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Environmental classification of physicochemical factors of groundwater as a new approach to water resource management (Case Study: Sarvestan Plain)

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Abstract

The results of this study show that from the viewpoints of acidity and bicarbonate, the quality of groundwaters of Sarvestan Plain is within the proper limits of drinking waters as shown in Schoeler diagram, national and WHO standards. The magnesium of 26 wells is within the limit of water with permissible drinking application while it was in the unauthorized limits of 77.3 and 74.4 mg/L for well 7and 9, respectively. But in regard to Schoeler diagram, all of the wells are classified as containing water with drinking quality. The level of sodium in wells 7 and 9 with 401.1 and 335 mg/L is higher than the standards and classified as water with unsuitable quality for drinking as shown in Schoeler diagram while the remaining 26 wells are ranked as containing water with proper quality for drinking with a sodium content of less than the above standards. Due to the fact that marl, shale and evaporative formations are ubiquitous in depth and around the studied region, the movement of groundwater based on the typography of the plain, passing from geological formations containing high levels of calcium ion, absorption of sodium and magnesium as the useful metallic elements by plants and climatic conditions of the region are the most significant factors reducing the acidity and content of bicarbonate, sodium and magnesium in groundwater of Sarvestan Plain.

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Introduction

Based on the climatic classifications and coupon classification, Iran is among the dry and desert steppes in which water and its access were the most significant problems from long time ago. In ran, an annual volume of 7 billion m^3 water is withdrawn from groundwater resources which is almost two third of water consumed in the country. This issue highlights the significance of groundwater resources in supplying the water requirements of the country (Yusefi *et.al*, 2010). Most of the regions in the country faces numerous problems such as increase of water shortage in hot seasons which is due to their location in arid and semi-desert regions, irregularity of rainfall distribution from temporal and spacial viewpoints, abnormal rise of different demands for water (i.e. agriculture, industry and drinking), significant limitation of surface water resources, climatic changes and occurrence of drought cycles, increasing reduction of groundwater resources and their salinity (Azizkhani *et.al*, 2010). The unsystematic management of groundwater management as one of the most valuable national resources can exert irreversible damages of environment and national economy. There are numerous studies on pollution of groundwater waters in different regions of the world among which one could point to Asoky and Scheytt (2007), Gunduz *et.al*, (2010), and Reddy *et.al*, (2009). Palangi *et.al*, (2013) found out that the high concentrations of TDH and TD has led to loss of some waters of the region for consumption as drinking water. Chitsazan *et.al*, (2014) did a study on optimization of chemical quality of groundwater resources of Dezful Plan through GIS and following the analysis of parameters of chloride, sulfate, bicarbonate, sodium, magnesium, calcium, soluble materials, electrical conductivity and ratio of sodium absorption, they concluded that most of the diagrams are within proper limits for drinking and agricultural applications. They also studied the south and southeast of the region. The objectives of present study are to study the local variations of qualitative parameters of groundwater of Sarvestan Plan from the viewpoint of physicochemical factors of Mg, Na, HCO_3 and pH in a period of 7 years and develop a map of zoning changes through Geographical Information System (GIS) as a managerial and support instrument.

Materials and methods

Geographical Location of Studied Region

The Fars Province the area of which constitutes 7.5 percent of total area of Iran is one of the most significant producers of agricultural products (i.e.more than 10 percent of national production). This province has 2.2 million hectares of proper lands for agriculture. The Sarvestan Plain is 30 km away from southeast of Shiraz. This are leads to Khorame in longitude of 53˚, 13' East and latitude of 29˚, 17'. It leads to Shiraz in southwest, Jahrom Town in south and Fasa Town in the east. The total area of the region is 1641 km^2 of which 1067.60 km^2 is related to the plain and 573.40 km^2 is made of highlands. The location of Sarvestan plain in the national map with wells selected for measurement of above-mentioned parameters are shown in figure 1. In this plain, 1 well is located in residential area, 19 wells have agricultural application and 8 wells are used for irrigation of pasture.

Meteorology of region

Based on the diagrams of precipitation, the temperature and mean annual evaporation, the mean values of precipitation, temperature and evaporation for the statistical period of 40 years were respectively 379.8 mm, 17.1˚C, and 2222.8 mm. In regard to Demarton classification, the region has an arid climate.

