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Chemical Analysis of Ground Waters in Tabriz Area, Northwestern Iran

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Hydrochemical investigations were carried out in Tabriz area, northwestern Iran, to assess the chemical composition of groundwater. The area falls in a semi-arid type of climate. In this area, groundwater has been exploited over the past century. A total of 26 representative groundwater samples were collected from different wells to monitor the water chemistry of various ions. Water presents a large spatial variability of the chemical species (Na-SO_4, Na-Cl, Mg-HCO_3, Na-HCO_3 and Ca-Cl) which is in relation to their interaction with the geological formations of the basin and evaporation. The hydro chemical types Na-SO_4 and Na-Cl dominate the largest part of the studied area. All the samples in the studied area falls under the category of medium sodium hazard and in high salinity zone. Such water shouldn't be used for plants and special management for salinity control is required.

Key Words: Hydrochemistry, Tabriz, Groundwater, Chemical composition, Salinity, Hazard, Sodium adsorption ratio.

INTRODUCTION

Groundwater is the primary source of water for human consumption, as well as for agriculture and industrial uses in Iran. Groundwater is an important resource in Iran. Continued population growth in Iran is rapidly depleting groundwater supplies in some areas. Further intensive use for irrigation makes groundwater a critical resource for human activities. The problem of groundwater quality deterioration has become urgent in Tabriz area in northwestern of Iran because of the intensive farming.

The study area lies in Tabriz flat shown in Fig. 1. The climate of the study area is considered to be semi-arid, the annual average precipitation being approximately 266 mm. Rainfall occurs from October to May, with a maximum during November and February of each year. The most important economic activity of the area is agriculture, the chief crops are garlic, potatoes and wheat, with actual irrigation being lower than total theoretical demand, as there is considerable deficit in relation to the amount of cultivated land. Despite the importance of groundwater in Iran, little is known about the natural phenomena that govern the chemical composition of groundwater or anthropogenic factors that presently affect them.

The aim of this study was to determine chemical water compositions and the main geochemical reactions, which control the groundwater composition in a semi-arid aquifer in western Iran.

EXPERIMENTAL

Water samples for chemical analysis were obtained during the year 2007 from the 26 wells shown in Fig. 1. Samples were analyzed in the laboratory for determining the pH and electrical conductivity of the major ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, HCO_3^- and NO_3^-). The determinations were made within 48 h after collection of the water samples. Calcium, magnesium, chloride and bicarbonate were analyzed by titration. Sodium and potassium were measured by flame photometry, sulfate by spectrophotometric turbidimetry and nitrate by colorimetry with a UV-visible spectrophotometer[1]. Care was taken that the HCO_3^- and Ca^{2+} ions were analyzed within 24 h of water sampling.

