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Analysis of extreme variability of fresh and saline groundwater occurrence in the semi-arid floodplain aquifer of the Lower Magdalena River, Colombia

Seinab Bohsung (1), Tibor Stigter (2), and Micha Werner (3)

(1) IHE Delft, Department of Water Science and Engineering, Delft, The Netherland (s.bohsung@gmail.com), (2) IHE Delft, Department of Water Science and Engineering, Delft, The Netherland (t.stigter@un-ihe.org), (3) IHE Delft, Department of Water Science and Engineering, Delft, The Netherland (m.werner@un-ihe.org)

Understanding the mechanisms that govern hydrogeological systems in warm semi-arid areas is important for the development and protection of their groundwater resources, especially where these are characterised by extreme spatial and temporal variability. Hydrological processes that are driving the Lower Magdalena Aquifer in northern Colombia have been poorly studied so far, although some awareness of the occurrence of brackish to saline groundwater limiting its usability existed. The aquifer underlies the Magdalena River floodplains, in an area formerly comprising numerous swamps, ca. 80 km downstream from where this major river discharges into the Caribbean Sea. Current research aimed at identifying the origin and spatial/vertical distribution of saline groundwater, as well as the importance of recharge from rainfall and surface water bodies in controlling the salinity distribution. For this purpose, vertical electrical soundings and water level monitoring were combined with the analysis of major ions, bromide, stable environmental isotopes and physicochemical parameters (temperature, pH, EC and alkalinity) in April and May of 2018. Results showed an extremely heterogeneous spatial distribution of EC (415 to 28400 μS/cm), with a tendency to decrease with decreasing distance to the main water courses that border the study site. This and the direction of groundwater flow suggest a (seasonal) recharging function by the surface water bodies, which is further supported by results from the geoelectrical measurements.Precipitation, although quite significant per event, has only minor local effects on the seasonal fluctuation of the piezometric surface as shown by the response of groundwater heads to rainfall. Moreover, no clear pattern of diffuse recharge is revealed by the vertical electrical soundings. Like in other semi-arid regions, high evaporation prior to infiltration is implied by a high EC and an enrichment of heavy isotopes, together with a diversion from the mixing line in the plot of δ^{18}O vs Cl for many of the shallow groundwater samples. A second type of salinity is found in deeper groundwater, not related to enhanced evapotranspiration. Halite dissolution as responsible mechanism is also rejected based on the Cl/Br ratio and relationship between Cl and ^{18}O. Instead, the combined occurrence of high Cl concentrations with high alkalinity, linked to intense silicate weathering and high initial partial pressures of CO_2, suggests the source of salinity to be linked to mixing with relict seawater, emplaced in clay-rich sediments during times of marine inundation of the area. The flushing of these layers in conjunction with silicate weathering, evaporation, and cation-exchange (evidenced in the Na/Cl ratios) gives rise to the observed water types. The spatial variability of fresh groundwater implies a rather low potential for its exploitation in the area, given the challenge to predict its occurrence. Considering the local circumstances, river bank infiltration could be an option should groundwater become important in enhancing the resilience to climate change in the area.