Origin and distribution of arsenic in fractured bedrock aquifers of the Canadian shield in the Abitibi-Témiscamingue region (Québec, Canada)

A multi-disciplinary approach

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Introduction

Arsenic (As) is a highly toxic element and its absorption can cause serious consequences on human health even at small dose due to long term exposure. Among all the routes of exposure, groundwater consumption represents the leading cause of poisoning worldwide. Arsenic occurrence in groundwater have been described in many areas in the world especially in sedimentary aquifers (e.g. Bangladesh, India, Argentina)[1, 2]. Elevated concentrations of As can also occur in fractured bedrock aquifers although only few studies have focused on this issue. In most cases, high concentrations of arsenic are the result of mobilization under natural conditions due to water-rock interactions[3].

In the Abitibi-Témiscamingue region (Province of Québec, Canada) (fig.1), As concentrations in private wells have been measured above the Health Canada and the World Health Organization guideline value of 10 ppb up to several hundreds ppb in some areas. This As contamination seems to be associated with fractured Archean rocks from the Canadian Shield. Rock units of the region consist mainly of metamorphosed volcanic and sedimentary rocks, intruded by granitoids and granitic rocks. This rocks are highly mineralized in some areas around major fault zones hence the importance of the mining industry in the region.

This work is based on a multi-disciplinary approach which aims to understand all the facets of the arsenic mobilization within a fractured bedrock aquifer.

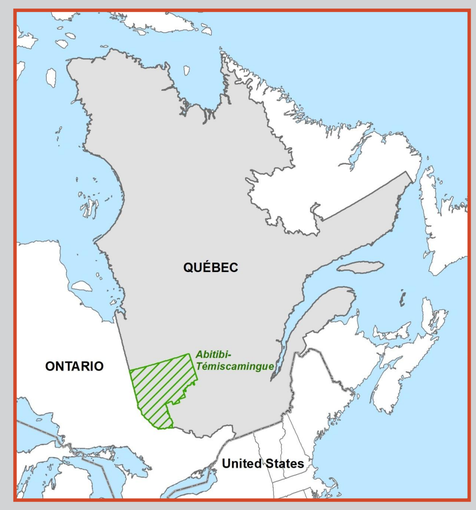


Fig. 1 - Location map of the Abitibi-Témiscamingue region in Canada

Arsenic in groundwater : a complex issue

Research hypothesis

The As occurrence in the bedrock groundwater seems to be the result of the action of 3 major factors (fig. 2.) :

i. Sources of arsenic
Oxidation of different As bearing sulfides (e.g. arsenian pyrite) and sulfosalts (e.g. arsenopyrite) from mineralized fractured areas in the Archean bedrock

ii. Arsenic mobility
Governed by secondary As-minerals precipitation as well as adsorption/desorption processes onto metal oxyhydroxydes and clay depending on :
- Metal and/or clay availability in the aquifer
- Eh-pH conditions
- Competitive anions for sorption
- Arsenic species

iii. Groundwater flow
Fracture networks with elevated As concentration characterized by slow groundwater flow → high residence time, low solid/liquid ratios