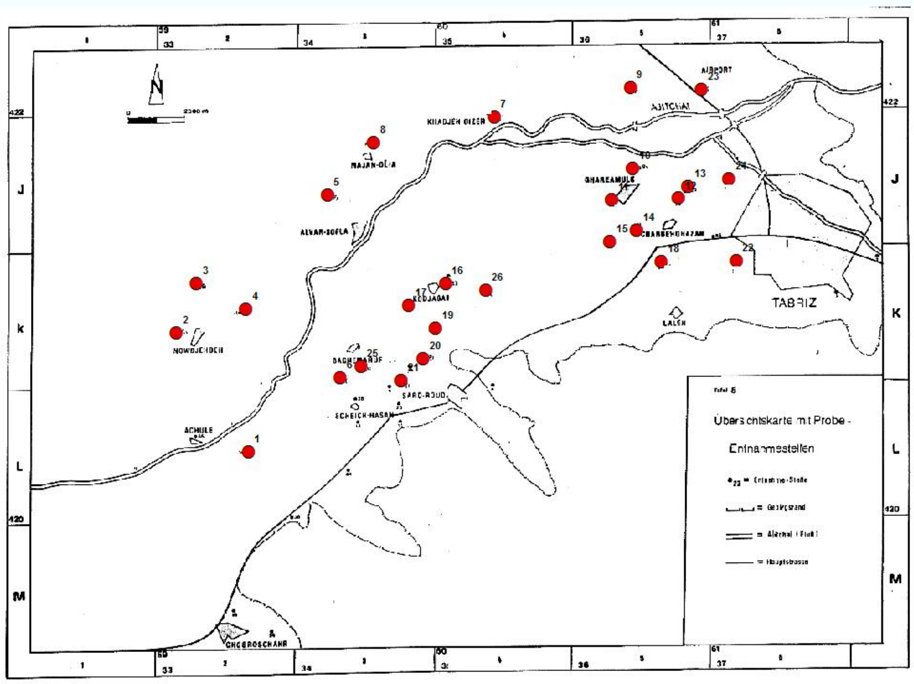

Fig. 1. Study area showing location of wells sampled for groundwater analysis

RESULTS AND DISCUSSION

The chloride concentration increases west and southeastward across the study area, as shown in Fig. 2. It ranges from 900 to 1500 mg L^{-1}. Maximum and minimum values of bicarbonate are 720 and 230 mmg L^{-1}, respectively. As shown in Fig. 3, the concentration increases eastward and southwestward. The sulfate concentrations range from 74 to 1100 mg L^{-1} and are higher in the center and east side of the study area, as depicted in Fig. 4. Nitrate values range from 0.0003 to 240 mg L^{-1}. Spatial distribution of nitrate concentrations is shown in Fig. 5. The results indicate that in 23 % of samples the concentration of nitrate is above the recommended guidelines of the World Health Organization (50 mg L^{-1}). The calcium concentration increases southwestward (Fig. 6). It ranges from 80 to 350 mg L^{-1}. The magnesium concentrations range from 20 to 180 mg L^{-1} and are higher in the southeast and westward (Fig. 7). The maximum and minimum concentrations of sodium are 900 and 130 mg L^{-1}. Spatial distribution of nitrate concentrations is shown in Fig. 8. The sodium concentration increases northeastward across the area. The average pH is 6.74; the maximum is 7.4 and minimum 6.5.

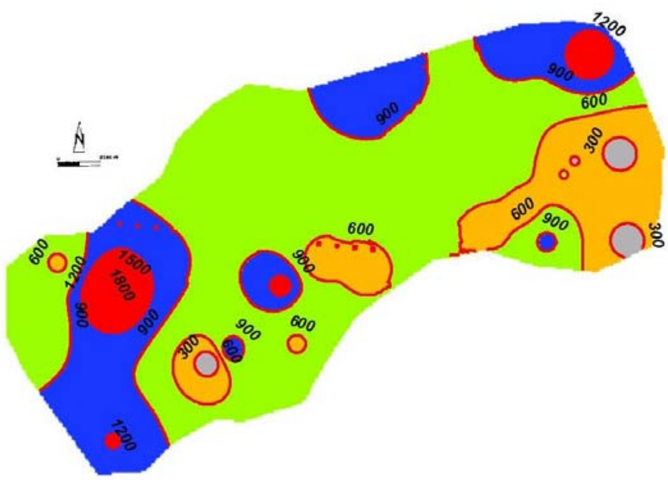

Fig. 2. Spatial distributions of Cl^- in the groundwater of the study area. Contour interval 1 mg L^{-1}

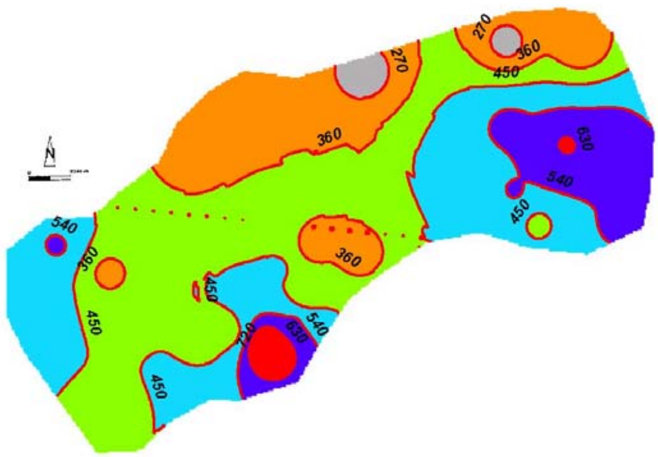

Fig. 3. Spatial distributions of HCO_3 in the groundwater of the study area. Contour interval 1 mg L^{-1}

