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Hydrogeochemical and isotopic investigation and water quality assessment of groundwater in the Sisseb El Alem Nadhour Saouaf aquifer (SANS), northeastern Tunisia

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ABSTRACT

In the Sisseb El Alem Nadhour Saouaf basin (SANS), as in all other arid regions, surface water is scarce and groundwater is the greatest most important source of water for all uses. This study aims to identify the processes governing groundwater mineralization in order to assess the suitability of the groundwater for drinking and agriculture purposes. This research used a geodatabase which includes information on hydrogeology, geochemistry, land cover, and geology. We identified the most important factors involved in the deterioration of water quality, including anhydrite and gypsum dissolution, silicate weathering, downward leakage between aquifers, evaporation, groundwater over-exploitation, and the overuse of fertilizers. Furthermore, the two following important factors were identified: the intrusion of Sebkhat El Kelbia and the vertical flow from the deep aquifer. Results were used to develop a conceptual geochemical model, wherein three geochemical regions were differentiated. Statistical techniques, such as Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were used to confirm the water affinities and the presence of three different geochemical regions. The water quality index (WQI), Wilcox and Richards's diagrams were performed to assess the suitability of groundwater to drinking and irrigation purposes. These indexes confirm the fact that the groundwater of this aquifer is not suitable for irrigation, neither for drinking. Furthermore, ^{18}O and deuterium isotope data indicate the importance of evaporation in the basin, and the recharge with modern rainfall.

1. Introduction

Nowadays, groundwater quality deterioration is the most common problem for arid and semi-arid areas (e.g. Liu et al., 2015; Caraballo et al., 2016). Indeed, the quality, the quantity and the regional dynamic flow of groundwater is controlled by the increasing demand for irrigation water, as well as the urbanization and demographic growth. Thus, to guarantee integrated water resource management, it is crucial to assess the chemical composition of the water and to control factors and phenomena responsible for any deterioration of its quality and to assess the suitability of the groundwater to drinking and to agriculture proposes.

In the last decade, the quality of groundwater has been a subject of considerable research. These researches were essentially based on chemical and stable isotopic investigations and statistical analysis, to highlight the role of water–rock interaction and to identify the source and processes controlling groundwater mineralization. These methods obviously help to understand the hydrodynamics of the groundwater and to constitute an excellent tool to conceptualize the functioning of the aquifer system.

The hydrochemical assessment and the statistical analyses are still very classic and it has been generally performed for many regions around the world. In Spain for example, Gil-Márquez et al. (2016) studied the chemical and isotopic composition of the groundwater of the evaporite-karst system, combined with geochemical inverse modeling, reinforced and complemented the current hydrogeological knowledge about the Brujuelo area (South of Spain). Therefore, results could be used to define specific actions for the adequate management, protection and, if necessary,

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restoration of the associated wetlands and for the mitigation of the effects of the briny groundwater over the quality of dependent-water resources downstream.

Also, these methods were used in Canada, in the Outaouais Region (Quebec) to identify the main processes responsible for the deterioration of groundwater quality and to develop a conceptual model for groundwater flow and geochemical evolution (Montcoudiol et al., 2014).

In the central Tunisia, Farid et al. (2013) have examined the geological, hydrodynamic and the geochemistry context of the Ain Bou Morra aquifer located in the North of Kairouan, through chemical and isotopic investigation and have considered the recharge area to be essentially within the Atlasian highlands and Oligocene outcrops of the region.

In the South of Tunisia, the quality of groundwater in Zarzis Peninsula has been the subject of the work of Agoubi et al. (2014). The study refers to Zarzis Peninsula shallow aquifer; climate, geology and geography are the factors giving rise to salinity. Several methods were used to determine the influence of various parameters on the salinity of groundwater. The results of this study show that the analysis of hydrochemical data using statistical techniques such as HCA, PCA and variographic analysis associated with geochemical modeling can help elucidate the hydrologic and geologic factors controlling water chemistry at a regional scale.

Saidi et al. (2009) have applied the susceptibility indexing method and the DRASTIC method in the Chebba-Mellouleche Aquifer (Eastern Tunisia) to examine the contamination susceptibility of this aquifer. They demonstrated that a clear degradation of the water quality throughout the Aquifer is grown. The used method seems to be efficient to assess the suitability of groundwater to drinking and irrigation.

