pH control with silicates minerals for *in situ* bioremediation of chlorinated solvents

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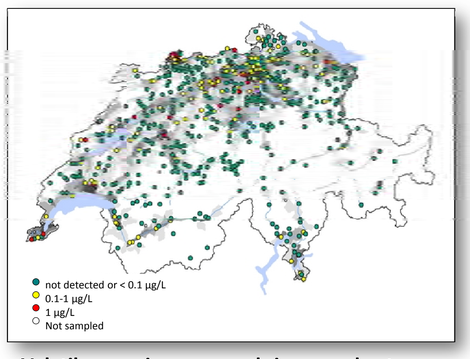
1 Background

What are chlorinated solvents?

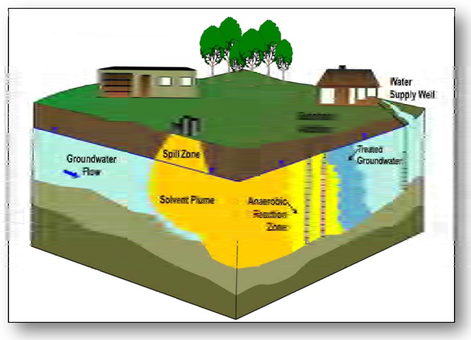
- PCE (tetrachloroethylene), TCE (trichloroethylene)
- Used as dry cleaning solvents and metal degreasing agents
- Toxic and suspected carcinogens
- Detected in 14 % of groundwater sampling stations in Switzerland



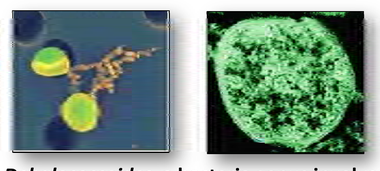
Volatile organic compounds in groundwater (Switzerland 2009) Source: OFEV

What is *in situ* bioremediation?

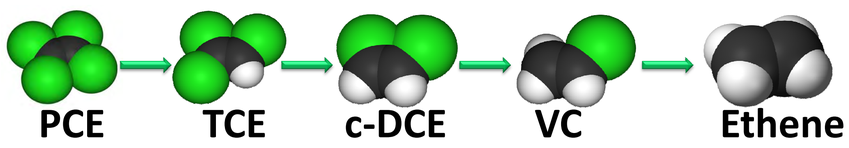
- *In situ* bioremediation (ISB) is a technology for removal of chlorinated solvents in groundwater. It relies on the activity of specialized bacteria that obtain energy for growth using PCE or TCE as an electron acceptor



Schematic diagram of enhanced *in situ* bioremediation Source: AFCEE 2004



***Dehalococcoides,* a bacteria genus involved in PCE dechlorination.**

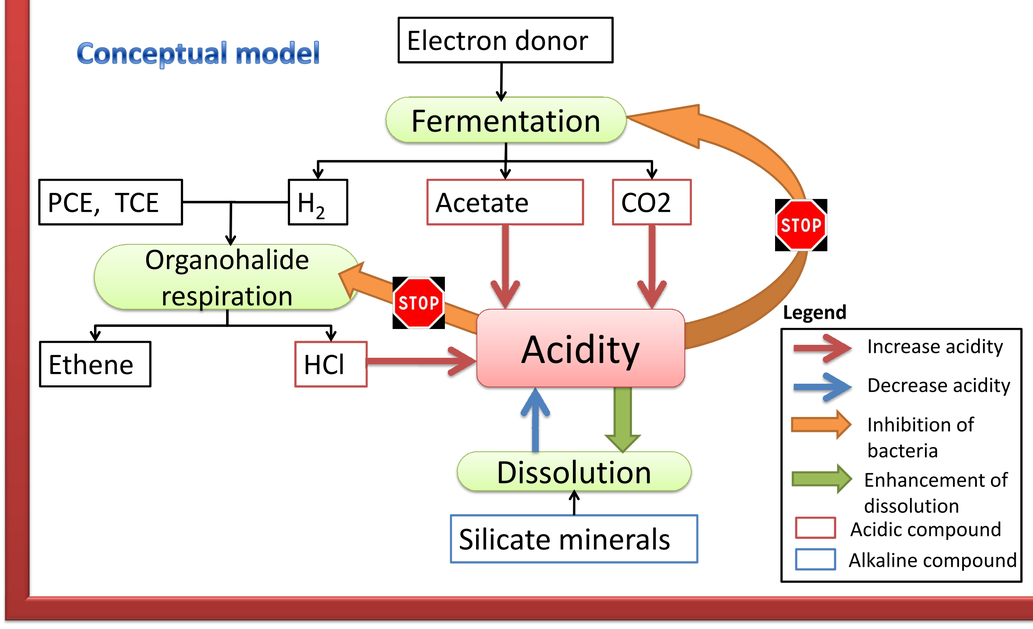


Reductive dechlorination pathway

2 Problem

In situ bioremediation of chlorinated solvents is an **acid-generating process**. Acidic conditions inhibit the activity of anaerobic bacteria. Therefore, development of an efficient pH control strategy is required. This study investigates the potential of silicate minerals to neutralize groundwater acidity.

