

# Controlling geological and hydrogeological processes in an arsenic contaminated aquifer on the Red River flood plain, Vietnam

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**Abstract:** Geological and hydrogeological processes controlling recharge and the mobilization of As were investigated in a shallow Holocene aquifer on the Red River flood plain near Hanoi, Vietnam. The geology was investigated using surface resistivity methods, geophysical borehole logging, drilling of boreholes and installation of more than 200 piezometers. Recharge processes and surface-groundwater interaction were studied using (i) time-series of hydraulic head distribution in surface water and aquifers, (ii) the stable isotope composition of waters and (iii) numerical groundwater modeling. The Red River and two of its distributaries run through the field site and control the groundwater flow pattern. For most of the year, there is a regional groundwater flow towards the Red River. During the monsoon the Red River water stage rises up to 6 m and stalls the regional groundwater flow. The two distributaries recharge the aquifer from perched water tables in the dry season, whilst in the flooding period surface water enters the aquifer through highly permeable bank sediments. The result is a dynamic groundwater flow pattern with rapid fluctuations in the groundwater table. A transient numerical model of the groundwater flow yields an average recharge rate of 60-100 mm/a through the confining clay, and a total recharge of approximately 200 mm/a was estimated from  $^3\text{H}/^3\text{He}$  dating of the shallow groundwater. Thus in the model area, recharge of surface water from the river distributaries and recharge through a confining clay is of the same magnitude, being on average around 100 mm/a. The thickness of the confining clay varies between 2 and 10 m, and affects the recharge rate and the transport of electron acceptors ( $\text{O}_2$ ,  $\text{NO}_3^-$  and  $\text{SO}_4^{2-}$ ) into the aquifer. Where the clay layer is thin, an up to 2 m thick oxic zone develops in the shallow aquifer. In the oxic zone the As concentration is less than 1  $\mu\text{g/L}$  but increases in the reduced zone below to 550  $\mu\text{g/L}$ . In the Holocene aquifer, As is mobilized at a rate of around 14  $\mu\text{g/L/a}$ . An As mass balance for the field site shows that around 1100 kg of As is annually leached from the Holocene sand and discharged into the Red River, corresponding to 0.01% of the total pool of As now present in the Holocene sand. © 2008 Elsevier Ltd. All rights reserved.

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Groundwater interactions; Groundwater tables; Holocene; Hydraulic heads; Hydrogeological; Mass balances; Modeling; Numerical models; Recharge processes; Recharge rates; Red rivers; Regional groundwaters; Shallow aquifers; Shallow groundwaters; Stable isotopes; Surface resistivities; Vietnam; Water tables; Groundwater resources; aquifer pollution; arsenic; borehole logging; electron; element mobility; floodplain; groundwater flow; groundwater-surface water interaction; Holocene; hydrogeology; installation; mass balance; numerical model; piezometer; recharge; stable isotope; Asia; Eurasia; Red River [Asia]

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