In the Sisseb El Alem Nadhour Saouaf basin, in northeastern Tunisia (Fig. 1), the main source of water supply is groundwater due to its relatively large reserves and the shortage of surface water. Over the last decade, groundwater exploitation in SANS basin has increased dramatically, mainly due to the development of agricultural activity. Consequently, this resource showed high mineralization leading to unsuitable use of water. Many factors control the chemical quality of the groundwater including water–rock interaction, recharge, geological structure, lithology and geochemical processes within the aquifer.

The Sisseb El Alem aquifer was the subject of several hydrogeological studies Due to its importance. Several studies were carried out and treated different hydrogeological aspects such as structural, sedimentology, stratigraphy, geophysical and geochemical studies (e.g. Castany, 1951; Delteil and Turki, 1986; Yaich, 1992, 1997; Hamza, 1992; Jeddi, 1993; Gharsalli et al., 2013; Houatmia et al., 2015; Hamdi et al., 2017).

The current paper will focus on the geochemistry and the interactions between the different aquifer layers. This study aims to identify the processes governing groundwater mineralization in order to assess the suitability of the groundwater for drinking and agriculture purposes and to propose a conceptual model of groundwater quality behavior. To carry out these objectives, we used geographic information system (GIS) to elaborate the different thematic maps, conventional graphical plots, ionic ratios, saturation index (PHREEQC) and statistics (correlation matrix, principal component analysis (PCA) and cluster analysis).

2. General setting

The study area covers 1100 km^2, with many rural agglomerations, relies on groundwater reserves. The topographic elevation ranges between 17 m on Sebkhat El Kelbia and 1340 m on Jebel Serdj. The hydrographic network is dense. It is composed of many wadis (Nebhana, Essid, Amor, Maarouf, Kseub, El Hamra, Ermal, Rogal, El Khioua, El Ouja). The SANS basin is a semi-arid region. Pluviometry fluctuates considerably from year to year and it is less

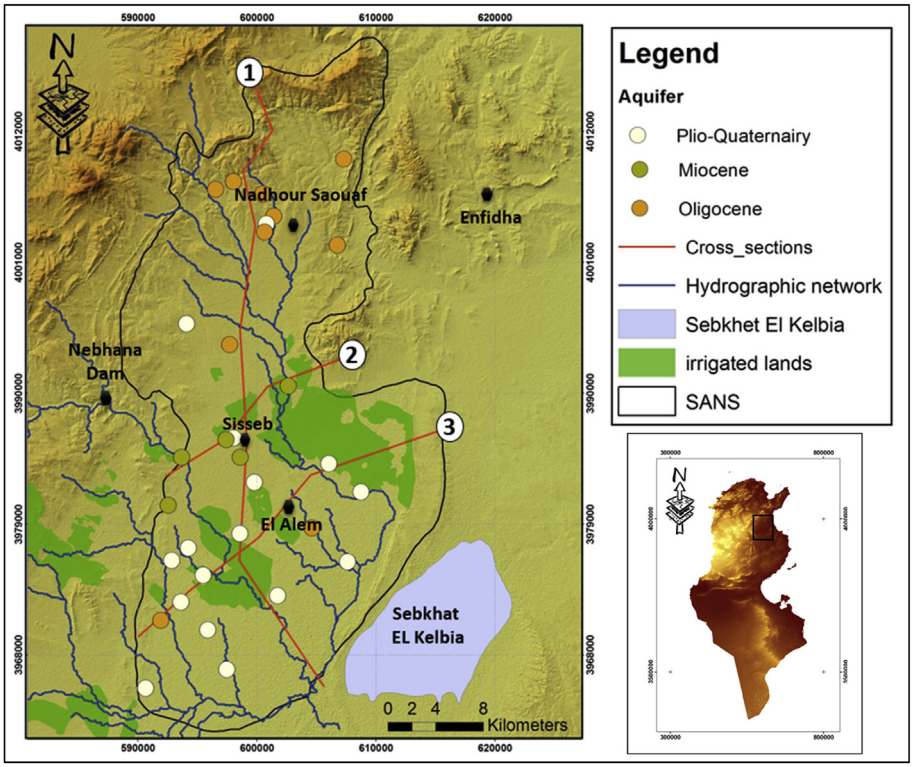

Fig. 1. Location of SANS basin, cross sections and water samples.