Hydrology of region

Base on the balance of aquifer in Sarvestan Plain, the variation of groundwater volume was 6.39 million m3. There is no inflowing surface or underground current into the plain. In this region, there is no permanent river. Therefore, the surface currents show up as seasonal rivers and no surface or underground water is artificially transferred to the plain through construction of associated structures. The mean depth of underground water in winter ranges between 3 to 60m. The highest negative variation and drop of groundwater level in the center of the plain is -19m while in southwest and northwest of the plain, it is respectively 10 and 12m.

Geological structure of the region

Based on the studies in the intended area, the geological formations of Asmari-Jahrom, Sachoon, Pabede-Gorpi, and Raz Kaghrar are located. The bedrock of the plain is made of Aghajari Formation while the Razak Formation constitutes its boundary. The fault set of Sarvestan has north-south direction which includes the most significant fault of the region. This fault surpasses the intended region in northern and southern areas. The Kahdan Fault is located in the south and Maharlo Fault is in the north of the plain. In general, there are two types of aquifer in the region which are karstic and alluvial aquifers. The calcareous formations and alluvial sediments form these aquifers. The large area of the plains and their feeding from surrounding highlands have assigned them high quantative potential and there are a lot of agricultural wells in them. Figure 2 shows the location of studies wells in the geological map of the region prepared through GIS.

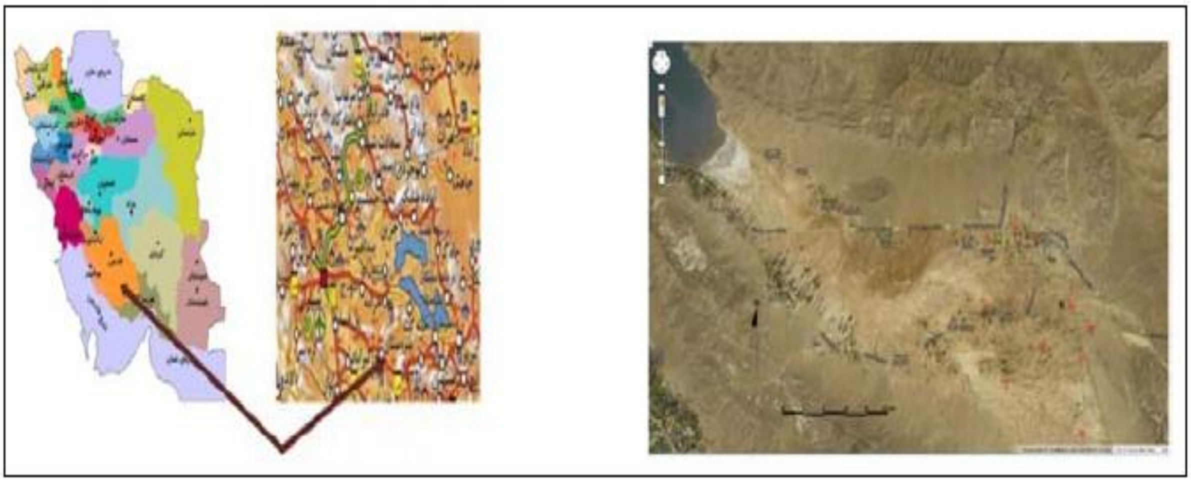

Fig. 1. Location of studied area in east of Sarvestan Plain in map of Iran.

Using utm (X, Y) and data of physicochemical parameters of water (pH, HCo_3^-, Na+,Mg2+), 28 wells were selecting during 2006-2012 in a way that first, they have complete statistics and second, the whole area of the plain is covered. The locations of all wells were determined on the map of land usage in GIS environment. With drawing of talweg, the numbering of wells was done from west to north and south and then to the east of the plain. Then, Google Earth Software was used to develop location map so as to determine the applications and Excel Software was used to determine mean, standard deviation, upper-lower limit, and variation coefficient. The variation diagram and zoning map of mean of each parameter were developed by GIS Software (Version 10 Surfer). Finally, the analysis of above diagrams was used to analyze the level of groundwater, precipitation, geological maps, zoning, location, application, field studies. The comparison with international standards and Schoeller diagram were used to analyze the mean of each parameter. In general, the two types of titrimetric and instrumental tests were done based on referential standard of 1998. The measurement of pH (Meteroohm 654, Swiss), bicarbonate by spectrophotometer (5000, DR), sodium by spectrophotometer (Palintest 7000) and sodium by titration (EDTAT) was done.

