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Water resources management strategies and its implications on hydrodynamic and hydrochemical changes of costal groundwater: Case of Grombalia shallow aquifer, NE Tunisia

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ABSTRACT

Information on groundwater quantity as well as quality is required by water managers and decision-makers for defining a sustainable management strategy. This requires a comprehensive assessment of the surface water and groundwater resources. This paper provides an assessment of water resources management strategy in the Grombalia region (Northeast Tunisia) and its impact on quantity and quality evolution of groundwater resources based on an approach that combines (i) hydro-climatic data, (ii) field monitoring, (iii) historic piezometric records, and (iv) geochemical and stable isotopes ($\delta^{18}O$ and $\delta^{2}H$) analyses. We apply this approach to identify the origin of the various water resources and outline how the actual water management impact the quantity and quality of the groundwater in the region.

As consequence of poor water resources management, the shallow groundwater levels have been disrupted: a groundwater rise is observed in the centre and a piezometric drawdown is observed in the upstream regions. Groundwater quality degradation was registered especially in the centre and downstream zones.

1. Introduction

There is a wide world consensus that groundwater is the most important source for drinking water and irrigation (Lachaal et al., 2010, 2011, 2012; Mohammadi et al., 2014; Zaidi et al., 2015; Thomas and Famiglietti, 2015; Jellalia et al., 2015; Asfahani, 2016). Sustainable groundwater resources is the main goal to achieve in water resources management (Amer et al., 2012; Palazzo and Brozovic, 2014; Wu et al., 2016). This requires an integrated assessment of the ground water resources. However, a comprehensive and integrated assessment of ground water resources is pretty hard due to the complexity of the groundwater system. Indeed, groundwater is a dynamic system with complex interactions with the distribution of rainfall both in time and space, surface water resources, intensities of irrigation, and water use and distribution. For instance, when water for irrigation is only from surface water it may result in alarming rise of water table creating problems of water-logging and salinization, rendering large areas unproductive. The overexploitation of groundwater through dug wells and shallow boreholes, may lower water table and causes seawater intrusion and salinization of coastal aquifers (Chekirbane et al., 2014; Van Camp et al., 2014; Askri, 2015; Sappa et al., 2015; Najib et al., 2016). In the case of intensive use of surface water for irrigation without good drainage system and a little shallow groundwater pumping, an increase of the water level (Wilson Tumwitike Mapoma et al., 2014; Kirby et al., 2015; Yousif et al., 2016), salinization (Maurice et al., 2012; Zghibi et al., 2013; Lachaal et al., 2014; Van Camp et al., 2014; Zhu et al., 2014; Wu et al., 2015; Mhamdi et al., 2015; Najib et al., 2016), and nitrate contamination (Zghibi et al., 2013; Walraevens et al., 2015; Askri, 2015) may occur. Therefore, proper understanding of the groundwater system behavior is essential in order to define a sustainable management plan which can cope with the impact of future global change on water resources.

Therefore, the objectives of this paper were to (i) address a quantitative and qualitative assessment of the groundwater in the

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Grombalia region, (ii) identify the major hydrogeo-chemical processes occurring in the Grombalia aquifer, and (iii) understand the effect of the current water management on the groundwater system in the region.

2. Study site description

The Grombalia plain is located in north east Tunisia and covering an area of 100 km^2 (Fig. 1). The Grombalia basin is 40 km away from Tunis and 20 km from Hammamet (Fig. 1a and b). It is bounded by Jbel Korbous on the Northeast, by Jbel Abdelrrahman and Takelsa syncline on the East, and by the Mediterranean Sea on the Northwest (Fig. 1b).

The geological features, mainly the normal faults of Borj cedria and Hammamet, have shaped the Grombalia basin into a Northwest-Southeast oriented graben (Fig. 1b). The Beglia (Miocene) and Segui Formations (Mio-Plio-Quaternary) are characterized by strong subsidence with variable depths (Chihi, 1995; Hadj Sassi et al., 2006) (Fig. 1c) ranging between 227 m in SOL-1 well and 877 m in BEL-3 well (Fig. 2), and reaching a1000 m in the Graben centre (Fig. 3).

The A-A′ hydrogeological cross section shows that the Grombalia aquifer system is limited to the E-NE by Jebel El Hofra and to the W-SW by the Mornag aquifer system (Fig. 3). The major geological outcrops in the study area are mainly Quaternary deposits made of sandstone and marl deposits (Fig. 3).

The groundwater flow system understudy is composed of shallow and deep aquifer systems. The aquifers are separated by a 15 m-thick clay unit (Ben Moussa et al., 2010) while the shallow aquifer is formed by the Quaternary sediments of alluvium, sands, and sandy clays reaching 50 m depth. The deep aquifer is composed by the Mio-Plio-Quaternary (Segui Formtion), Miocene (Beglia Formation), and Oligocene series. The Mio-Plio-Quaternary is characterized by lithological and geometric complexities and it is formed by intercalation of sand, sandy clay and clay deposits.

