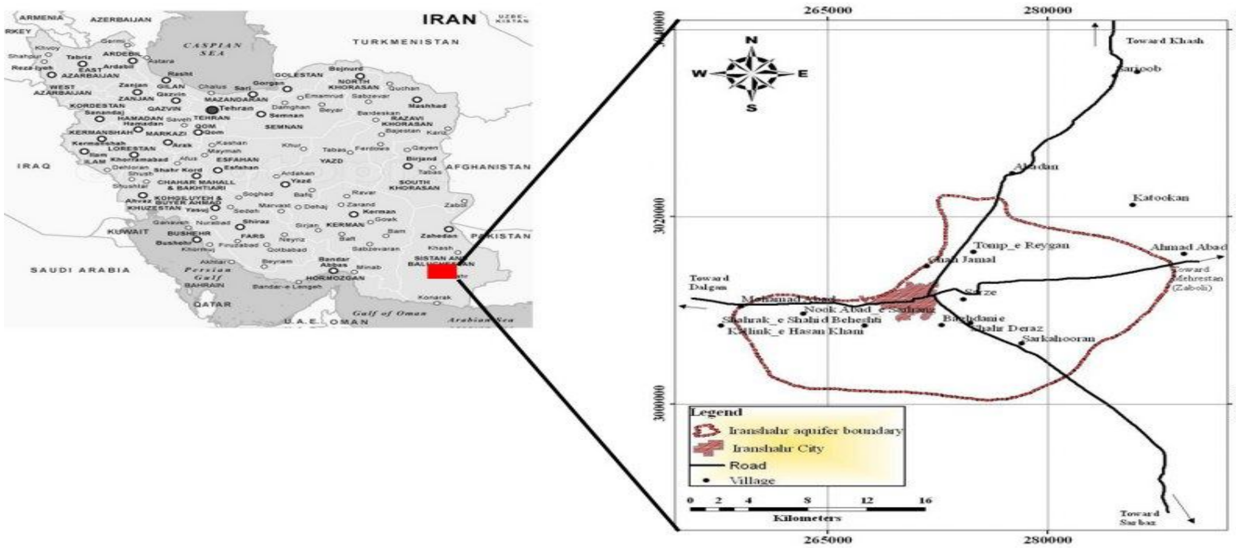

Figure 1: Location map of the study area

Geological conditions of the aquifer

The study area has a broad variety of rock units of different types surrounding the plain. The majority of this rock units belongs to the second and third geological time that can be divided to five major group from the perspective of lithology; A) Igneous rocks including hornblend-quartz diorite to granodiorite, porphyritic alkali-granite with (Late Cretaceous-Oligocene) age, South and southeast of watershed. B) Outcrop of ophiolitic plain including serpentinite, peridotite, dunite, gabbro, diabase, andesite, spilite belonging to late Cretacous in northeast, south and southeast of study area. C) Flysch zone of east of Iran including shale, sand and gravel associated with pelagic lime, red shale, and volcanic rocks related to Eocene in east, north and southeast area. D) Sedimentary rocks including sandstone and gravel shale with conglomerate layers related to Miocene-Pliocene in north and northwest of aquifer. E) Conglomerate and alluvial flats of area including alluvial sediments, alluvial fan, and torrential plains related to Quaternary in north and northwest of watershed surface [8].

Hydrogeological conditions of the aquifer

Based on a number of studies reported since 3 decades ago, which specify the hydrogeological conditions of the region, the location, number and category of underground layers as well as depth and broadness of the aquifer were identified (Figure 2).