Conceptual model



3 Objective

Evaluate the feasibility of silicate mineral utilization for pH control of *in situ* bioremediation of chlorinated solvents

4 Methods

Numerical modelling

- Geochemical code PHREEQC
- Batch model including microbial and geochemical processes
- Preselection of buffer candidates based on the result of the numerical model

Selection of 10 minerals for batch experiments

Batch experiments

- 10 silicates minerals tested
- Dehalogenating consortium growing on PCE and hydrogen
- Anaerobic conditions
- Measurements: pH, chloroethenes, dissolved cations

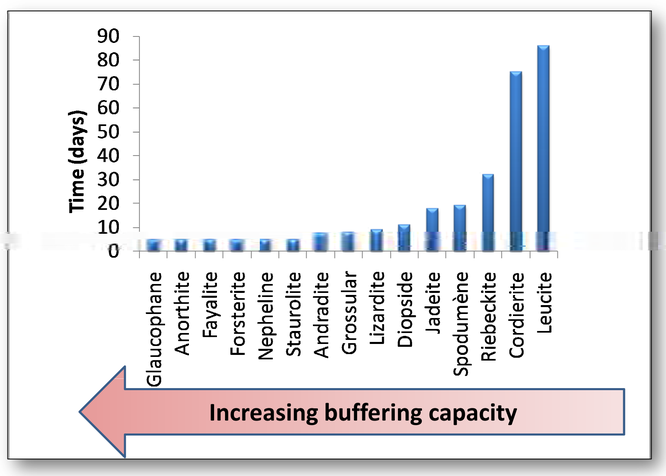
Selection of 1 mineral for column experiment

Flow-through column experiment

- Column (1): pure quartz
- Column (2): quartz + fayalite ($FeSiO_4$)
- Anaerobic conditions
- Abiotic conditions
- Circulation of a solution at pH 4.5
- Hydraulic residence time: 3 days
- Measurements: pH, chloroethenes, dissolved cations

5 Results

- Acid neutralizing potential is highly variable among silicate minerals. The **geochemical model** allows comparison of mineral buffering efficiency



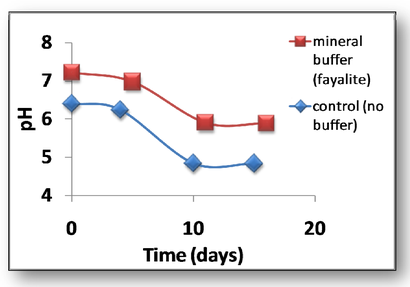
Time needed for complete degradation of 1 mmol of PCE with 4 m^2/l of mineral. Comparison of buffering potential

- **Batch experiments** demonstrated the acid-neutralizing potential of silicate minerals
- Three different behaviours were identified

Suitable buffers
- Olivine
- Diopside
- Fayalite

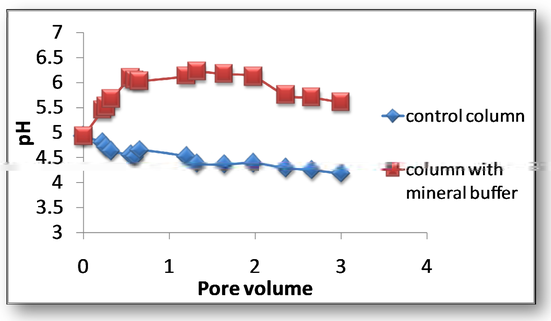
Toxic effects on bacterial activity
- Andradite
- Nepheline
- Forsterite

Insufficient buffering capacity
- Staurolite
- Glaucophane



Evolution of pH with and without mineral in batch experiments

- pH buffering by minerals was also demonstrated in **column flow-through experiments**
- Mineral dissolution in porous medium was 20 times higher than in batch



Evolution of pH with and without mineral in the column

6 Conclusion

- Both modelling and experimental results demonstrated the feasibility of using selected silicate minerals as buffering agent for ISB
- Mineral-induced inhibitory effects were detected underlying the need of batch experiments prior to application of this method at a contaminated site
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