Arsenic in groundwater of the Red River floodplain, Vietnam: Controlling geochemical processes and reactive transport modeling

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Abstract: The mobilization of arsenic (As) to the groundwater was studied in a shallow Holocene aquifer on the Red River flood plain near Hanoi, Vietnam. The groundwater chemistry was investigated in a transect of 100 piezometers. Results show an anoxic aquifer featuring organic carbon decomposition with redox zonation dominated by the reduction of Fe-oxides and methanogenesis. Enhanced P_{CO2} pressure causes carbonate dissolution to take place but mainly in the soil and unsaturated zone. The concentration of As increases over depth to a concentration of up to 550 ?g/L. Most As is present as As(III) but some As(V) is always found. Arsenic correlates well with NH_4, relating its release to organic matter decomposition and the source of As appears to be the Fe-oxides being reduced. Part of the produced Fe(II) is apparently reprecipitated as siderite containing less As. Results from sediment extraction indicate most As to be related to the Fe-oxide fractions. The measured amount of sorbed As is low. In agreement, speciation calculations for a Fe-oxide surface suggest As(III) to constitute only 3% of the surface sites while the remainder is occupied by carbonate and silica species. The evolution in water chemistry over depth is homogeneous and a reactive transport model was constructed to quantify the geochemical processes along the vertical groundwater flow component. A redox zonation model was constructed using the partial equilibrium approach with organic carbon degradation in the sediment as the only rate controlling parameter. Apart from the upper meter a constant degradation rate of 0.15 C mmol/L/yr could explain the redox zonation throughout the aquifer. Modeling also indicates that the Fe-oxide being reduced is of a stable type like goethite or hematite. Arsenic is contained in the Fe-oxides and is first released during their dissolution. Our model further suggests that part of the released As is adsorbed on the surface of the remaining Fe-oxides and in this way may be retarded.

Index Keywords: arsenic; concentration (composition); decomposition; dissolution; floodplain; flow modeling; groundwater; groundwater flow; methanogenesis; organic carbon; reduction; transport process; vadose zone; water chemistry; Asia; Eurasia; Hanoi; Southeast Asia; Viet Nam

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