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Predicting Groundwater Arsenic Contamination in Southeast Asia from Surface Parameters

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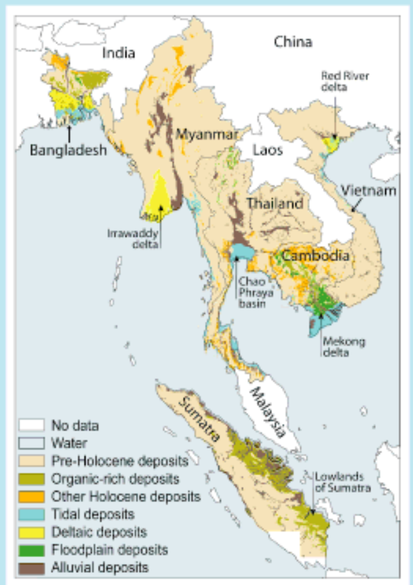
Approach

Arsenic contamination of groundwater resources is a major health threat to 50-100 million people in Asia. Arsenic originates from natural sedimentary phases from which it is released to the groundwater under reducing conditions. To efficiently respond to this threat, it is of crucial importance to pinpoint areas that are at high risk of groundwater arsenic contamination.
Using geology, soil properties and statistical analyses we have created maps that indicate which areas are at risk of arsenic groundwater contamination. These maps may guide natural and medical scientists as well as policy-makers to conduct research and implement mitigation programs.



Sedimentary depositional environments
Areas of known arsenic contamination (Bengal delta, Red River delta, Mekong delta) are floodplains fed by huge sediment loads. Regions exhibiting similar characteristics in Sumatra, Myanmar and Thailand have not been tested for arsenic contamination in a systematic manner.

Based on our logistic regression model, young sedimentary depositional environments were found to be key proxies for arsenic enrichment in aquifers, such as

- Deltaic deposits
- Organic-rich deposits
- Alluvial deposits
- Floodplain deposits

Soil texture and silt content in the topsoil served as a proxy for drainage conditions and chemical maturity of the sediment.

Research concept:
Creating a prediction model for arsenic in groundwater to pinpoint areas at risk of contamination, based on GIS data of surface geology and soil characteristics

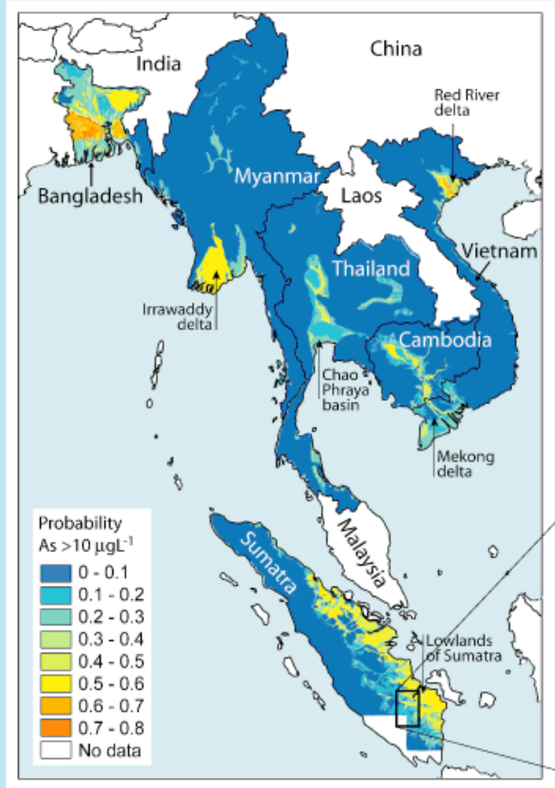
Prediction model

The relative importance of the surface proxies was evaluated with a logistic regression model using measured arsenic groundwater data of Bangladesh, Cambodia and Vietnam (n >5600).