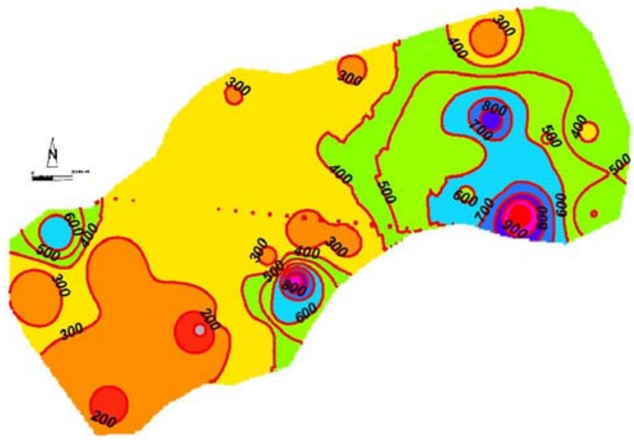

Fig. 4. Spatial distributions of SO_4^{2-} in the groundwater of the study area. Contour interval 1 mg L^{-1}

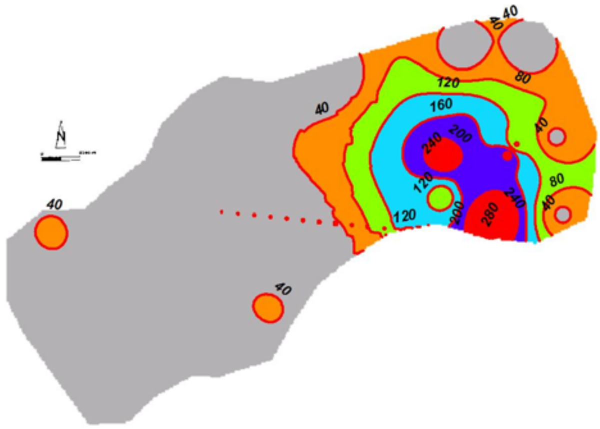

Fig. 5. Spatial distributions of NO_3^- in the groundwater of the study area. Contour interval 1 mg L^{-1}

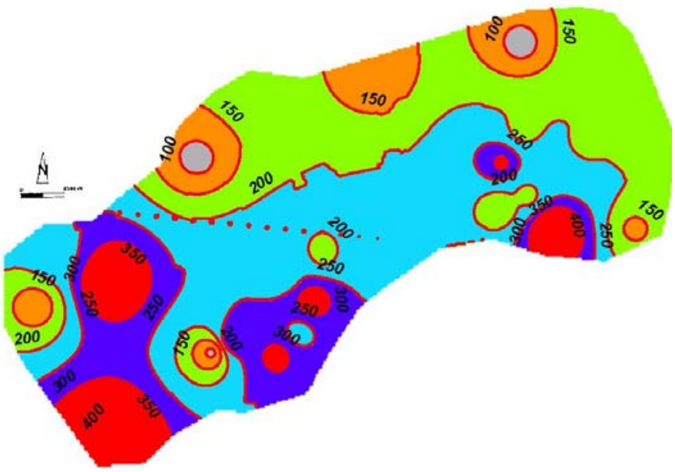

Fig. 6. Spatial distributions of Ca^{2+} in the groundwater of the study area. Contour interval 1 mg L^{-1}

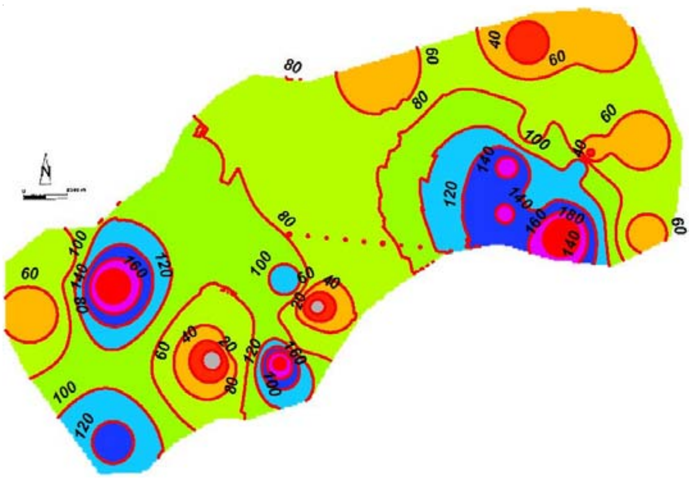

Fig. 7. Spatial distributions of Mg^{2+} in the groundwater of the study area. Contour interval 1 mg L^{-1}