Results and discussion

The increasing pollution of groundwater reservoirs in the past few decades and increase of awareness of human population about significance of this susceptible sources have led to widespread efforts to protect the clean groundwater resources and restoration of polluted aquifers. The cost of protecting clean aquifer is significantly lower than the cost of optimizing polluted aquifers (Rasmizade et.al, 2012). Rate of exploitation of material from the underground water resources is equally important, according to the type of use, physical and chemical and bacteriological characteristic is also important. Sometimes geological and climate change, pollution in nutrition sites, interference of fresh and saline water in coastal aquifers, urban and industrial waste and fertilizers used in agriculture which penetrates into the ground due to precipitation and irrigation; cause chemical characteristic of the underground water to change. In studying the chemical characteristics of water samples, chemical analysis is required. The prioritization of proper and high-quality locations of groundwater in an aquifer can be attended to as an important principle of qualitative management of water resources. The statistical expression of qualitative data is a proper method for introduction of qualitative characteristics of groundwater of the studied region. The calculated statistical parameters related to data of 28 wells of Sarvestan Plain are shown in table 1.

Study of Acidity Variation

The value of pH or concentration of hydrogen ions determines the acidity or alkalinity of the water. The pH is one of the significant physicochemical characteristics of water because most of the methods of water purification depend on pH. As shown in acidity zoning map (Figure 3), it is observed that mean acidity level in 28 wells is within the standard level of national and WHO standards and its maximum value is observed in well 10 with 8.02.

Table 1. Results of Dara Analysis of Physicochemical Parameters of Studied Wells in Sarvestan Plain (2006-2012).

Item	Unit	Max Mean	Standard Deviation	National Standard	WHO Standard	Schoeller Diagram
pH	-	8.02	0,23	6.5-9	6.5-9	-
Bicarbonate	mg/l	5.1	0.802	-	150	200
Sodium	mg/l	401.1	91.7	200	200	230
Magnesium	mg/l	77.3	18.3	150	50	130

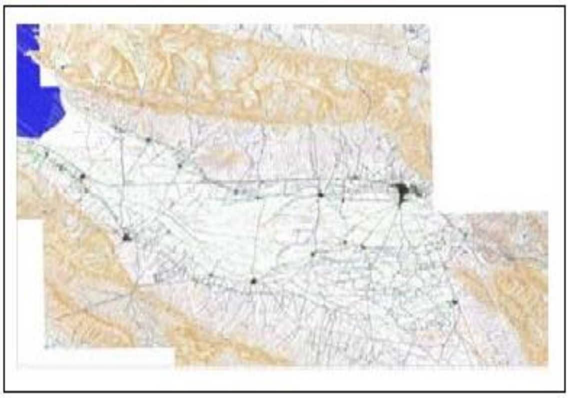

Fig. 2. Location of studied wells in Sarvestan Plain.

Analysis of changes of bicarbonate

The Carbonic Ac solves in the water and combines with the elements it contains. A part of it might also combine with water and produce carbonic acid while the other part is changed into carbonate and bicarbonate ions. Based on figure 4, the mean value of bicarbonate in water of 28 wells was in the group of drinking water with good drinkability in Schoeler diagram and in the permissible ranges of the above mentioned standards too. The highest mean of bicarbonate in well 16 was 5.1 mg. L. There is no value in national standard for value of bicarbonate.

Analysis of sodium variation

The sodium element, as one of the ubiquitous elements, is found in most of natural water resources due to its hive solubility. The value of sodium ranges from 1 to 100 mg. L in saline waters. The upper limit of tasting sodium in drinking water depends on many factors such as major anions of the water and temperature. The mean value of sodium in water of 26 wells, considering the zoning map in figure 5, is less than standard and WHO standards and within the category of potable water with good drinkability in Schoeller diagram. The wells 7 and 9 with respective value of 40.1.1 and 335.7 mg. L have the highest values of sodium which is higher than the above standards and categorized as a water with unsuitable drinkability degree.

