Geophysical Research Abstracts
Vol. 19, EGU2017-8230, 2017
EGU General Assembly 2017

Inter-relationship between shallow and deep aquifers under the influence of deep groundwater exploitation in the North China Plain

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In the North China Plain (NCP), the interaction between shallow and deep groundwater flow systems enhanced by groundwater extraction has been investigated using multi-isotopic and chemical tracers for understanding the mechanism of salt water transport, which has long been one of the major regional environmental hydrogeological problems in NCP. Information about the problem will be determined using multiple lines of evidence, including field surveys of drilling and water sampling, as well as laboratory experiments and physical and numerical simulations. A conceptual model of groundwater flow system along WE cross-section from piedmont area to coastal region (Shijiazhuang-Hengshui-Cangzhou) has been developed and verified by geochemical modeling. A combined hydrogeochemical and isotopic investigation using ion relationships such as Cl/Br ratios, and environment isotopes (δ^{18}O, δ^{2}H, $\delta^{34}S_{SO4} - \delta^{18}O_{SO4}$, $\delta^{15}N_{NO3}$-$\delta^{18}O_{NO3}$,δ^{13}C and ^{87}Sr/^{86}Sr) was reviewed and carried for determining the sources of aquifer recharge, the origin of solutes and the mixing processes in groundwater flow system under the anthropogenic pumping and pollution. Results indicate that hydrochemistry of groundwater is characterized by mixing between end-members coming directly from Piedmont recharge areas, saline groundwater formed during geohistorical transgression in the shallow aquifers of central plain, and to groundwater circulating in a deeply buried Quaternary sediments. We also reviewed the groundwater age (tritium contents, ^{14}C ages, ^{3}H-^{3}He ages, basin-scale flow modeling ages of groundwater) to recognize the local distributed recharge in this strongly exploited aquifer system. Finally, combined with the 1-D Cl transport modeling for the pore water of clay-rich aquitard, we reveal that salt transport in the aquitard is primarily controlled by vertical diffusion on million years' time scale, and the observed the salinized groundwater in deep aquifer may be caused by passing through "windows" or preferential flow path, rather than vertical flow through the aquitard.