1. Abstract

Ras El Hekma is located on the northwestern coast of Egypt as a triangular headland inside the Mediterranean. The scarcity of rainfall and high pumping rates degraded groundwater quality in the main water-supply wells. Saltwater intrusion is the major concern in coastal aquifers around the world explicitly in arid regions, where recharge is limited and groundwater withdrawals is the main source for potable water. In such arid areas, groundwater is being pumped from the aquifer that is hydraulically connected with the sea, causing lateral movement of seawater toward land and up-coning of the underlying saline water toward the pumping wells. In Ras El Hekma area, the groundwater occurs in the fractured limestone aquifer of Miocene age and a friable O-Olitic limestone aquifer of Pleistocene age, where structure settings, dissected elongated ridges as well as sequential local depressions act as barriers and favorable recharge sites for groundwater entrapments. Water chemistry, stable isotopes (δ 18O and δD), and multi isotope tracers were utilized to estimate the percent of seawater mixing in groundwater and the source of recharge for different aquifers. An analytical model for seawater intrusion was used to predict the extent of seawater intrusion along the coast, to determine the optimal pumping rates and to evaluate the recharge source for the coastal unconfined Pleistocene aquifer. Steady flow in an isotropic and homogenous medium with a sharp interface between the freshwater and seawater wedge is assumed. The seawater-freshwater interface was determined through the explicit equations assuming fuzzy and globally distributions of total pumping and recharge rates in the entire region. The conservative mass balance equation and the historical records of water level, groundwater salinity and conservative ions were used for model calibration. The models estimate average annual groundwater recharge and seawater intrusion along the coast for different pumping scenarios.

2. Site Descriptions

![Groundwater Flow Map](image)

Well location sites tapping Pleistocene aquifer, Ras El Hekma Area

![Subsurface Cross Section N-S](image)

3. Methodology

The groundwater geochemistry, isotopic results were utilized to develop an analytical model using Stack Assumption (Strack, 1976 and Mantoglou 2003). The models were calibrated using groundwater level changes and salinity variation. The models estimate average annual groundwater recharge and simulate seawater intrusion along the coast for different pumping scenarios.

4. Governing Equations

\[
\frac{d}{dx} \left( k \frac{d h}{dz} \right) + \frac{N - Q}{h} = 0 \quad \text{Zone 1}
\]

\[
\frac{d}{dz} \left( k \frac{d h}{dz} \right) + \frac{N - Q}{h} = 0 \quad \text{Zone 2}
\]

\[
\phi_{toe} = \frac{(b + d)}{2}^2
\]

5. Geochimtry, Isotopes and Seawater Mixing Indicators

![Distribution of groundwater Salinity in the study area](image)

Cumulative probability curves for Mg, Na, SO₄ ions in groundwater

Estimated SMWI for groundwater samples in Ras El-Hekma

6. Groundwater Flow Model

![Initial Conditions (No Pumping)](image)

![Volume of Freshwater and Seawater with different pumping rates](image)

Theta Contour map and X-toe under different pumping rates

7. Conclusion and Recommendation

1. The results lead to a better understanding of aquifer salinization due to seawater intrusion at the coast, and leaching of aquifer matrix leads to deterioration of groundwater quality.

2. The global groundwater salinity has been estimate with different pumping rates where the recommended amount of daily pumping should not exceed 250 m³/day.

3. According to the isotopic results obtained from the IT2 Isotope Trace Technologies Inc Lab, sites 18 and 19 should be investigated to determine the reasons for high evaporations at these sites.

4. The result of the analytical model shows a transgression of seawater inland and along the coast. The model and isotopic results recommend a decrease in pumping to the drilled wells in order to avoid further seawater intrusion along the coast and upwelling of deep saline groundwater.

8. References

