Geophysical Research Abstracts
Vol. 19, EGU2017-11738, 2017
EGU General Assembly 2017

Impact of sub-horizontal discontinuities and vertical heterogeneities on recharge processes in a weathered crystalline aquifer in southern India

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In the face of increasing demands for irrigated agriculture, many states in India are facing water scarcity issues, leading to severe groundwater depletion. Because perennial water resources in southern India consist mainly of crystalline aquifers, understanding how recharge takes place and the role of preferential flow zones in such heterogeneous media is of prime importance for successful and sustainable aquifer management. Here we investigate how vertical heterogeneities and highly transmissive sub-horizontal discontinuities may control groundwater flows and recharge dynamics. Recharge processes in the vadose zone were examined by analysing the propagation of an infiltration front and mass transfers resulting from the implementation of a managed aquifer recharge (MAR) structure. Said structure was set up in the Experimental Hydrogeological Park in Telangana (Southern India), a well-equipped and continuously monitored site, which is periodically supplied with surface water deviated from the nearby Musi river, downstream of Hyderabad.

An initial volume balance equation was applied to quantify the overall inputs from the MAR structure into the groundwater system, which was confirmed using a chloride mass balance approach. To understand how this incoming mass is then distributed within the aquifer, we monitored the evolution of water volumes in the tank, and the resulting lateral propagation front observed in the surrounding borehole network. Borehole logs of temperature and conductivity were regularly performed to identify preferential flow paths. As a result we observed that mass transfers take place in the way of preferential lateral flow through the most transmissive zones of the profile. These include the interface between the lower portion of the upper weathered horizon (the saprolite) and the upper part of the underlying fissured granite, as well as the first flowing fractures. This leads to a rapid lateral transfer of recharge, which allows quick replenishment of aquifers but may have severe implications regarding groundwater quality, whether contaminants originate from diffuse sources (such as fertilizers), or a localized injection of polluted surface water. These findings confirm previous studies about the non-linear behaviour of hard rock aquifers (Guihéneuf et al., 2014) and recharge processes (Boisson et al., 2015; Alazard et al., 2015). Depending on water level conditions, the aquifer shifts from a regional flow system (when superficial more connected and weathered levels are saturated), to independent local flow systems (when only the lower lesser fractured portion is saturated). Thus recharge seems to be controlled by the existence of (i) vertical heterogeneities within the unsaturated zone and (ii) highly transmissive sub-horizontal discontinuities, both of which controlling groundwater flows and recharge dynamics.