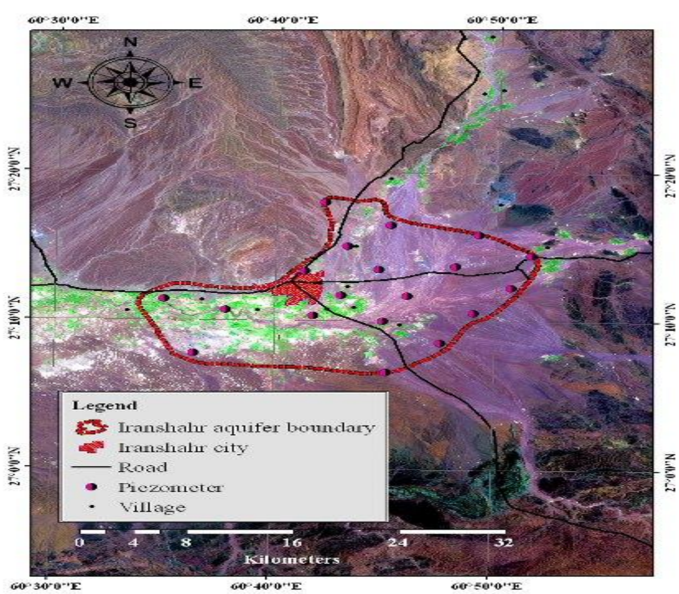

Figure 2: Location of observation wells and aquifer borders

Moreover from geological studies of exploration drilling it has been shown that there is a considerable spread of alluviums and Flysch facies in northeast of aquifer that act as an impermable barrier against water in north of the aquifer. The study aquifer is mainly of alluvial sediments with large grain particles including alternative sand, gravel and boulder. The alluvial sediments have been originated from sedimentation of Daman and Saradan rivers entering the plain.

In general, total percentage of fine grained sediments in the river bed from northeast and east toward west and center of plain has increased. Driller's log of wells and also geophysical studies have shown that the thickness of sediments in eastern parts of Iranshahr plain is about 100-120 meter, which sharply starts to get thinner in border areas [9]. The results of drilling in the plain area has identified the study aquifer as an unconfined aquifer in which the flow direction of groundwater extends from feeding areas in north, east and southeast to western borders of watershed [13] (Figure 3).

Geophysical investigations were carried out using electrical resistivity methods in the northeast and east parts of the plain (feeding area) shows over 100 ohm.meter (Ω.m) with respect to the large grain size of hydrous particles. This trend starts to decrease by 20 ohm.meter (Ω.m) as we close to the western and external parts of aquifer affecting hydrodynamic coefficient of aquifer [9].

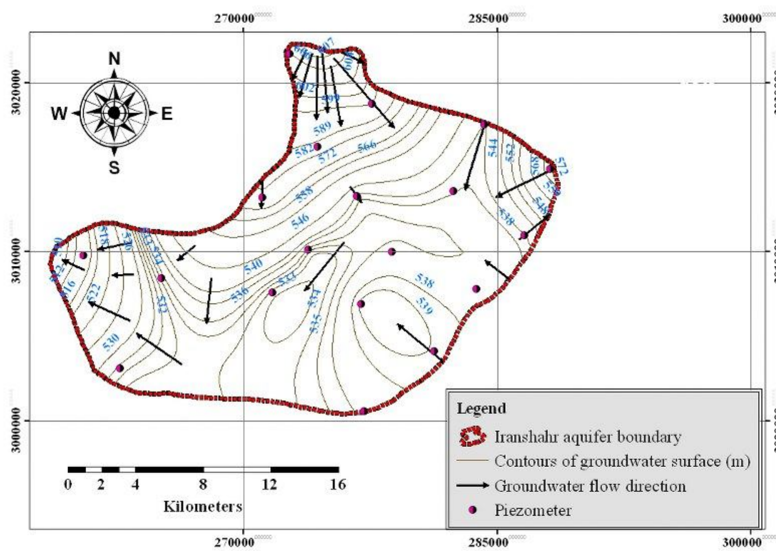

Figure 3: Contour map of groundwater level in aquifer of Iranshahr

MATERIALS AND METHODS

Evaluation of groundwater quality was carried out based on collected samples from 22 wells from different part of the aquifer during July-August 2011 (Figure 5). Statistical parameters of hydrochemical data such as correlation matrix, maximum, minimum, average, deviation criteria and variance of water samples is shown in table1,2. Figure 4 depicts general chemical quality of the aquifer. The graph shows that the highest concentration of ions is measured for sodium-potassium, chloride and sulfate, which are the main reason of water salinity. In the next sections, by means of qualitative assessment network the effect of overexploitation on the quality of water of piezometers and selective dug and drilled wells during the years, 2005, 2007, 2009, and 2011 has examined. In addition, the influence of excessive exploitation and water decline on enduring trend of quality change has been evaluated.

