Saline water circulation beneath the fresh-saline interface: results of laboratory experiments and numerical modeling

I. Oz[1,2], E. Shalev[1], Y. Yechieli[1], I. Gavrieli[1], H. Gvirtzman[2]
[1]Geological Survey of Israel
[2]Institute of Earth Sciences, Hebrew University of Jerusalem

ABSTRACT

In this study we examined the interface configuration and the circulation flow of saltwater within coastal homogenous aquifers adjacent to a saltwater body with a long term stratified water column. Such systems consist of three different water types: the regional fresh groundwater and the low and high salinity brines forming the upper and lower water layers of the saltwater body, respectively. High density difference, which is expected to be developed between the two water layers of the Dead Sea during the operation of the "Seas Canal" project, makes it an ideal case study for studying such systems.

The groundwater interface configuration and the density-driven circulation flows that develop in the aquifer are examined using laboratory experiments and numerical modeling at the same scale. The laboratory experiments were conducted in a two-dimensional rectangular flow tank, filled with granular material, simulating a homogenous and phreatic coastal aquifer. For the numerical modeling we used RST2D computer code and COMSOL Multiphysics (FEMLAB 3.5a) in order to quantitatively evaluate the coupled fluid and solute transport equations.

The results of both numerical simulations and the laboratory experiments show that the steady-state configuration of the fresh-saline interface is more complicated than those which developed within a coastal aquifer adjacent to a non-stratified saltwater body, as three interfaces between the three different water types are developed. The numerical model, which is calibrated against the salinity distribution and groundwater discharge rate in the laboratory experiments, allows the quantification of the flow rates and flow patterns. These flow patterns, which cannot be derived from laboratory experiments, show the development of three circulation cells which are confined between the three interfaces. We found that these unique configuration and flow patterns are sensitive to the model parameters (using dimensionless parameters), meaning that the creation of three-circulation-cells is limited to a certain range of values of each parameter. Outside of this range, only a single circulation cell develops, either by the two saltwater bodies, or by the high salinity brine solely. The threshold values for the transformation between these different flow configurations were also determined.

As mentioned above, the creation of three circulation cells in this hydrological system is predicted by numerical simulations solely. In order to validate these calculated flow patterns we have been conducting laboratory experiments, in which we expose the aquifer to brines with the exact same concentrations (density of 1100 kg/m3). By using this method we are able to monitor the progress of the dye color front over time and to calculate the flow velocities and the flow directions within the different levels of the saline wedge. At first we applied this method to the simple system of a single interface. Such systems consist of two different water types: the regional fresh groundwater and the saline water from the saltwater body. At the next stage, we will apply this method to the complex system of three interfaces and three circulation cells.

As expected, adjacent to a non-stratified saltwater body, a single circulation cell of the saline water forms beneath the interface. We examined the nature of the flow regime and the

sensitivity to changes in the parameters. The results show that the flow velocities in the saline area are increasing with depth (i.e.; when moving towards the lower boundary). The flow velocities also increased with distance (i.e.; when moving away from the saltwater boundary), although this trend is shifting next to the interface where the flow velocities decrease. The flow direction of the saline water beneath the fresh-saline interface is mostly sub-horizontal (parallel to the lower boundary), with a minor component downward. Preliminary result of parametric analysis shows that the magnitude of the downward component is mostly sensitive to changes in the transversal dispersivity.