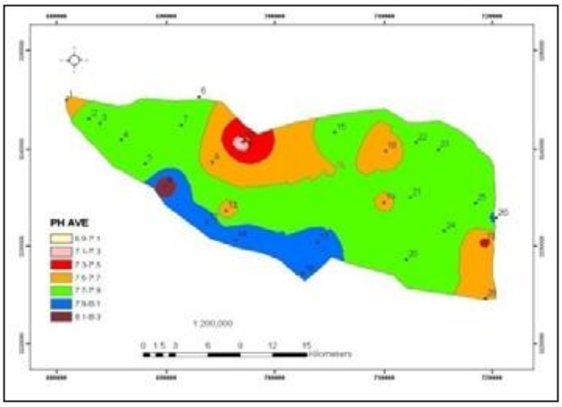

Fig. 3. Map of zoning mean acidity.

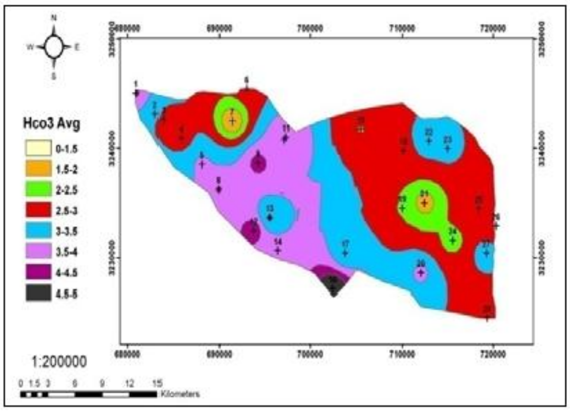

Fig. 4. Map of zoning mean bicarbonate content.

Analysis of magnesium variation

Magnesium is one of the normal water elements which makes soluble salts. The magnesium in water forms both carbonate and bicarbonate the concentration of which is less than combined elements of calcium. In high pH level, magnesium can be solved to low extent in water. The 26 wells had drinkable water based in WHO Standard and the remaining 2 wells (i.e. 7 and 9) with magnesium content of 74.4 and 77.3 mg. L were in permissible range while in Schoeller diagram, 28 wells were included in the category of properly drinkable water which satisfied the national standards too. The maximum value of magnesium was observed in well 9.

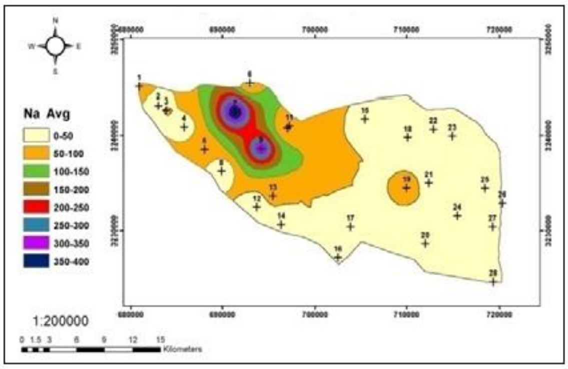

Fig. 5. Map of zoning mean sodium.

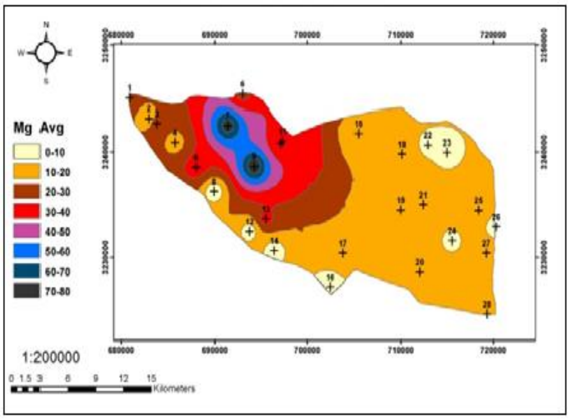

Fig. 6. Map of zoning mean magnesium.

