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AdvectAs challenge: multidisciplinary research on groundwater arsenic dissolution, transport, and retardation under advective flow conditions

E. Stopelli[1], A. Lightfoot[1], R. Kipfer[1], M. Berg[1], L.H.E. Winkel[2], M. Glodowska[3], M. Patzner[3], B. Rathi[3], O. Cirpka[3], A. Kappler[3], M. Schneider[4], E. Eiche[4], A. Kontny[4], T. Neumann[4], H. Prommer[5], I. Wallis[6], D. Vu[7], M. Tran[7], N. Viet[7], V.M. Lan[7], P.K. Trang[7] & P.H. Viet[7]
[1]*Eawag, Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland*
[2]*Eawag and Institute of Biogeochemistry and Pollutant Dynamics, ETH Zürich, Zürich, Switzerland*
[3]*Geomicrobiology and Hydrology, University of Tübingen, Tübingen, Germany*
[4]*Institute of Applied Geosciences, KIT, Karlsruhe, Germany*
[5]*University of Western Australia and CSIRO Land and Water, Perth, Australia*
[6]*School of Environment, Flinders University, Adelaide, Australia*
[7]*CETASD, Vietnam National University, Hanoi, Vietnam*

ABSTRACT: Constant exposure to groundwater contaminated by arsenic (As) constitutes a major health risk for millions of people worldwide. Therefore, the biogeochemical and physical processes responsible for the release, transport and retardation of As in groundwater need to be identified to optimize groundwater management strategies, both in rural and urban areas. River delta regions in Asia constitute a relevant spot to study the presence of As in drinking water, due to the interplay among the natural release of As from sediments, the onset of redox fronts in aquifers, which can sharply change the mobility of As, and the anthropogenic increased groundwater extraction for the supply of growing urban areas. The AdvectAs project involves several teams to promote transdisciplinary research on the environmental behaviour and spatial heterogeneity of As in groundwater under advective conditions associated with extensive pumping of pristine groundwater from the city of Hanoi, Red River delta region in Vietnam. In autumn 2017 a sampling campaign in the vicinity of Hanoi was carried out, integrating sediment analyses, geochemical, mineralogical and microbiological studies, hydrogeochemical characterization of groundwater, groundwater dating and transport modelling. The first outcomes of the hydrogeochemical analyses will be presented in this contribution.

1 INTRODUCTION

The health of an estimated 200 million people is threatened by high levels of arsenic (As) in drinking water. This is specifically the case for river plains and river delta regions of Asia, where rural inhabitants often rely on naturally contaminated groundwater as primary drinking water source. It has been shown that exposure to groundwater with elevated As levels can be exacerbated by large-scale pumping of groundwater from growing urban areas (Erban *et al*., 2013; Winkel *et al*., 2011), which can promote the horizontal and vertical advection of As from shallow aquifers to previously uncontaminated groundwater resources.

Several studies have indicated that the biogeochemical reduction of iron minerals coupled to oxidation of organic matter plays a key role on the release of As from Holocenic sediments (Eiche *et al*., 2017; Fendorf *et al*., 2010; Muehe *et al*., 2014; Rodriguez-Lado *et al*., 2013; Smedley *et al*., 2002). Nevertheless, many aspects concerning As release, transport and (im)mobilisation remain largely unravelled, like the kinetics of As mobilisation processes, the role of bacteria in these processes, and the relative contribution of locally released or of advected organic matter and As to the contamination of groundwater bodies.

AdvectAs is aimed at understanding and predicting As mobility under advection induced by extensive pumping of groundwater by means of transdisciplinary research involving mineralogy, microbiology, hydrochemistry and modelling.

2 METHODS

2.1 *Site selection*

The site selected for the AdvectAs project is located on a peninsula of the Red River delta region, some 10 km southeast of the city of Hanoi, Vietnam. The growth of Hanoi has promoted a tremendous increase of groundwater abstraction from Pleistocene aquifers, causing an expansion of the drawdown of several kilometres (Winkel *et al*., 2011). This has impacted the site of our

investigation, where the advective front has reversed the natural direction of the groundwater flow towards Hanoi (Stahl *et al*., 2016). The peninsula is also characterised by the patchy presence of dissolved As in shallow wells (Berg *et al*., 2008; Eiche *et al*., 2008). Part of this spatial heterogeneity is linked to the presence of a Fe-dominated redox transition zone between Holocene and Pleistocene aquifers which plays a relevant role in the mobility of As (Postma *et al*., 2007; Rathi *et al*., 2017). All these anthropogenic and biogeochemical features make the site ideal to provide deeper multidisciplinary understanding of the factors responsible for the spatial heterogeneity of dissolved As in wells and to extend the results to other delta regions in Asia impacted by As contamination and extensive groundwater pumping.

2.2 *Set of analyses*

An interdisciplinary sampling campaign was carried out in September and October 2017, aimed at investigating the interactions of biogeochemical processes responsible for As behaviour associated to redox transition zones. Sediments are being analysed for their geochemical and mineralogical composition, including magnetic susceptibility, and for the stability of mineralogical phases, particularly redox-sensitive Fe-bearing oxides and hydroxides. The microbial abundance, bacterial community characterization and metabolic potential are being described to understand the role of the microbial component on As release and stabilization. Analyses of the hydrogeochemical composition of groundwater and groundwater dating are being carried out to improve the understanding and description of the water flow, the movement of pollution and the frame of chemical and physical conditions where biogeochemical processes can take place. Finally, reactive transport modelling is combining the data in order to quantify not only the small-scale processes determining the presence of As in groundwater but also to make predictions of As behaviour at larger-scale.

3 RESULTS

3.1 *Hydrogeochemical analyses*

Focus of this conference contribution will be the presentation of the first outcomes from the hydrogeochemical analyses. An accent will be put on the implications for the factors responsible for small-scale spatial heterogeneity of As and the consequences of extensive pumping on the mobility of As, to promote a better long-term management of groundwater resources.

3.2 *Further results*

A brief overview of the outcomes from sediment analyses, microbial characterization, and groundwater dating and modelling will be also presented.

4 OUTLOOK

The interdisciplinary research of the AdvectAs project is aiming at promoting a better understanding of the natural and anthropogenic factors responsible for the spatial spread and heterogeneity of As contamination in groundwater in the Hanoi area. A further goal is to provide evidence for optimised management strategies of water resources, to ensure better quality of drinking water both to rural and urban areas characterised by extensive pumping.

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