Impact of untreated sewage infiltration on metalloid cycle in shallow aquifer: case study with implications for SE´Asia

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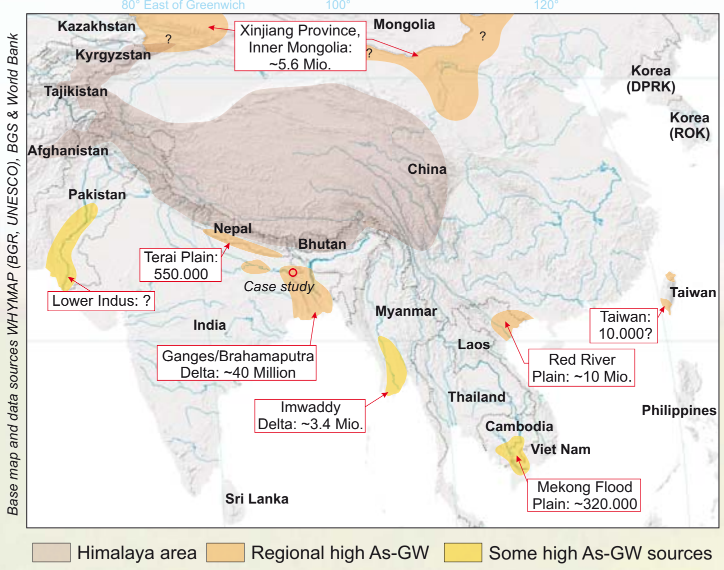
Introduction

Natural high arsenic (As) levels in groundwater of the Bengal-Delta-Plain are considered to be "The largest mass poisoning in human history" (WHO, 2000). During last decade further affected aquifers in SE-Asia have been identified, mostly in rural areas and intensively used as drinking and irrigation purposes. Therefore, millions of people are at risk to suffer from chronic arsenic poisoning.

Based on a case study, the calamity including the role of infiltrating sewage is characterized. The link between local and regional scale enables recommendations for identifying potentially affected aquifers.



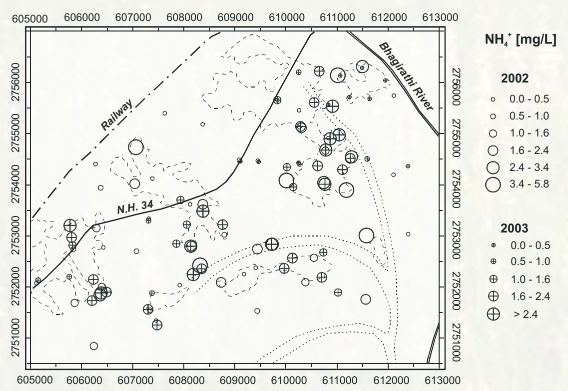
Regional geotectonic frame

The Map (left) illustrates known aquifers with high dissolved As content and estimations of peoples at risk by consuming high As-water in SE-Asia hints to a geotectonic context of the calamity:

The affected areas represent alluvial deltas or flood plains. Extreme erosion rates in Himalaya belt led to mobilisation and accumulation of huge sediment loads transported by receiving rivers during last glaciation and early holocene. Therefore, large alluvial basins are filled with immature sediments. In a tropical climate a perfect basis for microbial and geochemical processes.

Geochemical study of shallow aquifer in Malda District, India: C_{org}-degradation, redox zontation and metalloid (As) distribution

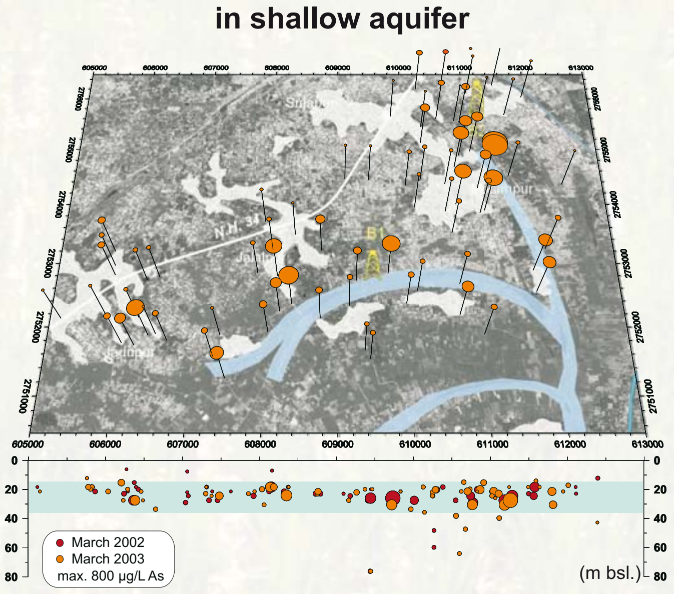
Tracing the origin of organic matter by its degradation products



- PO_4^{3-}, NH_4^+: degradation products of Corg., either natural (e.g., peat) or anthropogenic (sewage) origin.
- NH_4 >1mg/L: associated with oxbow channels and villages; $r_{As, NH4+}$ = 0.69

