Joint Research Centre

Modelling arsenic hazard in groundwater in Cambodia:

a geostatistical approach using ancillary data

Rationale

Arsenic in shallow groundwaters extensively utilized for drinking, irrigation and/cooking in many parts of the world, including Cambodia, represents a major environmental hazard (Charlet and Polya, 2006). The goal of this work is to develop a spatial model to estimate As concentration in groundwater in Cambodia and hence predict areas of high As hazard as tool to inform the development of adequate measurements to reduce risks to human health.

Data mining

The As database built up analyses carried out by Polya et al. (2005) during the period 2002-2005. It consists of 571 geo-referenced measurements of total As concentrations (ppb) in water of wells. The statistical analyses were performed on the log-transformed As values to account for normality of the data. A number of auxiliary variables, in the form of raster maps, were also compiled for the entire study area and their values were extracted for each single observation. The auxiliary raster maps that we considered were: Elevations derived from the 90m SRTM DEM; Slope; Topographic wetness index; Hydrologic Flux Length; convergence index; Five images obtained by Principal Component Analysis of the Normalized Difference Vegetation Index (NDVI) derived the MODIS sensor at 250m resolution for the period Jan 2000 - Dec 2001; Rasterized map of permanent water bodies, intermittent flooded areas and dry lands.
All these auxiliary variables were converted to 12 principal components that were finally used to build a multiple regression equation describing the As content in groundwater.

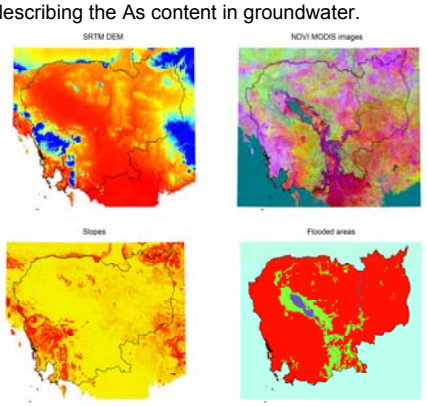

Fig 1: Some of the auxiliary variables used produce the regression model for As concentration in groundwater.

An exploratory analysis of the data by means of Principal Component Analysis reveals a clear association between As concentrations, flooded areas, the reflection values of the first NDVI image, the topographic length of flux and the topographic convergence index.

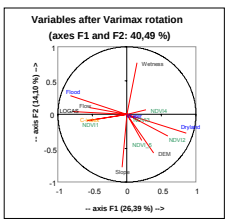

Fig 2: Principal Component Analyses of the combined database; Relationship between logAs and the residuals of the multiple regression model

Geostatistical mapping

We used a geostatistical mapping approach based on regression-kriging. First we create a continuous map of As by non-linear regression analysis between the As values and the auxiliary data and finally we added the surface of the interpolated residuals resulting from such previous model.

The best fitted regression model obtained in this work (R^2 = 0.5634) corresponds to the equation:

$$\log As = a + \sum_{i=1}^{12} \left(pr_i \times X_i \right) + \varepsilon$$

Where "a" is the interception value, "pr_i" are the coefficients for each predictor variable "X_i" and "ε" is the residual error.
The residuals of the regression model showed spatial structure. They were interpolated by ordinary kriging and added to the multiple regression map.

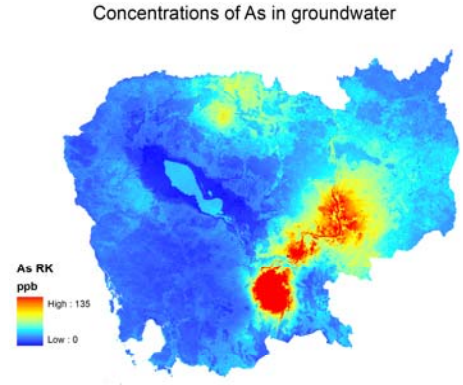

Fig 3: As content in groundwaters (µg L^{-1}) estimated by regression-kriging.

Conclusions

The study revealed that there is a strong correlation between topographic environmental variables and the content of As in groundwater. This result is broadly consistent with the findings of Buschmann et al. (2007) and is not unexpected given models of microbial mediated arsenic mobilization in recent low lying sediments (Islam et al., 2004; Polya et al., 2003, 2004, 2005; Charlet and Polya, 2006;Lear et al., 2007; Rowland et al., 2004, 2007). Kandal, Prey Veng and Kampong Cham are provinces with the highest evident arsenic hazard, indicating the requirement for development and implementation of policy control measurements.

References and Acknowledgements

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