Assessment of effective infiltration in the deep arid vadose zone of the Negev, Israel

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The Israeli national site for radioactive waste is situated in the Yamin Plain, within the Negev desert. Estimation of water recharge to the ~500 m deep vadose zone underlying the site is crucial for assessing risks related to contaminants transport. However, estimation of water fluxes in deep arid vadose zones is a challenging task because of their small magnitude and the lack of a direct measurement technology. Studies conducted in a deep arid vadose zone in Nevada, USA point to complex transient flow dynamics, in which the direction of water flow in the top of the vadose zone is upward while in the rest of the section water flows downwards to the water table.

In this study we present a combination of techniques which are used to obtain an initial evaluation of the water dynamics in this environment. These techniques include direct and continuous measurements of water content at the upper 5.5 m of the vadose zone through a vadose zone monitoring system which contain FTDR water content sensors; profiles of water content, leachable chloride and soil texture; and numerical modeling.

The monitoring of the upper 5.5 m of the vadose zone during the years 2014-2018 indicates that even after extreme rain events of ~ 50 mm (constituting more than a half of the annual rainfall) there is no water infiltration to the lower parts of the section. These results exemplified the need for an alternative method to detect low water fluxes that characterize this arid area. We therefore use an inverse modeling approach where numerical solutions of water movement in the vadose zone are fitted to measured profiles of chemical and physical parameters from two shallow boreholes in the Yamin Plain. The water content of both boreholes revealed an extremely dry environment, with low saturations and high pore-water chloride concentrations, above 15,000 mg/l, in certain depths. Peak chloride concentrations did not coincide in the two boreholes, raising the question whether these peaks are connected to water fluxes or to changes in soil texture, which can inhibit water infiltration.

Numerical simulations were then used to solve water flow and solute transport. Input parameters, including chloride deposition rate, precipitation rate, and surface run-off fraction were varied to fit the measured chloride profiles. Results indicate very small water fluxes of less
than 1 mm/yr in the bottom of the vadose zone. The simulations also show that the mass of chloride in the profile is less than the one expected based on estimated chloride deposition rate and published records of paleo-rain. These results suggest either a delayed climate shift to dry conditions compared to previous estimates for the region (8000 yr BP), and/or a partial input of the 4 g/m²/yr of deposited chloride, possibly due to runoff.