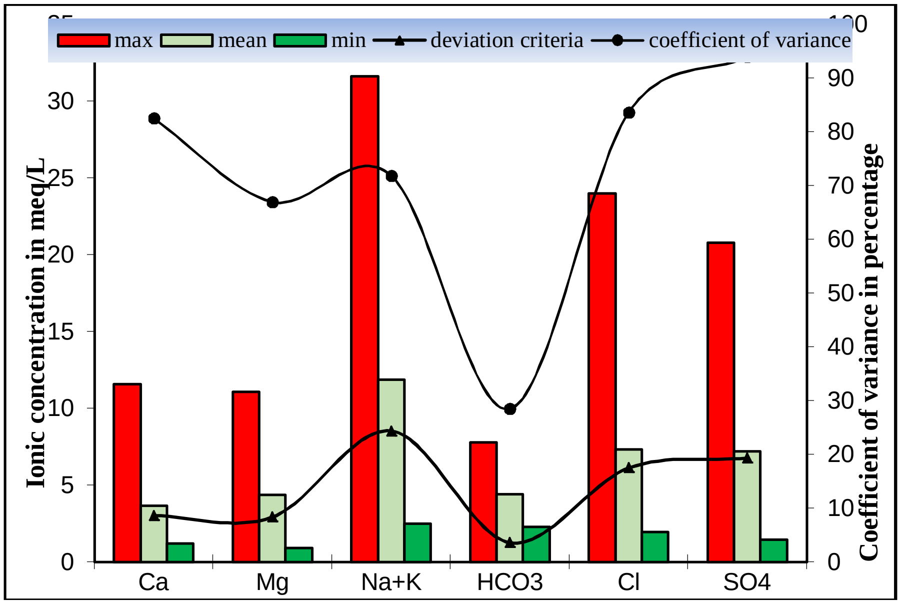

Figure 4: Statistical parameters of chemical components in the study aquifer

Table 1: Statistical characteristics of chemical components for sample wells in the aquifer of Iranshahr

Parameter	**SO_4^{2-} (meq/L)**	**Cl^- (meq/L)**	**CO_3^{2-} (meq/L)**	**HCO_3^- (meq/L)**	**K^+ (meq/L)**	**Na^+ (meq/L)**	**Mg^{2+} (meq/L)**	**Ca^{2+} (meq/L)**	**pH**	**TDS (mg/L)**	**EC (µS/cm)**
Mean	7.19	7.32	0	4.42	0.12	11.75	4.35	3.65	7.45	1202.73	1863.14
Deviation criteria	6.75	6.11	0	1.26	0.04	8.5	2.91	3.01	0.25	905.87	1238.46
Coefficient of variance	0.94	0.83	-	0.29	0.33	0.72	0.67	0.82	0.03	0.75	0.66
Maximum	20.79	23.98	0	7.79	0.2	31.43	11.06	11.59	7.98	3530	4710
Minimum	1.43	1.94	0	2.3	0.05	2.39	0.9	1.19	7.08	330	622

Table 2: Correlation coefficient between chemical components for sample wells in study aquifer

