Innovative downhole geophysical methods for high frequency seawater intrusion dynamics monitoring

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ABSTRACT

The detailed characterization of salt water intrusion is a key to understand both submarine groundwater discharge and manage often intensively exploited groundwater resources in coastal areas. With the objective to study the response of a coastal aquifer to a series of boundary conditions, a new experimental site has been developed through a clastic aquifer located north of Barcelona (Spain). This hectometer scale site is located 50 m from the seashore and equipped with 17 nearby shallow holes, with depths ranging from 15 to 28 m.

In order to study not only the sedimentary structure but also the response of the aquifer to a set of natural boundary conditions, downhole geophysical measurements have been deployed over the past 3 years in an innovative manner, either in a time-lapse or stationary manner. The downhole measurements are complicated by the unconsolidated nature of the sediment, obliging to perform all measurements through PVC. Also, the granitic nature of the sediment prevents clays identification from a direct use of gamma ray profiles. For this, constituting minerals (quartz, albite, feldspar, microcline, illite) were identified from X-ray diffraction on cores, and spectral gamma logs used to determine the illite fractions from Th/K ratios.

In time lapse, high frequency electrical resistivity induction measurements show that preferential flow paths through the aquifer can be identified in a fast and reliable manner. Also, changes in depth of the fresh to salt water interface (FSWI) are precisely described, either in response to marine tides, or to a short but intense mediterranean rain event. Changes on the order of than 1.70 m are obtain in less than a day of heavy rain. Overnight as well as seasonal changes such as months of dryness are also illustrated due to the variability of pore fluid salinity and temperature, even over short periods of time such as tens of minutes.

In stationary mode, the spectral natural gamma sensor located in front of the FSWI fluctuation zones records changes in front of all radioactive peaks (from K, Tl, Bi, but also Ra with Rn) during intense rain events such as that of October 19, 2017. This places constraints on Ra and Rn production rate during such an event, leading to trace fresh water outpour into the sea.

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