

Chemical and Isotopic Evidence for Seawater Intrusion – Examples from the Coastal Aquifers of the Mediterranean and the Dead Sea

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Increase in salinity of groundwater is a major problem in coastal aquifers, impairing the use of groundwater for various purposes. It is essential to determine first the origin of salinity in order to be able to cope with this problem. In general, high salinity could result from several sources other than seawater intrusion. These include pollution from various origins, such as industrial and agriculture and also from brines which are not connected to the present sea. In such cases, one can not assume hydraulic connection between the saline and fresh water bodies as simple fresh-saline water interface. Therefore, the chemical characteristics should serve as constraints for the hydrological simulation in order to understand the present situation and forecast future trends.

Chemical and isotopic analyses are the best tools for identifying the specific sources of salinity and their geochemical evolution (e.g. Jones et al., 1999). Therefore, these tools have been used in studies of coastal aquifers in many parts of the world. This review discusses the cases of both the Mediterranean Sea and the Dead Sea. The chemical composition of the major ions in saline groundwater (Na, K, Ca, Mg, Cl, SO₄ and Br), as well as the isotope composition, were measured and compared to that of seawater in order to track its sources.

Most samples in the Mediterranean coastal aquifer were found to be quite similar to seawater, implying that the main process here is mixing of seawater with fresh groundwater. Simple mixing is also inferred from the stable isotope composition of both oxygen and hydrogen. The results, therefore, indicate that in most cases the source of the salinity in the Mediterranean coastal aquifer is seawater. The geochemical evolution of the seawater, along its penetration inland from the sea, was examined from the slight deviations from the simple mixing lines. The deviations are due to water rock interaction, mainly by cation exchange process (Appelo et al., 1990; Sivan et al., 2005). This process is expressed by the significant increase of the concentration of Ca and the decreasing of Na and K in the solution as compared to simple mixing. The various components of the carbonate system (including alkalinity, dissolved inorganic carbon (DIC), $\delta^{13}\text{C}_{\text{DIC}}$ and $^{14}\text{C}_{\text{DIC}}$) indicate that when seawater interacts with aquifer rocks the main process beside cation exchange is oxidation of organic matter, as reflected in relatively low $\delta^{13}\text{C}$ and ^{14}C values (Sivan et al., 2005, Russak et al., this proceeding). In some parts of the Israeli Coastal Aquifer, different water composition was found (e.g. high nitrate or other pollutants) implying that the salinity source is industrial or agricultural.

The hydrological situation in the Dead Sea Coastal Aquifer is more complicated since it hosts brines which probably originated from old lakes that existed in this area. The chemical composition of these brines is indeed different from that of the present Dead Sea (Figure 1), implying that they are not in a direct hydraulic connection with the sea and therefore can not be regarded as part of the regular fresh-saline water interface system. The brines near the sea are similar to the Dead Sea indicating on closer hydraulic connection.

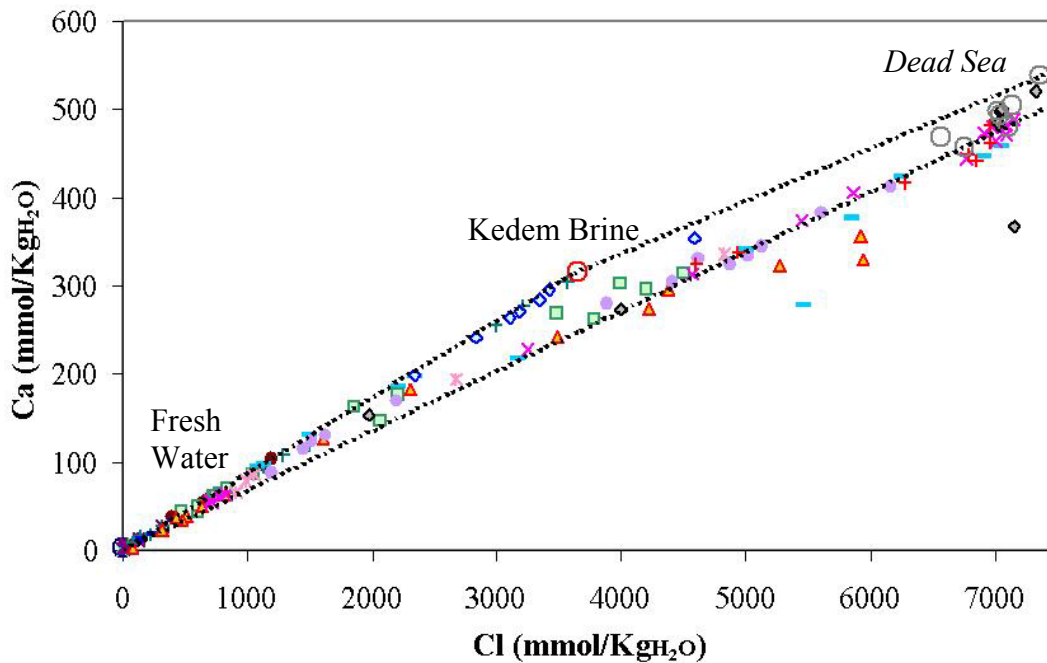


Figure 1. Chemical composition of groundwater in the Dead Sea area indicating that simple mixing between Dead Sea brine and fresh groundwater can not explain the chemistry of all water bodies (Levenberg, 2005).