Correlation matrix	**K^+**	**Na^+**	**Mg^{2+}**	**Ca^{2+}**	**$HCO3^-$**	**$SO4^{2-}$**	**Cl^-**	**EC**	**TDS**
K^+	1								
Na^+	0.672	1							
Mg^{2+}	0.693	0.916	1						
Ca^{2+}	0.694	0.761	0.800	1					
$HCO3^-$	0.438	0.660	0.491	0.398	1				
$SO4^{2-}$	0.731	0.978	0.945	0.839	0.572	1			
Cl^-	0.698	0.935	0.956	0.883	0.482	0.952	1		
EC	0.710	0.980	0.951	0.855	0.577	0.989	0.979	1	
TDS	0.698	0.961	0.950	0.891	0.562	0.974	0.989	0.991	1

RESULTS AND DISCUSSION

Conductivity measurement is one of the most important methods to determine the salinity of water [3]. EC (electrical conductivity) variation in study aquifer shows to be on increase from eastern borders to west areas (Figure 5).

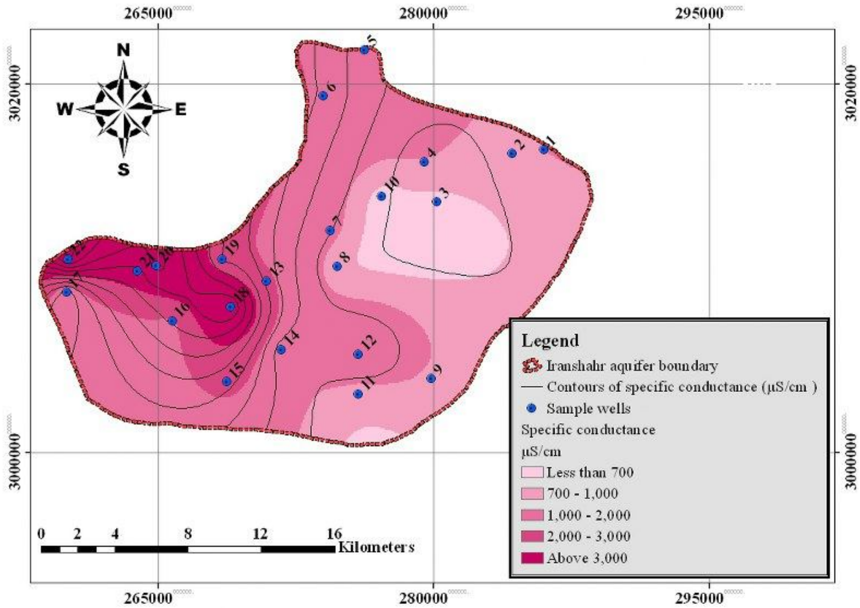

Figure 5:Location of sample wells and conductivity of the study aquifer in 2011

There has been different hydrogeochemical processes resulting in an increase on salinity of groundwater, that we discuss it in next sections. The existence of evaporate facies (salt and gypsum) in sedimentation series of Miocene era like Miocene sediments in central part of Iran and Zagros area [9] is one of the most important factor resulting in a change in ionic concentration of sulfate, chloride and sodium ions. Sedimentations are caused by erosion of these structures especially in northwest area of aquifer. Abrupt increase in concentration of sulfate ion can be seen in Figure 6 for sample wells 6, 18-21. The exclusive behavior of Total Dissolved Solids (TDS) with mentioned ions can be seen in Figure 7. It is also clear that this phenomenon is the main reason for water salinity of groundwater in whole parts of study aquifer.