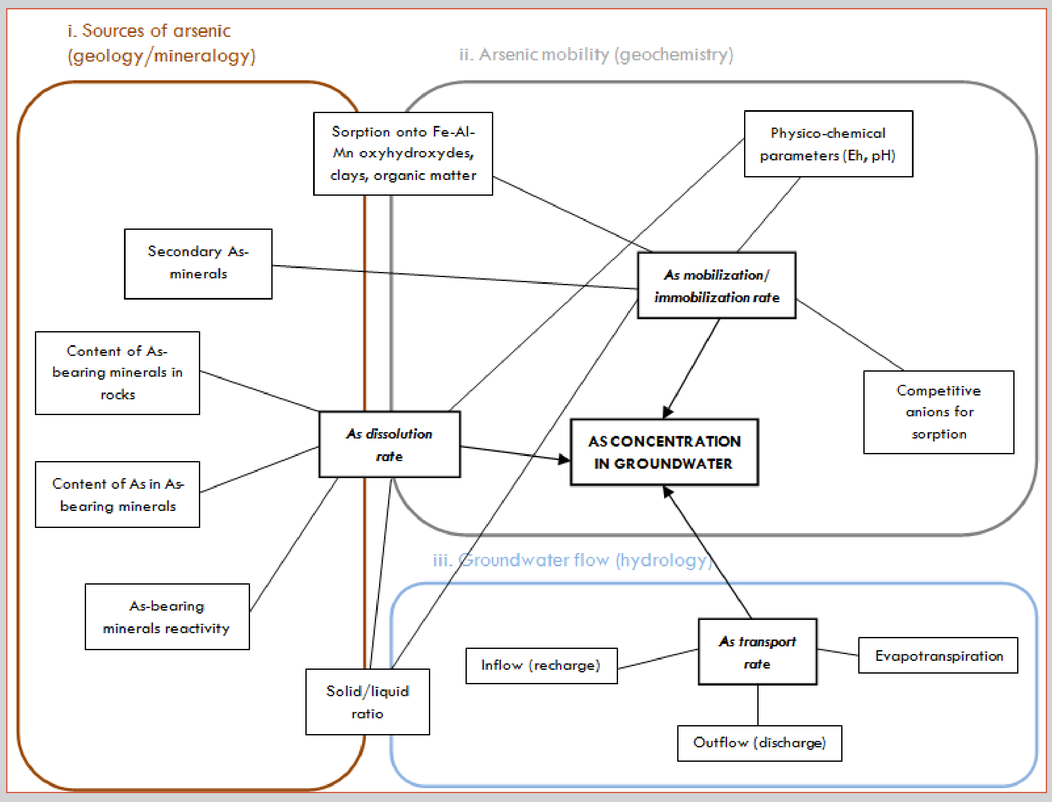


Fig. 2. Conceptual scheme of arsenic occurrence in the bedrock groundwater

Objectives

(1) Characterize the arsenic occurrence in groundwater i.e. mobility and distribution (As species) of arsenic

(2) Identify the As-bearing minerals sources of As into groundwater

(3) Assess the influence of mineralogy on As concentrations in groundwater

Use of a multi-disciplinary approach

(1) Hydrochemical characterization of groundwater

A groundwater sampling campaign was carried out from June to August 2014 using available domestic wells. The sample sites were selected based on geological features and using historical data from the Public Health Agency about As concentrations in private wells (fig. 3).

Analyzes of the following parameters are pending :

- Alkalinity, major and trace elements
- Arsenic species (As^{V}, As^{III}, MA, DMA) separated *in situ* by Solid-Phase Extraction (SPE) cartridges method[4] (analyzed for total As by ICP-MS)

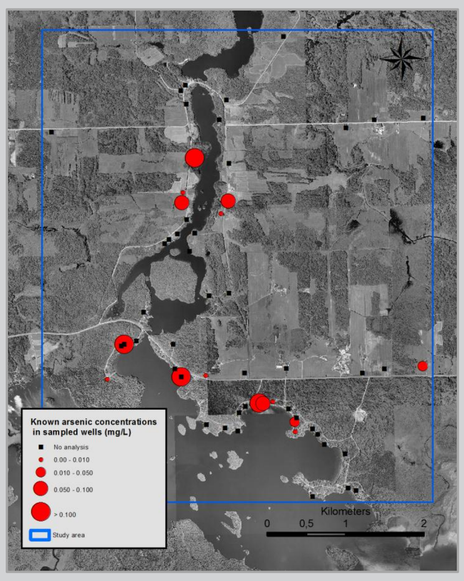
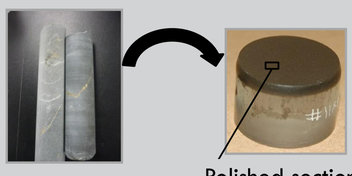


Fig 3. - Location map of the sampled wells in the Duparquet/ Rapide-Danseur study area

Passage of a groundwater sample through SPE cartridges

- As concentrations of filtered and unfiltered samples (to determine particular As)

(2) Mineralogical identification of As-bearing minerals



Cores samples — Polished sections

Identification of As-bearing minerals (arsenopyrite) using optical microscopy in reflection mode

Mineralogical tools :

- Optical microscopy using reflected light (1) (UQAT)
- Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy analyzer (2) (UQAT)

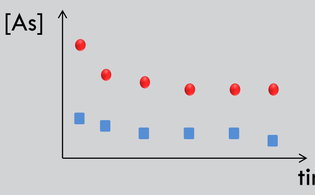
- Electron Probe Micro-Analyser coupled with Wavelength Dispersive Spectroscopy

(+) Integration of new knowledge about regional groundwater flows in fractured bedrock[5]

(3) Column laboratory experiments

Simulation of As release into water from rock samples. Experiments close to natural conditions :
- Eh-pH range
- Solid/liquid ratio
- Groundwater flow

Monitoring of As concentration and others major and trace elements by ICP-MS analysis



Perspectives

- A better understanding of arsenic mobilization in fractured aquifers which still remains an understudied and poorly understood issue although fractured aquifers are increasingly used as water supply from around the world.
- A regional benefit with a better knowledge and a healthier use of the local water resource.
- An emerging concern in mineralized areas where acidification and metal/metalloids concentrations could increase in context of climate change[6] (variation of water table and minerals oxidation, warmer temperature and anoxic conditions as well as vulnerability of mining industries to extreme climatic events).

References and acknowledgement

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