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Sedimentology of Arsenic Pollution in the Alluvial Bengal Delta Plains: Example from 24 Parganas and its Global Application

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ABSTRACT

The decline in world sea-level between 125ka and 18ka exposed sediments of the World's deltas to weathering and erosion. The exposure culminated in the formation of a palaeosol that is preserved today in the Bengal Basin, and other world deltas, as an impermeable clay dubbed here the Last Glacial Maximum Palaeosol (LGMP). In the Bengal Basin, this LGMP exerts a strong control on flow, and so on the location of arsenic pollution in the basin's shallow aquifers.

The LGMP was formed on interfluvial regions of the Bengal Basin. It is now present discontinuously across the Bengal Basin at a depth ranging from 20 – 35 m, where it can be identified by drilling and resistivity survey. The LGMP forms an impermeable barrier to downward flow of groundwater, but not to horizontal flow. It caps brown-coloured unpolluted aquifers of Pleistocene age that underlie interfluves, thereby protecting them from downward movement of dissolved arsenic, and dissolved organic matter, that would otherwise introduce arsenic pollution from overlying arsenic-polluted Holocene aquifers, or cause reduction of FeOOH and release of sorbed arsenic to groundwater. In palaeo-channels between the interfluves, the LGMP is absent and hydraulic continuity exists between largely unpolluted Pleistocene aquifers and overlying Holocene arsenic-polluted aquifers. In such setting, the absence of the LGMP allows arsenic pollution and dissolved organic matter to migrate downwards into the Pleistocene aquifers. The organic matter drives reduction of FeOOH and so contributes to arsenic pollution.

Horizontal flow of groundwater allows arsenic-polluted water and organic matter to invade unpolluted parts of the aquifer that lie in the interfluvial regions beneath the LGMP. In those regions, the brown sands retain a capacity to sorb migrating arsenic onto FeOOH. As a consequence, reserves of unpolluted water exist beneath interfluvial regions that could last many tens of years at current rates of arsenic migration of a few metres per year. The identification of the LGMP by drilling and resistivity survey offers a practical prospect for identifying areas underlying it that can provide long-term supplies of low-As water from shallow (< 50m deep) aquifers of the Bengal Basin.

In order to investigate the mechanism of As release to anoxic ground water in alluvial aquifers, our team of scientists sampled ground waters from 3 piezometer

nests, 79 shallow (<45 m) wells, and 6 deep (>80 m) wells, in an area 750 m by 450 m, just north of Barasat, near Kolkata (Calcutta), in southern West Bengal. High concentrations of As (200–1180 lgL_1) are accompanied by high concentrations of Fe (3–13.7 mgL_1) and PO4 (1–6.5 mgL_1). Ground water that is rich in Mn (1–5.3 mg L_1) contains <50 lgL_1 of As. The composition of shallow ground water varies at the 100-m scale laterally and the metre-scale vertically, with vertical gradients in As concentration reaching 200 lgL_1 m_1. The As is supplied by reductive dissolution of FeOOH and release of the sorbed As to solution. The process is driven by natural organic matter in peaty strata both within the aquifer sands and in the overlying confining unit. In well waters, thermotolerant coliforms, a proxy for faecal contamination, are not present in high numbers (<10 cfu/100 ml in 85% of wells) showing that faecally-derived organic matter does not enter the aquifer, does not drive reduction of FeOOH, and so does not release As to ground water. Arsenic concentrations are high (_50 lgL_1) where reduction of FeOOH is complete and its entire load of sorbed As is released to solution, at which point the aquifer sediments become grey in colour as FeOOH vanishes. Where reduction is incomplete, the sediments are brown in colour and resorption of As to residual FeOOH keeps As concentrations below 10 lgL_1 in the presence of dissolved Fe. Sorbed As released by reduction of Mn oxides does not increase As in ground water because the As resorbs to FeOOH. High concentrations of As are common in alluvial aquifers of the Bengal Basin arise because Himalayan erosion supplies immature sediments, with low surface-loadings of FeOOH on mineral grains, to a depositional environment that is rich in organic mater so that complete reduction of FeOOH is common.