Environmental Hydro-Geochemistry of Groundwater Resources in Ravar Plain, Northern Kerman Province, Iran

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Extended Abstract

Introduction
Groundwater resources in arid-semiarid areas in the entire world are suffering from problems of over-abstraction and decline of water tables. In addition to the issues related to quantity, degradation of groundwater quality is now of major importance in the arid and semiarid regions. In such areas, natural factors such as the low precipitation, combined with high evapotranspiration, result in higher changes in groundwater composition. Besides the natural factors, a range of human related factors might influence the chemical quality of the groundwater. For this reason, hydro-chemical evaluation of groundwater resources, particularly in arid and semiarid regions, is of great importance. Ravar Plain located in Kerman province is a typical arid region with high evaporation rate and low annual rainfall. Another important feature of this area is abundance of evaporative rock units which are important in terms of quality of groundwater. Groundwater is the only source of water for drinking and irrigation purposes in the plain. The objective of the present study is to evaluate the environmental and hydro-chemical properties of these resources and to determine the natural or anthropogenic factors influencing the groundwater quality.

Materials and Methods

Study area
The Ravar region with an area of 4080 square kilometers is located in north part of Kerman province, between longitudes 57°30’56˝E and latitudes 31°30’31˝N (Fig. 1). The average elevation (altitude) of the study area is 1,170 m above sea level. Due to proximity of Ravar plain to the Lut Desert, it has a desert climate condition that is characterized by low mean annual precipitation (47 mm) and high evaporation rate (approximately 3,766 mm). Geologically, the study area falls in the central zone of Iran. The geologic formations exposed in the study area are ranged in age from Precambrian to Quaternary and include sedimentary (chiefly evaporative in nature) and igneous rocks and unconsolidated materials (Quaternary deposits).

Fig. 1. the map shows Ravar plain and groundwater sampling points
Groundwater sampling
Eighteen groundwater samples were collected from abstraction wells throughout the plain (Fig. 1). Samples were analyzed in the laboratory for the major ion chemistry and heavy metals by means of standard methods. The pH and Electrical Conductivity (EC) were measured using calibrated pH and EC meters. Calcium and chloride (Cl\textsuperscript{−}) and bicarbonate (HCO\textsubscript{3}−) were also determined using titration method. Mg was determined by subtracting the hardness from the Ca content. Sodium was also measured by flame photometry. Sulphate (SO\textsubscript{4}\textsuperscript{2−}) and nitrate (NO\textsubscript{3}−) were also determined by gravimeter and spectrophotometer, respectively. Total dissolved solids (TDS) were computed by multiplying the EC by a factor of 0.65. Heavy metals were measured by atomic absorption spectrophotometer (AAS) equipped with a graphite furnace. To get a better understanding of hydro-chemical mechanisms controlling the groundwater composition, multivariate statistical techniques were applied to hydro-chemical data. The measured hydro-chemical parameters were also compared to permissible limits set by World Health Organization (WHO) for drinking water purposes. Graphical methods were used to analyze the hydro-chemical data and to determine the groundwater chemical evaluation.

Results and Discussion
Variations of major ion concentrations and some physicochemical parameters in the Ravar groundwater resource
According to the spatial distribution map of pH values, the maximum level of this parameter is observed near the recharge area. Toward the discharge area, chloride and sulfate become gradually dominant. EC level also tends to increase from the recharge area toward discharge area in the direction of the groundwater flow path. It seems that high rates of evaporation, followed by dissolution of evaporated minerals are the most important hydro-chemical factors controlling the variations of ion concentrations and some physicochemical parameters of water samples. Although anthropogenic sources such as irrigation-return flow and leaching of domestic wastewater can increase the content of sulfate, nitrate and bicarbonate in the groundwater resources, the effect of natural processes (i.e. evaporation and dissolution of evaporative rocks) on variation of ion concentrations is more obvious and effective. The chemical composition of water samples from the study area is plotted on the Piper diagram. According to this diagram, the hydro-chemical types of groundwater samples are typically Na-SO\textsubscript{4}-Cl.

Effect of evaporation process on hydro-chemical quality of groundwater resources of the Ravar plain
In order to explore the effect of evaporation on quality of the Ravar groundwater resources, the mean of parameters measured in the recharge and discharge areas were mutually compared. As it was expected, levels of TDS, EC and major ions such as sodium, chloride, sulfate, calcium and magnesium measured in the discharge area is approximately 5 times higher than their corresponding parameters measured in the recharge area. Therefore, it can be stated that levels of hydro-chemical parameters of local groundwater resources are significantly controlled by evaporation process. It can be also possible that some anthropogenic activities might influence the groundwater quality via irrigation-return flow. However, the impact of anthropic activities on the groundwater composition is negligible when compared to natural process that control hydro-chemical characteristics of local groundwater.

Concentration and origin of heavy metals in groundwater resources of the Ravar plain
Generally, concentration of heavy metals in the groundwater resources of the study area is low and almost all measured metals (except for Pb) are within the permissible limits for drinking water. It is also found that anthropogenic sources such as road traffic can be responsible for high concentrations of lead in the some groundwater samples. Generally, the origin of heavy metals in the groundwater resources can be related to coal-bearing black shales units exposed in the study area. Related to arsenic, it can be inferred that the alkaline prevailing in the groundwater, the As can be as released and occurred as soluble ions in the groundwater composition.

Multivariate statistical analysis
Results obtained from principal component analysis (PCA) indicated that investigated metals are grouped into three principal components. The first component, explaining the highest percentage of the total variance, has strong positive loadings on TDS, TH, EC, SO\textsubscript{4}\textsuperscript{2−}, Mg\textsuperscript{2+}, Ca\textsuperscript{2+}, NO\textsubscript{3}−, Cl\textsuperscript{−} and Na\textsuperscript{+} and this indicates dissolution of evaporative minerals. This component represents the role of evaporation in variation of groundwater quality. The first component shows strong negative loadings on Pb and Se, indicating the same source (coal-bearing black shales) for these elements. The second component is associated with the As and pH suggesting that As release are associated with increase in water pH. HCO\textsubscript{3}− and Pb have also strong positive loadings in this component which can explain correlation of lead with pH. The component 3 accounts for 20 % of the total variance. This shows strong positive loadings on Mn and Cd indicating again similar origin for these two elements (coal-bearing black shales). These findings are consistent with the results obtained from cluster analysis.
Conclusion
Evaporation process, followed by dissolution of evaporite minerals are the most important factors controlling the chemistry of groundwater in the Ravar plain. Anthropogenic activities such as agricultural activities and road traffic are also responsible for high concentrations of some constituents (e.g. nitrate, bicarbonate and some heavy metals) in the groundwater samples. Based on the results of T multivariate statistical analysis, the origin of heavy metals in the groundwater resources of the study area is found geogenic (natural), probably related to coal-bearing black shales units in the study area.

Keywords: groundwater resources, heavy metals, hydro-geochemistry, Kerman, Ravar plain.