Enhancing the Efficacy of Permeable Reactive Barriers

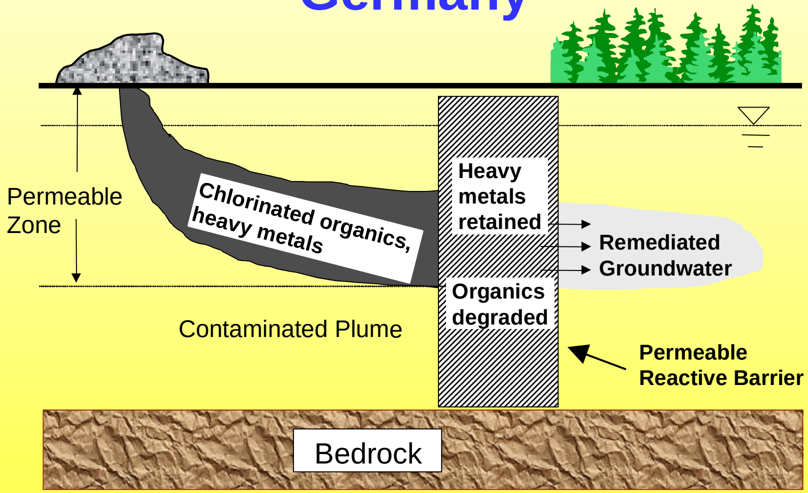
T. Meggyes[1,4], M. Csővári[2], K. E. Roehl[3], F.-G. Simon[4]

[1]University of Wolverhampton, UK

[2]Mecsek Öko Zrt, Pécs, Hungary

[3]Karlsruhe University, Karlsruhe, Germany

[4]Federal Institute for Materials Research and Testing (BAM), Berlin, Germany



MOKKA Conference, Budapest, 15 June 2007

BAM

Contents

Permeable Reactive Barriers (principle)
PEREBAR EU-project
Materials considered/tested
Development of a selective contaminant-binding chemical compound
Electrokinetic technique to enhance the long-term performance of PRB
Accelerated testing to model ageing processes
Experimental pilot-scale permeable reactive barrier
Life span calculation

Permeable Reactive Barriers (PRB)

Treatment types (in-situ)

- **physical,**
- **chemical**
- **biological**

Reactive materials in underground trenches

No groundwater removal or soil excavation

Structure types

- **continuous reactive barriers**
- **funnel-and-gate**

Feasibility - life span of the reactive materials

- **remediation processes (oxidation)**
- **reaction products (precipitates)**
- **exhaustion of sorption capacity**

10 to 20 years - no experience over such periods

PEREBAR EU-project

Long-term Performance of Permeable Reactive Barriers

Participants: Austria, Germany, Greece, Hungary and UK

Overall goal: evaluate and enhance the long-term performance

Emphasis: sorption, precipitation of heavy metals

Processes impairing barrier performance

Test sites

- **Pécs, Southern Hungary: uranium**
- **Brunn am Gebirge, Austria**

Materials considered/tested

- zeolite
- hydroxyapatite (HAP)
- activated carbon
- hydrated lime
- elemental iron

Uranium attenuation mechanisms:

- HAP: precipitation
- Iron: reductive precipitation & adsorption

Sulphates: no detrimental effect

Carbonates: detrimental effect (iron only)

Development of a selective contaminant-binding chemical compound

- PANSIL: silica coated with modified polyacriloamidoxime
- Support matrix: sand
- High efficiency: pH 4 – 8
- Uranium-specific
- No precipitation of by-products

Electron micrograph of PANSIL

Electrokinetic technique to enhance the long-term performance of PRB

Electrokinetic fence
Upstream installation
Preventing charged species from being transported by the groundwater
Precipitation around the electrodes
Removal of groundwater constituents helps increase life span of PRB

BAM

Accelerated testing to model ageing processes

Column experiments

Uranium-contaminated water flowing through a laboratory column filled with iron or HAP