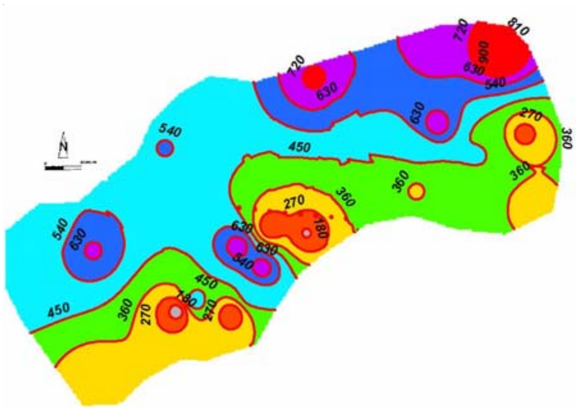

Fig. 8. Spatial distributions of Na^{+} in the groundwater of the study area. Contour interval 1 mg L^{-1}

Hydrochemical species: The piper diagram in Fig. 9 constructed using AqQA Software shows the relative concentrations of the different ions from individual water samples. Five main water types have been identified on the basis of major ion concentrations.

Based on dominant cations and anions these 5 groups are shown in the following way:

The Na-Cl represents 54 % of the total number of water samples analyzed, while Na-SO_4 and Ca-Cl represent 19 % and Na-HCO_3 and Mg-HCO_3 represent 4 %, respectively. The Na-Cl type water is dominated in the most part of studied area with the sodium range from 4 to 40 mmol L^{-1}, while chloride range from 2.5 to 52 mmol L^{-1}, respectively. The Na-Cl water type are distributed from the south-west to the south-east of the studied area. The dominant cation is sodium. Water of Na-SO_4

and Ca-Cl types are less distributed in the studied area and only 5 wells have this type of water. However, a good amount of sodium chloride containing waters suggests that evaporational sediments are the dominant facieses in the studied area. Nitrates are soluble in water and not adsorbed by clay rich soils. This suggest that high NO_3^- concentrations in the groundwaters relate to removal of NO_3^- from soils, since nitrogen fertilizers represent the main source of NO_3^- in this extensively farmed region. In the area studied, various anthropogenic activities such as intensive agriculture, vegetable production, horticulture and poultry farming have been going on for a long time. Recharge from precipitation and irrigation may carry nitrogen compounds from the soil into the aquifer, often resulting in elevated nitrate concentrations in wells. Important nonagricultural sources of nitrate in the studied areas include municipal and industrial discharges containing nitrogen bearing effluent and atmospheric deposition. The sodium concentration increases eastward across the area where anthropogenic activities have been going on for a long time.

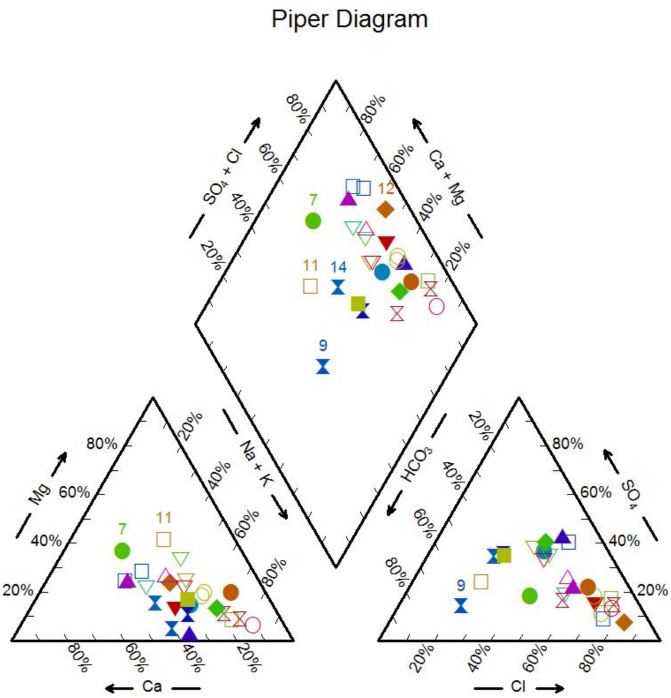

Fig. 9. The piper diagram for the groundwater samples of studied area

The origin of solutes: Compositional relations among dissolved species can reveal the origin of solutes and the process that generated the observed water compositions. Statistical analyses indicate a positive correlation between some pairs of parameters.

The Na-Cl relationship has often been used to identify the mechanisms for acquiring salinity and saline intrusions in semi-arid regions[2-4]. The high Na^+ and Cl^- contents detected in certain samples may suggest the dissolution of chloride salts. A parallel enrichment in both ions indicates dissolution of chloride salts or concentration processes by evaporation. These two mechanisms and saline intrusions from west are predominate in the studied region, with a distribution of values close to one in most cases (Fig. 10).