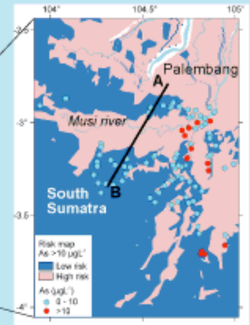
Probability (P) of having an arsenic concentration above 10 µgL^{-1}

$$P = \frac{\exp(C+\sum_{i=1}^{n} ?_i X_i)}{1+\exp(C+\sum_{i=1}^{n} ?_i X_i)}$$

Modelled probability of arsenic >10 µgL^{-1}

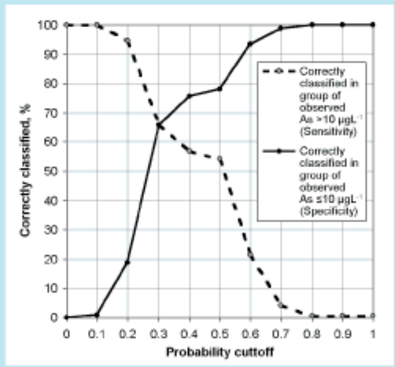


The model highlights a ~100,000 km^2 risk area along the east coast of Sumatra (Indonesia). This model prediction was validated with a groundwater survey, carried out in the province of South Sumatra (Winkel et al. 2008b).



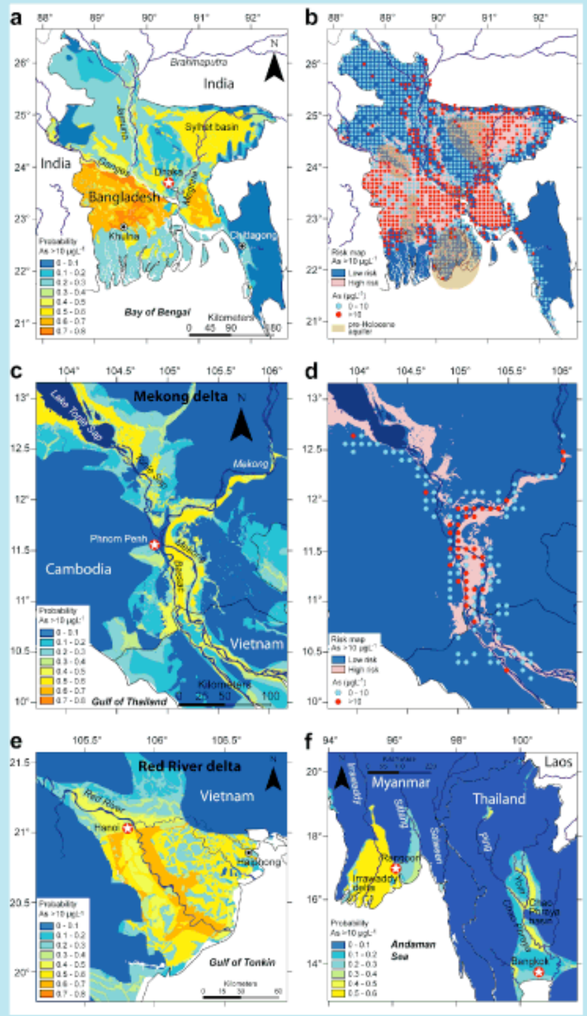
South Sumatra geological transect

Model performance



Model classification results
The graph shows the sensitivity (true positives) and specificity (true negatives) of the model for different probability cutoff values. A probability threshold of 0.4 was applied to delineate low- and high-risk areas in the binary risk maps shown above for South Sumatra and in Figures b and d to the right.

Probability and binary risk maps (As >10 µgL^{-1})



Bangladesh
a, Continuous probability. **b**, Binary map indicating high- and low-risk areas overlain by aggregated arsenic concentrations. Areas where groundwater is mainly drawn from Pleistocene aquifers are sketched in brown.

Mekong delta (Cambodia and Vietnam)
c, Continuous probability. **d**, Binary risk map overlain by aggregated arsenic concentrations.

Red River delta (Vietnam)
e, Continuous probability.

Myanmar and Thailand
f, Continuous probability of the Irrawaddy delta (Myanmar) and Chao Phraya basin (Thailand).

References

Winkel L., Berg M., Amini M., Hug S.J., Johnson C.A. Predicting groundwater arsenic contamination in Southeast Asia from surface parameters. *Nature Geoscience* **2008a**, 1, 536-542.

Winkel L., Berg M., Stengel C., Rosenberg T. Hydrogeological survey assessing arsenic and other groundwater contaminants in the lowlands of Sumatra, Indonesia. *Applied Geochemistry* **2008b**, 23, 3019–3028.

Amini M., Abbaspour K.C., Berg M., Winkel L., Hug S.J., Hoehn E., Yang H., Johnson C.A. Statistical modeling of global geogenic arsenic contamination in groundwaters. *Environmental Science & Technology* **2008**, 42, 3669-3675.