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Residence Time estimation for the Highly Arsenic Contaminated Groundwater in Sonargaon, Bangladesh

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Large-scale natural arsenic contamination of groundwater has been a serious problem in a number of areas around the world, especially in Asian countries, in many cases having a major impact on potable water.

Throughout a series of our studies in Sonargaon, Nayakaganj, Bangladesh (Mitamura et al., 2008; Itai et al., 2008; Seddique et al., 2008), vertical infiltration of surface water into the shallow aquifer would promote the As contaminated groundwater. In those studies, Mitamura et al. (2008) reported that the highly As contaminated wells are occasionally installed into the finer and micaceous sediment, and that the geological structure of the aquifers is an important control on the formation of As-contaminated groundwater in Bangladesh. Seddique et al. (2008) pointed out that the detrital biotite is a primary source of As, and chemical weathering of this mineral is an essential mechanism forming chemical composition of groundwater including As concentration. Heterogeneous distribution of major chemical component and oxygen and hydorogen isotopic ratios of the groundwaters indicated vertical infiltration of surface groundwater into the shallow sediments (Itai et al., 2008). The three-dimensional groundwater flow model numerically predicted that water recharged from the ground surface beneath the flood plain moves approximately 10 m to 20 m vertically downward, with a gradually increasing horizontal flow, toward the underlying Pleistocene middle mud layer (aquitard) (Nakaya et al., 2010). Groundwater pumped up from tube wells in the Holocene aquifer for daily use is recharged in several areas in the flood plain. The model also predicted that hotspots with the highest As concentrations ($>$ 700 ppb) are formed on the vertical groundwater flow paths during surface water recharge and not on the horizontal flow paths. Therefore, the model supported the view that chemical weathering of detrital minerals in Holocene sediment (shallow aquifer) is an essential mechanism forming chemical composition of groundwater including As concentration.

In this study, to estimate the residence time of As highly contaminated groundwater in Holocene aquifer, we measured the concentrations of CFCs, 3He/4He and As in groundwater samples, including DO, sampled carefully at 20-25 m depth private tube wells in a recharge zone, As hot-spot in September and December, 2010. The apparent residence time is estimated to be from about 30 to 10 years from 3He/4He and from about 43 to 27 years from CFC-113. The As in groundwater ranges from 100 to 1250 ppb. The apparent residence time for high As groundwater ($>$500 ppb) ranges from about 40 to 27 years from CFC-113 in September samples, while it ranges from about 43 to 27 years from CFC-113 and from 28 to 10 years from 3He/4He in December samples. For December samples, higher As indicates shorter residence time. Moreover, As increases in concentration with depth from 100 ppb at 5 m depth to 700 ppb at 10 m depth for groundwater samples from survey wells. Since shorter residence time means shorter path length of groundwater flow from three-dimensional groundwater flow model (Nakaya et al., 2010), at our study site, the results lead to the As mobilization model that As is strongly released during vertical infiltration from surface to about 20 m depth for 10-20 years in As rich Holocene aquifer and As is transported by horizontal flow path without As release.

Keywords: groundwater, arsenic pollution, Bangladesh, residence time