The dissolution of halite ions in water release equal concentrations of sodium and chloride into the solution, but analytical data in Fig. 10 deviates from the expected 1:1 relation indicating that a fraction of sodium is associated with an anion other than chloride.

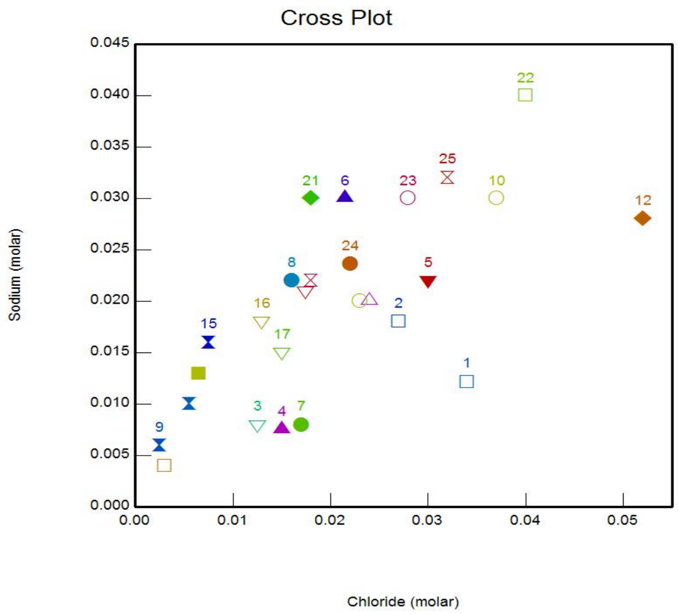

Fig. 10. The value of Cl^- as a function of Na^+ in the groundwater samples

A Na/Cl molar ratio higher than one is typically interpreted as reflecting Na^+ released from silicate weathering reactions[5]. Silicate dissolution can be a probable source for Na^+ in groundwater in the studied area. One potential source of excess Na^+ is weathering of sodium plagioclase in the metamorphic rocks of the studied area. The excess of sodium in these samples may also result from dissolution of sodium sulfate minerals. Those samples with a value of Na/Cl ratio higher than one also show a deficit in $Ca^{2+} + Mg^{2+}$ and this is consistent with a Ca^{2+}–Na^+ cation exchange process which leads to a softening of the water[6,7]. The contribution of potassium to the groundwater in these samples is modest. The low levels of potassium in natural waters are a consequence of its tendency to be fixed by clay minerals and to participate in the formation of secondary minerals[8].

Salinity hazard: The quality of irrigation water depends primarily on its silt and salt content. Water used for irrigation always contains measurable quantities of dissolved substances, which as a general collective term are called salts. They include relatively small but important amounts of dissolved solids originating from dissolution or weathering of the rocks and soils. The electrical conductivity is a useful parameter of water quality for indicating salinity hazards. In general water with conductivity values below 750 µs/cm are satisfactory for irrigation.

Relative proportion of sodium to other cations: A high salt concentration in water leads to formation of a saline soil and high sodium leads to development of an alkali soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of caions and is expressed in terms of sodium adsorption ratio (SAR). If the proportion of sodium is high the alkali hazard is high and conversely if calcium and magnesium predominate, the hazard is less. If water used for irrigation is high in sodium and low in calcium the cation exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles.

The values of SAR in the ground water of studied area ranged from 2.5 to 14.6 as evident from the SAR values. The samples in the studied area falls under the category of medium sodium hazard.

Conclusion

Chemical analysis of some groundwater samples collected at different locations in the Tabriz area of Iran showed that 5 main types of groundwater such as Na-SO_4, Na-Cl, Mg-HCO_3, Na-HCO_3 and Ca-Cl are present within the study area. This study has demonstrated that the chemical composition of groundwater differs according to water types. The highest increase is observed in the concentration of the nitrate in the Ca-HCO_3 and Ca-SO_4 facies reflecting the degree of human influence. The values of SAR in the ground water of studied area ranged from 2.5 to 14.6 as evident from the SAR values. All the samples in the studied area falls under the category of medium sodium hazard.

Since, all samples of the study area fall in high salinity zone. Such water shouldn't be used for plants and special management for salinity control is required.

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