Palaeo-hydrogeological control on groundwater As levels in Red River delta, Vietnam

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Abstract: To study the geological control on groundwater As concentrations in Red River delta, depth-specific groundwater sampling and geophysical logging in 11 monitoring wells was conducted along a 45 km transect across the southern and central part of the delta, and the literature on the Red River delta's Quaternary geological development was reviewed. The water samples (n = 30) were analyzed for As, major ions, Fe^{2+}, H_2S, NH_4, CH_4, ??^{18}O and ??D, and the geophysical log suite included natural gamma-ray, formation and fluid electrical conductivity. The SW part of the transect intersects deposits of grey estuarine clays and deltaic sands in a 15-20 km wide and 50-60 m deep Holocene incised valley. The NE part of the transect consists of 60-120 m of Pleistocene yellowish alluvial deposits underneath 10-30 m of estuarine clay overlain by a 10-20 m veneer of Holocene sediments. The distribution of ??^{18}O-values (range -12.2? to -6.3?) and hydraulic head in the sample wells indicate that the estuarine clay units divide the flow system into an upper Holocene aquifer and a lower Pleistocene aquifer. The groundwater samples were all anoxic, and contained Fe^{2+} (0.03-2.0 mM), Mn (0.7-320 ?M), SO_4 (<2.1 ?M-0.75 mM), H_2S (<0.1-7.0 ?M), NH_4 (0.03-4.4 mM), and CH_4 (0.08-14.5 mM). Generally, higher concentrations of NH_4 and CH_4 and low concentrations of SO_4 were found in the SW part of the transect, dominated by Holocene deposits, while the opposite was the case for the NE part of the transect. The distribution of the groundwater As concentration (<0.013-11.7 ?M; median 0.12 ?M (9 ?g/L)) is related to the distribution of NH_4, CH_4 and SO_4. Low concentrations of As (??0.32 ?M) were found in the Pleistocene aquifer, while the highest As concentrations were found in the Holocene aquifer. PHREEQC-2 speciation calculations indicated that Fe^{2+} and H_2S concentrations are controlled by equilibrium for disordered mackinawite and precipitation of siderite. An elevated groundwater salinity (Cl range 0.19-65.1 mM) was observed in both aquifers, and dominated in the deep aquifer. A negative correlation between aqueous As and an estimate of reduced SO_4 was observed, indicating that Fe sulphide precipitation poses a secondary control on the groundwater As concentration.

Index Keywords: Aquifers; Calcite; Clay deposits; Clay minerals; Concentration (process); Electric conductivity; Estuaries; Gamma rays; Geophysics; Groundwater; Hydrogeology; Iron compounds; Iron ores; Manganese; Manganese compounds; Offshore oil well production; Oil well logging; River control; Rivers; Sedimentation; Underground reservoirs; Wells; Alluvial deposits; Aqueous; Electrical conductivities; Flow

systems; Gamma-ray; Geological controls; Geological developments; Geophysical loggings; Geophysical logs; Groundwater samplings; Higher concentrations; Holocene; Holocene sediments; Hydraulic heads; Hydrogeological; Low concentrations; Major ions; Monitoring wells; Negative correlations; Phreeqc; Pleistocene; Pleistocene aquifers; Red river deltas; Secondary controls; Speciation calculations; Sulphide precipitations; Vietnam; Water samples; Groundwater resources; aquifer; arsenic; electrical conductivity; Holocene; hydrogeology; iron; oxygen isotope; paleohydrology; Pleistocene; precipitation (chemistry); salinity; siderite; speciation (chemistry); sulfur compound; well logging; Asia; Eurasia; Red River Delta; Southeast Asia; Viet Nam

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