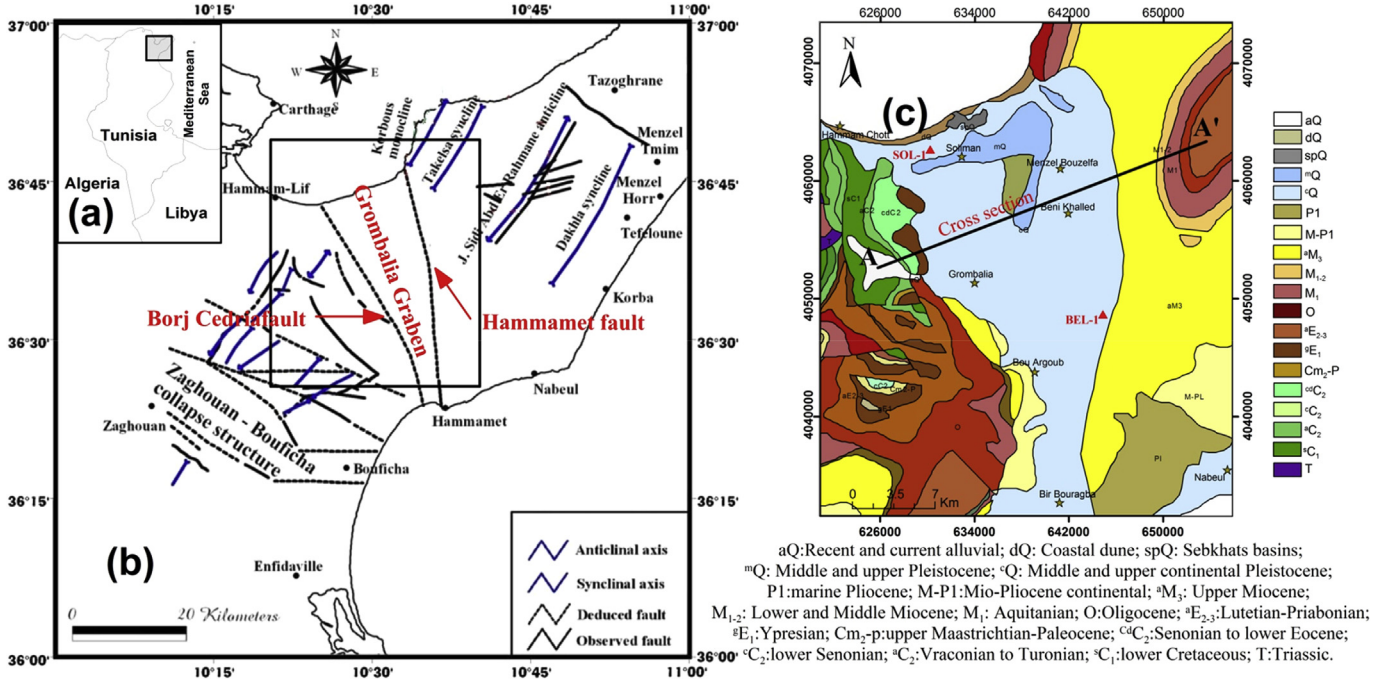
The climate is Mediterranean with an average annual precipitation of 486 mm and average annual temperature of 17 °C, as based on more than 100 years of rainfall records of the Grombalia raingauge station. More than 60% of the annual precipitation occurs in the rainy season which extends from November to March. In addition to the seasonal variability, inter-annual differences in rainfall can occur. For instance, rainfall recorded between 1987–1988 was 192 mm against 1063 mm for the period of 2003–2004 as recorded by the Grombalia rain gauge station.

The study aquifer has been overexploited during the last years leading to a notable decrease in the piezometric levels as well as in the quality of the water (Gaaloul et al., 2014; Chenini et al., 2015). As a response, the local authorities have raised the need since 1984 for providing supplementary water through water transfer network from the Medjerda and Ichkeul basins located in the North-West of Tunisia. These resources have been mainly used for irrigation and drinking water.

Previous chemical studies showed the degradation of Grombalia groundwater quality (Ben Moussa et al., 2009). A high salinization was observed in the aquifer due to both natural processes, including dissolution of geological rocks such as halite and gypsum (Charfi et al., 2013a; Tlili-Zrelli et al., 2013), and to human-made activities mainly related to industrial and irrigation development (Ben Moussa et al., 2009, 2010).

3. Materials and method

In this work, 147 water samples were collected during four piezometric and hydrochemical sampling campaigns on March 2013, November 2013, April 2014, and April 2015 (Table 1). During the field surveys, the water samples were collected simultaneously with the piezometric observations. Some in-situ measurements including temperature (T), electrical conductivity (EC), and pH were performed during the survey. A particular attention has been paid to preserve the collected water samples for further chemical analyses. Sulfate (SO_4^{2-}) concentration was measured using the gravimetric method. Chloride (Cl^-) was analyzed using titration technique according to the Mohr method. Bicarbonate (HCO_3^-) and Carbonate (CO_3^{2-}) were determined by titration with sulphuric acid.



aQ:Recent and current alluvial; dQ: Coastal dune; spQ: Sebkhats basins; ^{m}Q: Middle and upper Pleistocene; ^{c}Q: Middle and upper continental Pleistocene; P1:marine Pliocene; M-P1:Mio-Pliocene continental; $^{a}M_3$: Upper Miocene; $M_{1\text{-}2}$: Lower and Middle Miocene; M_1: Aquitanian; O:Oligocene; $^{a}E_{2\text{-}3}$:Lutetian-Priabonian; $^{a}E_1$:Ypresian; Cm_2-p:upper Maastrichtian-Paleocene; $^{cd}C_2$:Senonian to lower Eocene; $^{c}C_2$:lower Senonian; $^{a}C_2$:Vraconian to Turonian; $^{s}C_1$:lower Cretaceous; T:Triassic.

Fig. 1. (a) Geographical location, (b) Structural map of the Cap-Bon region (Mzali et al., 2016), and (c) Geological map of the study area (Ben Haj Ali et al., 1985).