# Seawater intrusion characterization in the coastal section of Sfax superficial aquifer (Tunisia)

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## ABSTRACT

In southern Tunisia, groundwater constitutes the main water resource for agriculture development, industry and drinking water. Consequently, the high demand induces the increase of groundwater quality degradation risk. The salinization and contamination are the main sources of pollution, especially in coastal area, where the potential risk of sea water intrusion, due to over-exploitation, is highly present.

The knowledge of the historical and present rate of movement of the seawater and the determination of the present location of the interface between freshwater and seawater are needed to provide the information required by the authorities to make decisions on changes of management operations.

The shallow aquifer system of the Sfax region, Tunisia is located in the Mio-Pliocene layers formed by sand and clay and with several permeable zones separated by less-permeable beds. During the last 30 years, the intensive pumping combined to the absence of integrated water resources management plan, resulted in the permanent decline of the piezometric head and the degradation of the groundwater quality. The decrease of the well-level appears mainly in the coastal region parallel with the increase of groundwater salinity. We performed a regional hydro chemical study on a total of 1400 shallow groundwater samples within 180 km length and till 10 Km far from the coastline.

The total dissolved solids content of groundwater is highly variable (750–21000 mg/l).

Hydrochemical diagrams and ion balance demonstrated that the salinization is controlled by several intermixed processes such as seawater mixing, anthropogenic contamination, and water–rock interaction. To evaluate the relative degree of seawater mixing, we used the 'Seawater Mixing Index' (SMI) based on the concentration of Na, Mg, Cl, and SO4 and geophysical logs.

**Keywords:** Coastal aquifer; Salinization; Seawater Mixing Index; vertical sampling, Tunisia.

## INTRODUCTION

In such arid and semi-arid environments, groundwater is a significant part of the total water resource, and plays an important role as a water supply both for drinking and irrigation. Aquifers in the coast are generally fragile and in most of the regions the shallow aquifers are easily depleted due to over exploitation of groundwater.

The present study concerns the coastal area of the Sfax region, Tunisia that is a typical Mediterranean coastal aquifer system. The shallow aquifer system is located in the Mio-Pliocene layer formed by sand and clay and it consists of several permeable zones separated by discontinuous aquitards.

Because of rapid economic growth and lack of precipitation, the use of groundwater resources has increase dramatically. In some region, substantial over-exploitation of groundwater create serious problems, for example, intense mineralization of groundwater, land desertification and salinization, degeneracy of vegetation, lowering of the regional

water table and modification of the natural flow system that induces lateral flow from seawater to the continent. If such situation continues, further deterioration of the environment and ecosystem of the vast area is unavoidable. Some safeguarding measures for groundwater resource protection must been undertaken.

The knowledge of the historical and present rate of the seawater intrusion and the determination of the present location of the interface between freshwater and seawater are needed to provide the information required by the authorities to make decisions of management operations.