Tracking the movement of uranium

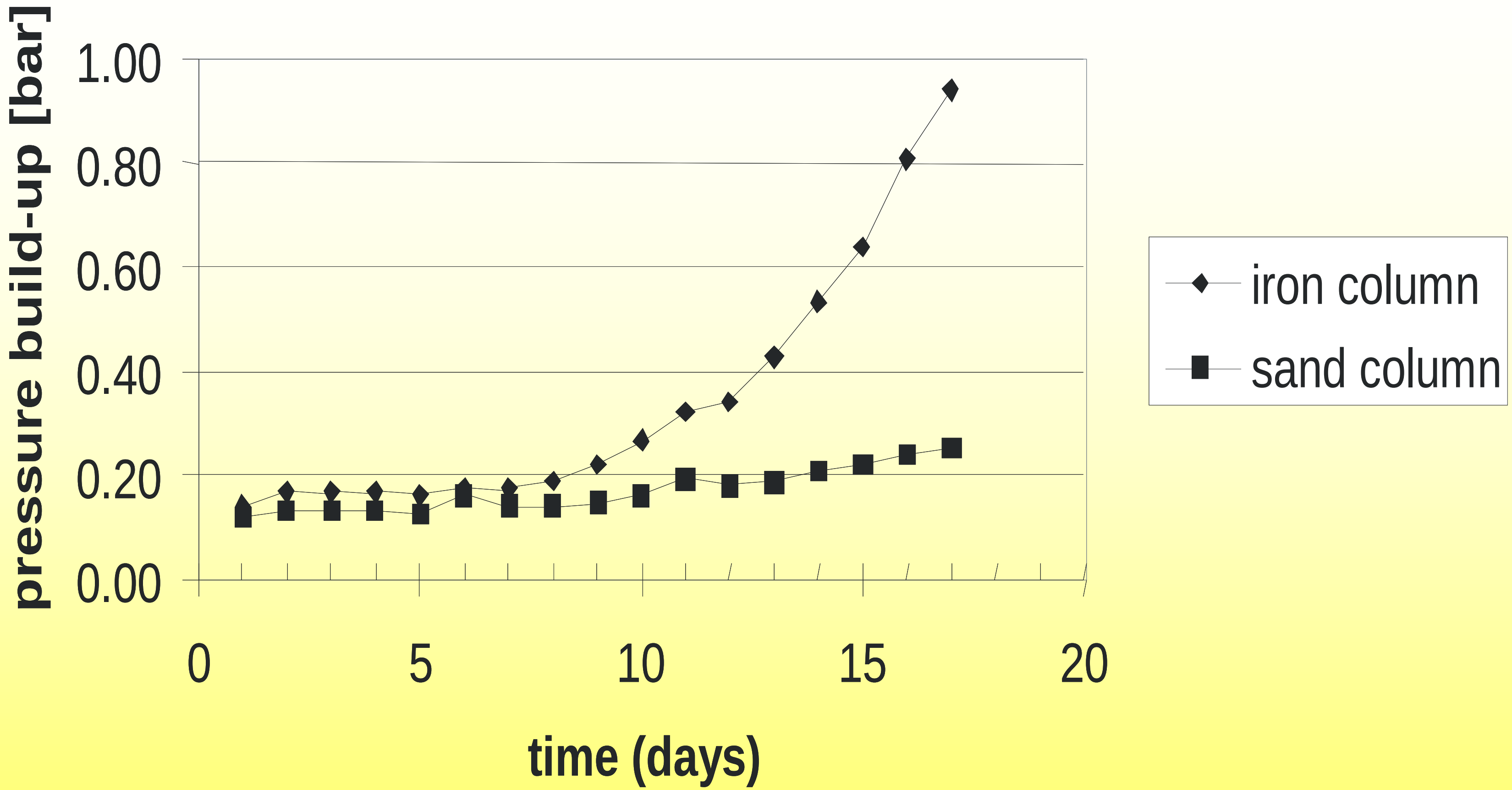
^{237}U radioindicator (half-life 6.75 days)