The other importance of geochemical and isotopic analysis (mainly radioactive isotopes) is to determine the rate of seawater intrusion and the connection between the sea and the aquifer. The radioactive dating of groundwater (tritium and ^{14}C) yields mostly young seawater in the Mediterranean Aquifer, indicating relatively fast rate of seawater intrusion. In several locations, older seawater (>10000 years, Yechieli et al., 2008; Figure 2) was found implying either poor connection to the sea and/or existence of seawater from the time of sea level rise in Late Pleistocene.

Similarly, Dead Sea type brines were found at different distance from the sea exhibiting different preliminary ages, depending on the rate of intrusion. Age calculation with the ^{14}C method could be problematic in this area since groundwater may contain dissolved organic carbon (e.g Methane) which probably contributes very negative $\delta^{13}\text{C}$ and low ^{14}C values (Avrahamov et al., 2008). In some cases, relatively high radiocarbon and tritium values imply that, although the Dead Sea water level decline at extreme rate of 1 m/yr, its brines still penetrate into the coastal aquifer. The rate of brine penetration will be compared to that obtained by hydrological simulations.

Future tools can include other isotopic and chemical tracers, some of which were never used before. These can include tritium-helium, CFC and more for age determination and other stable isotopes (e.g. B, Sr and S isotopes).

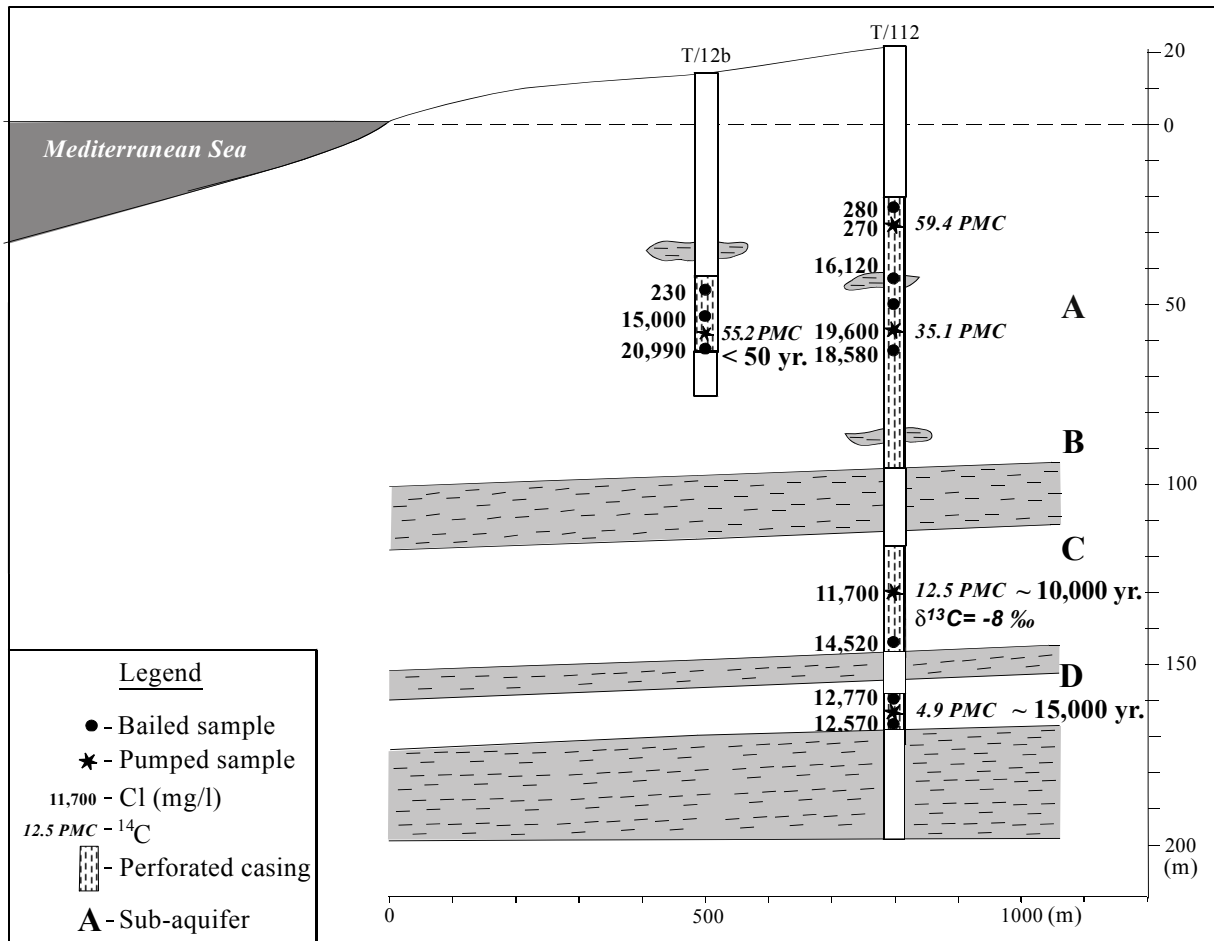


Figure 2. Preliminary ages of saline groundwater in the Mediterranean coastal aquifer in Israel (Yecheili et al., 2008).

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