Conclusion

Each country has its distinctive characteristics of potable waters based on the potential of water resources and climatic conditions. It is a reality that the standard of drinkable water in an arid and desert country is different from a country with high level of precipitation. For instance, the higher limit of chloride in drinking water is 5 mg/L while in Argentina, it is 60 mg/L. To determine the suitability of drinking water, different diagrams were offered among which the Schoeller diagram is widely used in hydrogeology of drinking waters. The chemical classification of water, determining the origins of groundwater, the level of ions in the water and comparison of water passing from different sediments as well as chemical suitability of these waters for usage in agriculture, industry and drinking can significantly contribute to solving this problem. The results showed that the use of Schuler diagrams and preparation Map of the zoning parameters in waters Underground of drinking , If the range of aquifer water quality good, But somehow contaminated with harmful substances and toxic, Quality disappears and they cannot be drinking. Zoning maps show a good image of the chemical hydro-geology and Help in solving some of the problems of hydro-geological study area and As well as the exploitation of groundwater from the point of view of agriculture , Drinking and industries for engineers in the design and choice of technology helps desired. (Moghimi, 2007). The pH level in ground water depends upon equilibrium mode of carbon dioxide, carbonate and bicarbonate. The level of pressure and temperature affects the equilibrium mode too. Most of the ground waters have a pH ranging from 6 to 8.5. Due to the fact that reduction of precipitation, increase of temperature and intensity of evaporation reduce CO_2 level and the fact that the geological structures of Sarvestan Plain are mostly made of gypsum and salt compounds, these factors probably balance pH to the permissible ranges of national and WHO standards. The primary source of bicarbonate ion in groundwater is the solved CO_2 in water of rainfall and snowfall. The CO_2-containing water solves carbonate materials in its way and produces bicarbonate. The form of CO_2 depends on pH variation. The CO_2 molecules appear as bicarbonate in pH level of 4.5 to 8.5. Due to reduction of precipitation and flow of groundwater streams, and increase of temperature and intensity of evaporation, these factors are seemingly the most important ones which reduce dissolution of existing materials in geological structures of the pain. This results in a case in which the value of bicarbonate is within the permissible ranges of the above-mentioned standards and the water has good drinkability as shown in Schoeller diagram. In the soils of arid regions, the soil is almost saturated by calcium, sulfate, chloride and sometimes, nitrate. As a result, the soil solution has a high level of accumulated calcium and sodium and calcium attain balanced levels because of competition with calcium. In addition, the absorption of sodium as the useful element and magnesium as the highly consumed and the only metallic element in the chlorophyll of plants and green cover of pastures as well as type of geological structures around and at the depth of the plain with gypsum and salt compounds, it seems that the level of sodium and magnesium in the water of 26 wells is within the category of waters with good drinkability and less than upper limits of the intended standards. Due to the fact that wells 7 and 9 have the maximum mean of sodium and magnesium (i.e. magnesium compared with WHO Standard) and the issue that the two wells are in the evaporative region of the saline Maharloo Lake, it is probably the phenomenon of penetration and immigration of saline water of the lake toward the plain which reduce the level of precipitation, intensity of evaporation and recent droughts which increased the values of these two parameters in the intended wells. In this regard and from the perspective of groundwater drinkability, 26 wells are suitable for drinking from the viewpoint of factors of acidity, bicarbonate, sodium, and magnesium compared with national and WHO standards and Schoeler diagram. Therefore, it is suggested that other chemical parameters affecting the quality of water in Sarvestan Plain might be studied too. This study matches the results of Pathak (2012) in his study called "Assessment of physicochemical quality of groundwater by multivariate analysis in some populated villages nearby Sagar City" which studied 14 parameters and stated that electric conductivity of 75 samples were less than WHO standards and the pH value of all samples ranged from 5.5 to 8.5. He also concluded that there is an association between alkalinity and hardness of carbonate and bicarbonate. In addition, Sayad, Mohammadzade and Velayati (2011) stated that compared with Schoeler diagram, the groundwater of aquifer is classified as completely unsuitable to good while the intended water standards showed it as belong to medium to good groups.

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