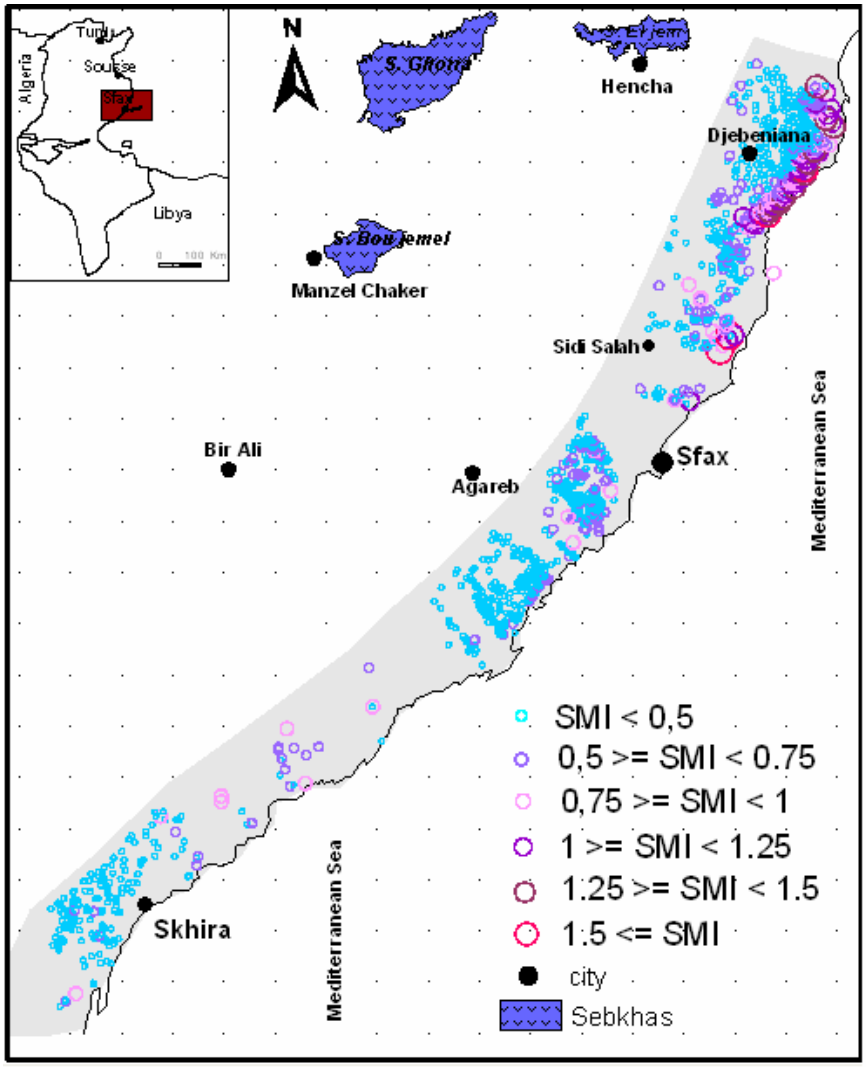


**Figure1. Location of study area and spatial distribution of the SMI index.**

## METHODS

To check the conditions and provide a reasonable assessment of changes and variations in the quantity and quality of groundwater, the historical study presents an important and necessary step. To attempt this aim, we use monitoring data collected by the general direction of water resources (DGRE) during 35 years. More than 180 wells and 50 piezometers are selected to assess the piezometric level and 30 wells to control salinity parameter [CRDA 1970, 1979, 1990, 2001, 2005].

For evaluating the relative degree of seawater mixing, we propose the utilisation of 'Seawater Mixing Index' (SMI) [Park et al. 2005]. This parameter is based on the concentrations of four major ionic constituents in seawater (Na, Cl, Mg, and SO4) as follow.

$$\mathrm{SMI} = a \times \frac{C_{\mathrm{Na}}}{T_{\mathrm{Na}}} + b \times \frac{C_{\mathrm{Mg}}}{T_{\mathrm{Mg}}} + c \times \frac{C_{\mathrm{Cl}}}{T_{\mathrm{Cl}}} + d \times \frac{C_{\mathrm{SO_4}}}{T_{\mathrm{SO_4}}}$$

Where the constants a, b, c, and d denote the relative concentration proportion of Na, Mg, Cl, and SO4 in seawater; C is the measured concentration in mg/l; and T represents the regional threshold values of the considered ions, which can be estimated from the interpretation of cumulative probability curves. If the calculated SMI value is greater than 1, the water may be considered to obviously record the effect of seawater mixing.

To apply this methods, we performed a regional hydrochemical study (DGRE, 2003) on a total of 1400 shallow groundwater sampled in coastal band within 180 km length and 10 Km distance from the coastline.

**RESULT AND DICUSSION**

During the last 30 years, the intensive pumping together with the absence of any integrated water resources management plan, resulted in the permanent decline of the piezometric head and the degradation of the groundwater quality. The decrease of the well-level appears mainly in the coastal region and essentially in coastal zones of Djebeniana, Sidi Abid - El Hajeb (Sfax), Gargour, Sidi Mhadheb, Chaffar and Skhira. The total dissolved solid contents of groundwater are highly variable (750–21000 mg/l). The lowering of the level goes in parallel with the increase of salinity (lower piezometric head in the order of 0.3 m/year and the salinity in the order of 0.15 g/l).