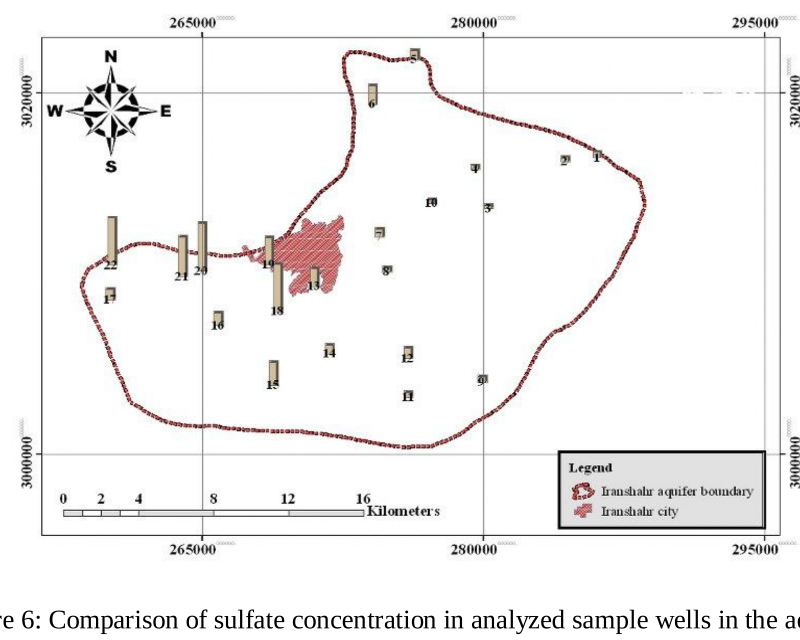

Figure 6: Comparison of sulfate concentration in analyzed sample wells in the aquifer

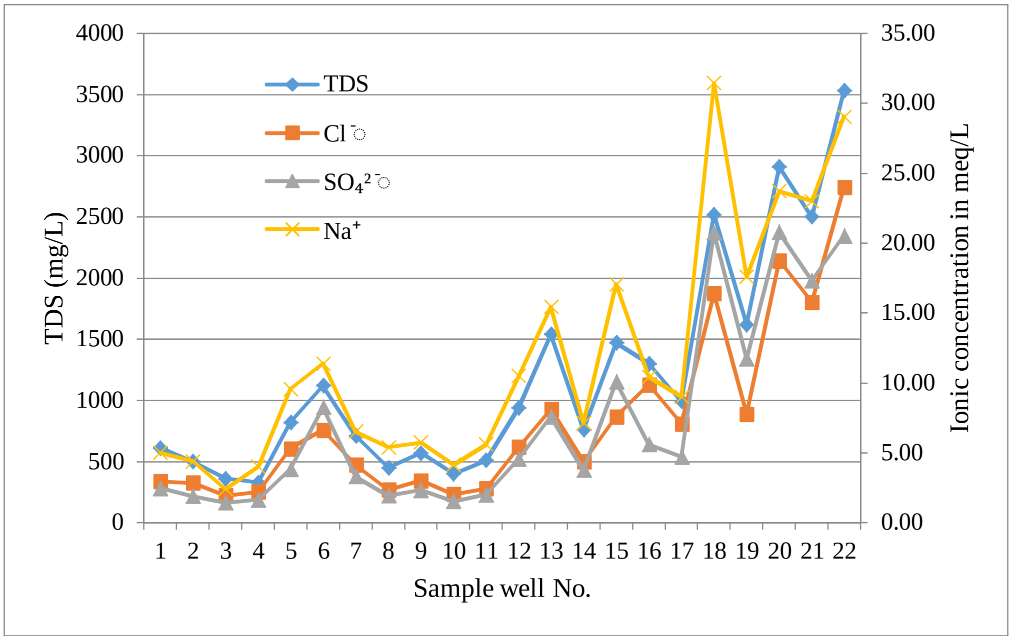

Figure 7: Correlation between TDS and concentration of sulfate, chloride and sodium ions in different parts of the study area

Hydrogeology factor is another important reason for the quality change of groundwater. In feeding area of aquifer due to the large size of alluvium sediments as large as sand, gravel and boulder, high rate of permeability is expected. Based on pumping tests, transmissibility coefficient reaches to about 6134 m^2/d (square meter per day). Because of the fact that there is an increase in percentage of fine grained sediments such as clay minerals from east to center and west areas, a decrease in sediment ability is recorded by 890 m^2/d [9]. As a result an increase in interaction with geological matrix, dissolution of related compounds and ion exchange with clay minerals result in an increase in water salinity from east to west area of aquifer.

