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Ionic and isotopic ratios for identification of salinity sources and missing data in the Gaza aquifer

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Abstract

Groundwater is the only source of fresh water in the Gaza Strip. However, it is severely polluted and requires immediate effort to improve its quality and increase its usable quantity. Intensive exploitation of groundwater in the Gaza Strip over the past 40 years has disturbed the natural equilibrium between fresh and saline water, and has resulted in increased salinity in most areas. Salinization in the coastal aquifer may be caused by a single process or a combination of different processes, including seawater intrusion, upconing of brines from the deeper parts of the aquifer, flow of saline water from the adjacent Eocene aquifer, return flow from irrigation water, and leakage of wastewater. Each of these sources is characterized by a distinguishable chemistry and well known isotopic ratios. In this paper Na/Cl, SO_4/Cl, Br/Cl, Ca/(HCO_3+SO_4), and Mg/Ca ionic ratios were used to distinguish different salinization sources. $\delta^{11}B$ and $^{87}Sr/^{86}Sr$ isotopic composition were also included in the model to study their importance in this monitoring task. The task of monitoring and the associated decision making process are characterized by a high degree of uncertainty with respect to input data and accuracy of models. For this reason, probabilistic expert systems, and more specifically, Bayesian belief networks (BBNs) are used to identify salinization origins. The BBN model incorporates the theoretical background of salinity sources, area-specific monitoring data that are characteristically incomplete in their coverage, expert judgment, and common sense reasoning to produce a geographic distribution for the most probable sources of salinization. The model is also designed to show areas where additional data on chemical and isotopic parameters are needed.

Keywords: Salinization; Ionic ratios; Isotopes; Bayesian networks; Monitoring

1. Hydro-geological setting

The coastal aquifer lies along the southeastern edge of the Mediterranean Sea and extends from the foothills of Mt. Carmel southward to Gaza and northern Sinai. It is composed of Pliocene–Pleistocene age calcareous sandstone, unconsolidated sands,

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and layers of clays (Vengosh and Rosenthal, 1994; Vengosh et al., 1999; Mercado, 1985). In the Gaza Strip, the aquifer extends about 15–20 km inland, where it overlies Eocene age chalks and limestone or the Miocene–Pliocene age Saqiye Group. The Saqiye Group is a 400- to 1000-m thick sequence of marls, marine shales, and claystones. Approximately 10- to 15-km inland from the coast, the Saqiye Group pinches out, and the coastal aquifer rests directly on Eocene chalks and clastic sediments of Neogene age (see M&E, 2000; Vengosh and Rosenthal, 1994; Vengosh et al., 1994; Mercado, 1985). Fig. 2 presents a generalized geological cross-section of the coastal aquifer.

Near the coast in the Gaza Strip, clay layers subdivide the coastal aquifer into four separate sub-aquifers (Fig. 2). They extend inland about 2- to 5-km, depending on location and depth. Further east, the marine clays pinch out and the coastal aquifer can be regarded as one hydro-geological unit. Sub-aquifer A is unconfined, whereas sub-aquifers B1, B2, and C become increasingly confined towards the sea.

2. Available data

The modeling and analysis reported here are based upon the results of a recent (2000) water quality survey of 101 municipal and agricultural wells. Those wells were sampled and tested for calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}), potassium (K^{+}), bromine (Br^{-}), chloride (Cl^{-}), nitrate (NO_3^{-}), bicarbonate (HCO_3^{-}), and sulphate ($SO_4^{=}$). Fig. 1 shows the locations of the sampled wells. The analysis

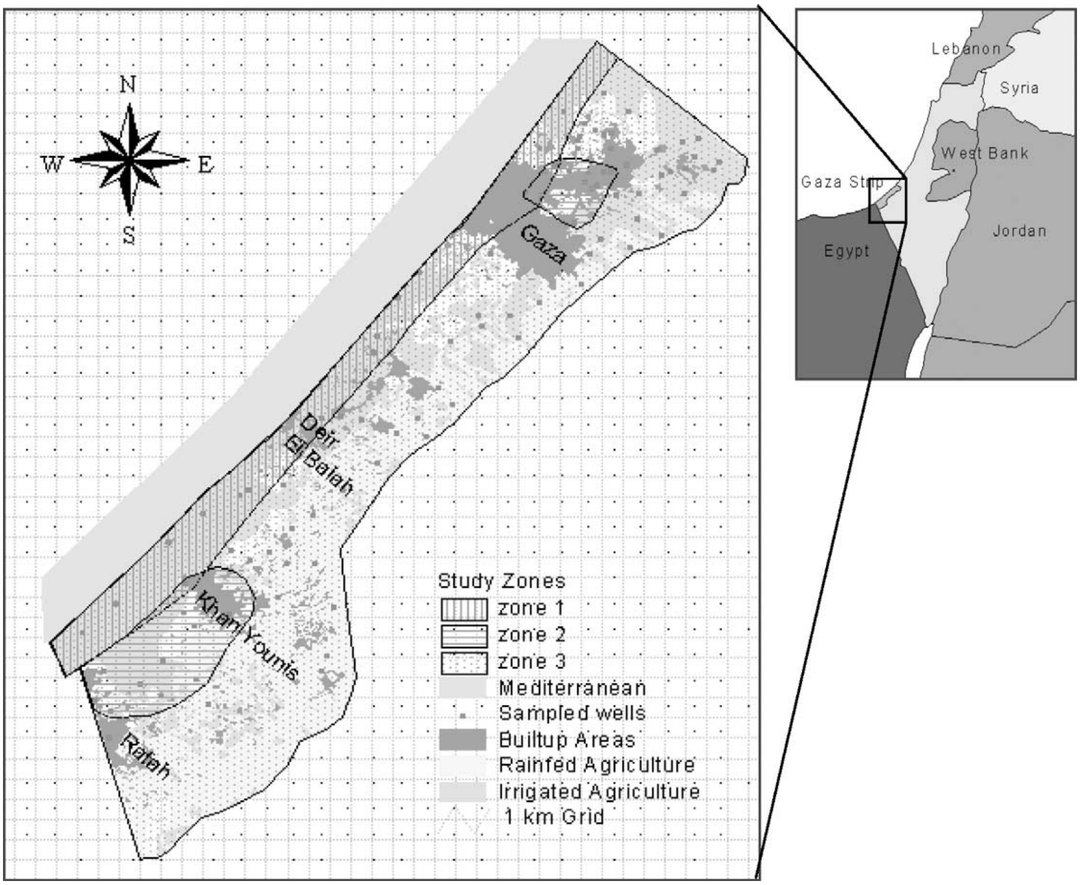

Fig. 1. Location map showing land use and sampled wells.