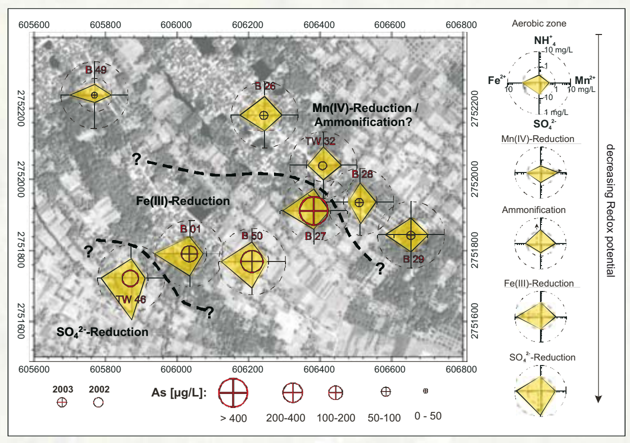
High NH_4 in shallow groundwater is associated with oxbow channels (fine-grained, C_{org}-rich sediments) and villages. The latter may be originated by infiltration of untreated sewage water, locally in close vicinity of drinking water wells.

Spatial and depth distribution of dissolved As in shallow aquifer



- Obvious **vertical zonation**: Major occurrence of dissolved As in shallow aquifer within 15-30 m bsl.
- Very „patchy" spatial distribution of As even within zone (15-30 m depth), high As groundwater sources are associated with oxbow channels and villages.

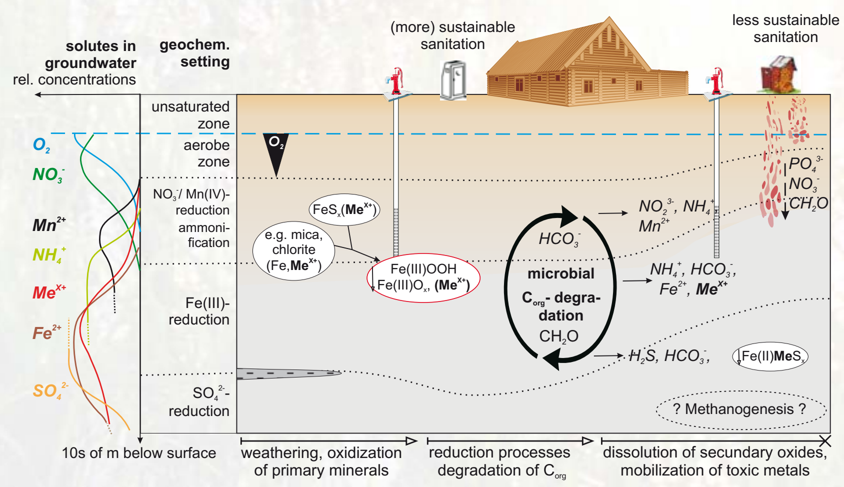
Small scale lateral redox-zonation



- Redox-sensitive solutes NH_4, Mn, Fe, SO_4 in radial diagrams illustrate predominating redox conditions.
- Delineation of areas with similar redox conditions reveals small-scale redox zonation. Highest As is associated with Fe(III)-reduction zone.

Not only vertical (see left), but also a **lateral redox-zonation** is responsible for the patchy distribution of redox-sensitive metalloids (such as As) in groundwater.

Process Understanding & Implications for Remediation



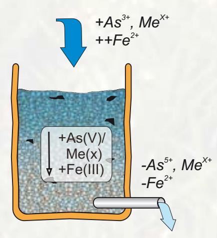
Conceptual model about As and other metal(loid)s cycle (Me^{X+}: As, Sb, Mn, Mo, Ni, V) in shallow alluvial aquifer:

Weathering of primary Fe-bearing silicates/ sulfides result in Fe(III)-phases coprecipitating with metalloids. Microbial degradation of NOM consume oxygen, nitrate and subsequently Fe(III) as electron acceptor. Therefore, not only Fe^{2+}, also its Me^{X+} load dissolve into groundwater.

Since reduction and mobilisation is controlled by degradation of natural organic matter, **nutrient rich sewage** input accelerates the process. This generally takes place in **holocene alluvial deltas** and **flood plains of SE-Asia** with comparable hydrogeologic conditions.

Simple „first aid" remediation

reversing the mobilisation process



Advantages of simple sand filter:
- simple construction, cheap materials
- Long livespan, easy maintenance
- effective Me-removal with high Fe^{2+} !

Conclusions

Interacting tectonic, microbial and geochemical processes result in metal(loid)s mobilisation of SE-Asias holocene alluvial aquifers. This is locally accelerated by infiltrating C_{org}-rich sewage waters.

Pre-Identification of potentially affected aquifers using **Geoindicators**:

- Geology: young (holocene) alluvial aquifers
- Hydrogeology: very low hydraulic gradient
- Hydrochemical setting: suboxic to anoxic - Eh, Fe, DO, Mn, NO_3-NH_4, SO_4-H_2S
- Availability of organic matter: NH_4, DOC, P, HCO_3, sanitation monitoring, coli. germs
- Morphology: plain relief, oxbow channels, dead water?

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