Another significant factor which affects the quality of aquifer is overexploitation of groundwater. Statistic has shown that the number and volume of study wells has increased from 57.2 MCM (million cubic meter per year) in 1985 with 101 well to 132 MCM in 2003 with 654 well [2]. Figure 8, 9 compares the groundwater maps and conductivity of aquifer in the years 2005, 2007, 2009 and 2011.

A contour map of groundwater is considered as high as 535 meter as criteria line and it has become thicker during different years. Based on the map in the year 2005, the level of groundwater where had a small thick in aquifer area has stretched toward the center of aquifer, as a result it, overexploitation over the past years has experienced a fall and the criteria line has fell into interior levels in the year 2011.

From contour maps of electric conductivity, 2800 µS/cm is chosen as reference line for comparison during different years. As can be seen, contour maps of 2800 is moved toward east and central area of aquifer and in the year 2011 contour curve has encircled half of western and central parts of aquifer. This movement can be justified considering the drought condition and reverse flow of groundwater due to overexploitation of wells in this part of the plain. In other words reverse flow of groundwater has caused the penetration of saline and polluted water to the aquifer and an increase to the electrical conductivity and affecting the quality of aquifer.

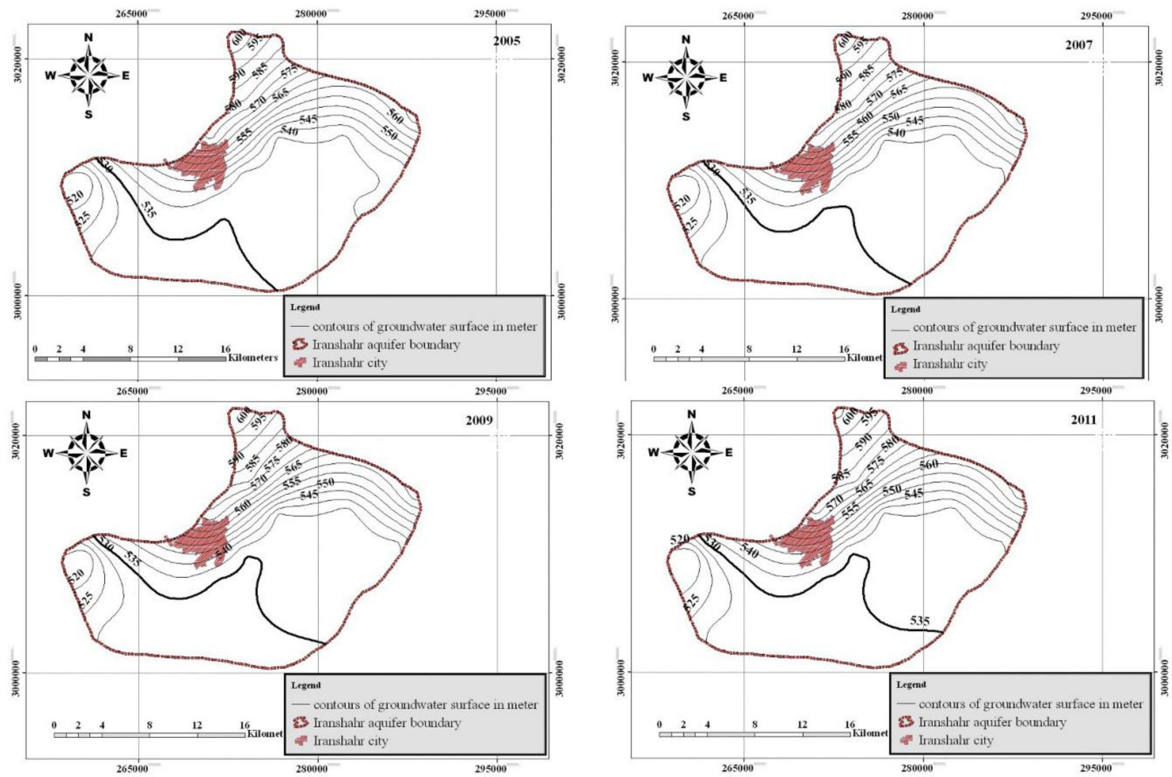

Figure 8: Contour maps of groundwater for study aquifer of Iranshahr during the years 2005-2011

