Modelling of groundwater arsenic contamination in Nepal: Geostatistical predictions of risk using remote sensing images

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Block Regression Kriging approach from surface variables

This study uses ancillary surface variables in addition to arsenic concentrations from shallow (<100m) groundwater samples to produce a quantitative 2 dimensional model of the Terai region of Nepal which partially explains the variability in mean arsenic groundwater concentrations. The model is based upon regression-kriging techniques which have previously been successfully implemented to predict spatial distribution of contaminants in soils and groundwater [1]. The groundwater database used to create and validate the presented model was provided by the Nepalese National Arsenic Steering Committee and the Nepalese Environment and Public Health Organization [2]. This database is a compilation of 18,635 unique data points from across the Terai region of Nepal.

Discussion of Results

The accuracy of the model is highly variable and there is a great degree of uncertainty associated with its predictions in some areas. This is primarily due to the uneven (clustered) distribution of samples, although the effects of numerous other compounding factors will also be discussed.

Despite the limitations inherent in the data a realistic overview of the distribution of arsenic in shallow groundwater across the Terai plain is achieved. Strong correlations are observed between topographic variables and arsenic concentration in groundwater – consistent with the findings of Lado *et al* [1]. The model predicts which un-sampled areas may be more likely to host groundwater with high arsenic concentrations and also demonstrates in which areas there is the highest uncertainty of risk.

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[1]. Lado, *et al*., (2008) *Applied Geochemistry*, **23**, 3010-3018. [2]. Shrestha, B.R, *et al*., (2004) *National Arsenic Steering Committee (Nepal), Environment and Public Health Organization (Nepal)*, p.126.

Experimental study of Ge sorption to particulate organic matter

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As a trace constituent of natural waters, Ge has received much interest owing to its chemical similarities to Si. Nevertheless, their behaviour is not identical. The decoupling of Ge and Si is reflected by distinct Ge/Si ratios, most notably for the two primary marine Ge inputs: riverine and hydrothermal [1,2]. Accordingly, Ge/Si ratios recorded in diatom opal have the potential to serve as a paleoproxy, but their utility has been complicated by additional unknown sinks and/or sources. However, the role of particulate organic matter (POM) as a non-opal Ge sink has been largely unexplored. The organophilic nature of Ge [3] and its reported strong complexation with organic acids [4] indicate that organic matter has the potential to play a key role in Ge cycling.

To study this potential role, we conducted a series of sorption experiments focused on the effects of POM on Ge behaviour at various [Ge], pH and contact times. Experiments were run by suspending 200 mg of pre-cleaned POM in MilliQ water, buffered to a pH ranging from 6 and 8, and spiked with a known [Ge]. Solution aliquots were collected, centrifuged and analysed by ICP-MS.

Results show significant and rapid sorption of Ge to POM. Ge sorption increases with contact time, first rapidly (22-50% sorption at 1 hr), then slowly (52-65% at 4 hrs) – likely corresponding to rapid adsorption followed by slow interparticle diffusion. Ge sorption onto POM also exhibits a strong pH-depedence, decreasing from pH 6 to 8. Dissolved Ge is present largely as $H_4GeO_4^0$ throughout this pH range, and so the pH effect is likely a function of (de)protonation of POM surface functional groups rather than Ge speciation.

These experiments demonstrate the propensity of Ge to interact with POM, pointing to an important sink for Ge in the natural environment. Additional studies will focus on the nature of sorption as a function of POM types and establishing if it is coupled with Ge-isotope fractionation. Such studies contribute to a more quantitative understanding of Ge cycling in natural waters and the potential of Ge isotopes as a paleoceanographic proxy.

[1] Froelich *et al*. (1992) *Paleoceanography* **7**(6), 739-767. [2] Mortlock *et al*. (1993) *Earth Planet Sci Lett* **119**, 365-378. [3] Bernstein (1985) *GCA* **49**(11), 2409-2422. [4] Pokrovski & Schott (1998) *GCA* **62**(21-22), 3413-3428.