Hydrochemical assessment of saline groundwater in an alluvial floodplain of Red River, Vietnam, using PCA-based end-member mixing analysis

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An alluvial aquifer in a floodplain of the Red River delta, Vietnam, was studied to elucidate the water quality status (especially, salinity problems) and hydrochemical processes. We collected hydrochemical and isotopic data of groundwater samples from the Kien Xuong district of Thai Binh province, Vietnam. The groundwater showed a broad hydrochemical facies change from Ca-HCO_3 through Na-HCO_3 to Na-Cl types, indicating the occurrence of progressive freshening (i.e., freshwater mixing) accompanying cation exchange. Principal component analysis (PCA) of hydrochemical data indicated three major hydrochemical processes: 1) salinity gradient (freshening), 2) water-rock interaction, and 3) redox process. The end-member mixing analysis (EMMA) was also performed to interpret the geochemical reactions accompanying freshening. The results showed that the mixing model with two component dimensional space can best explain the processes, as indicated by the lowest relative root-mean-square error (RRMSE) for Cl and Na ions. This indicates three end-members are possibly involved in mixing process: rain water, seawater, and Ca(-K)-HCO_3 type groundwater. Mass balance calculation using the multivariate mixing and mass balance calculation (M3) model indicates the occurrence of cation exchange and Fe-, Mn-, and sulfate reduction during the freshening process. Sulfur and oxygen isotope data of SO_4 indicated the bacterial reduction of sulfate from both anthropogenic (such as chemical fertilizers) and seawater origins. This case study shows the successful applicability of PCA-based end-member mixing analysis to assess complex hydrogeochemical processes encountering in groundwater accompanying freshening and anthropogenic contamination.