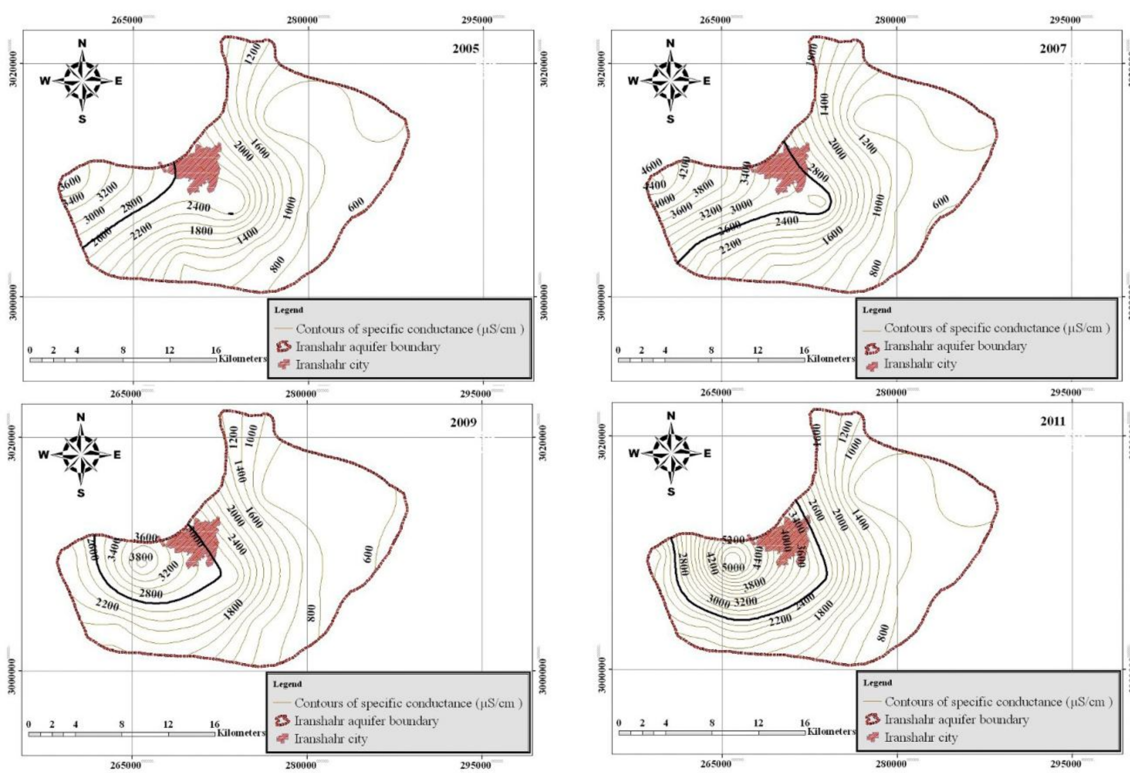

Figure9: Contour maps of electrical conductivity versus µS/cm in Iranshahr aquifer during the years 2005-2011.

Conclusions

Chemical analysis of samples has shown that the maximum ionic concentration is for sodium-potassium, chloride and sulfate which are the main reason for water salinity in Iranshahr aquifer. Of other remarkable reasons for the salinity of this aquifer are evaporate facies of Miocene era, and the effect of grain size of alluvial materials on hydrodynamic coefficient of aquifer. Excessive exploitation of wells in central parts of aquifer that has caused a fall in groundwater level associated with movement of low quality waters from western and external parts of aquifer are of the most important factors resulting in water salinity and infection of groundwater in the aquifer.

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