Generally, we note that the intensive exploitation and its effects are very local, they manifest especially in the coastal regions where access is easy to the groundwater. This state is in relation with the important thickness of the aquifer (greater than 75m) and the hydrodynamic characteristics that play in favor of the exploitation.

The effect of the seawater intrusion is visible with a progression of SMI values in direction of the sea, values pass to 0.75 to higher 1.5. The samples from coastal band are affected by the mixture and the phenomenon has a direct impact in the quality of the groundwater and presents the more critical state generally along the entire coastline.

The values of SMI greater than 0.75 are recorded in the areas of Skhira, El Hajeb, the east of the regions of Sidi Salah and Djebeniana region. This observation indicates a sensitivity of these areas to the effect of the seawater intrusion but the more important mixture (SMI>1) is manifested in the northern zone (east of Djebeniana city).

The continuing decline of the piezometric level in the eastern part of Djebeniana city (12 m/ 30 years) and the individualisation of a permanent regional cone of depression confirm the results obtained by the SMI.

In the second step, to examine the lateral and vertical distribution of the SMI in term of distance in relation to the coastline and the depth of each well the charts presentations of figures (2 and 3) are achieved.

On the figure 2, we note that the samples with a SMI greater than 1 have a tendency of preferential localisation at a distance less than 8 km from the coast line. Also, the correlation between SMI and the depths of the wells shows that the influence of seawater intrusion (SMI>1) is virtually absent to a depth greater than 40 m (figure 3).

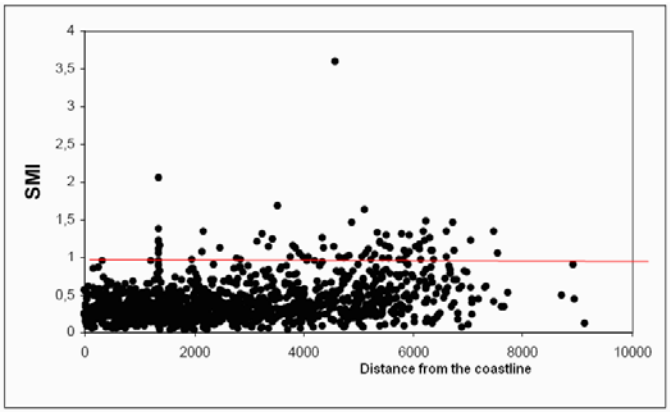


**Figure2.Lateral distribution of SMI index.**

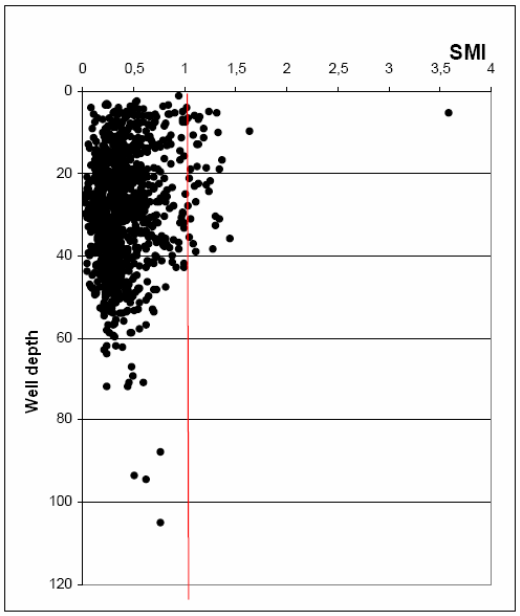


**Figure 3. Vertical distribution of SMI index.**

## CONCLUSION

The interval of current influence of sea water along the groundwater system of the Sahel of Sfax does not exceed the 8 km laterally and 40 m vertically.

The geophysical and hydrochemical logs confirm that seawater intrusion processes and its importance in coastal aquifers is not linked only to the state of the exploitation but it is heavily influenced by the geological complexity of the site (technical, lithology …) and topographical features, idea confirmed in the work of Pulido-Leboeuf et al (2003) and Barlow (2003).

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