Understanding the uranium uptake capacity

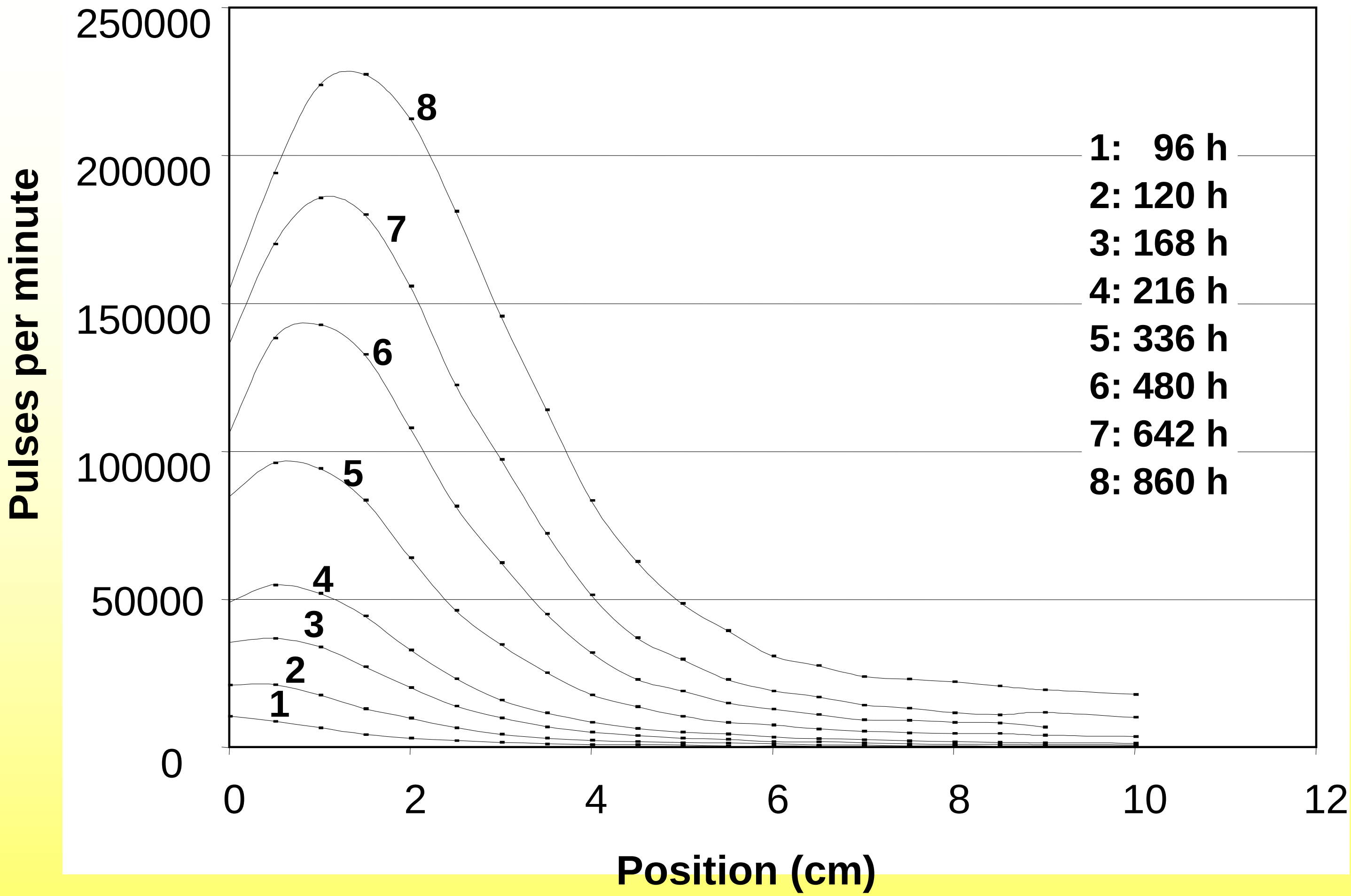
Flow velocity: 2.5 times natural GW flow velocity

BAM

Accelerated test of ageing: pore clogging, BAM, Berlin

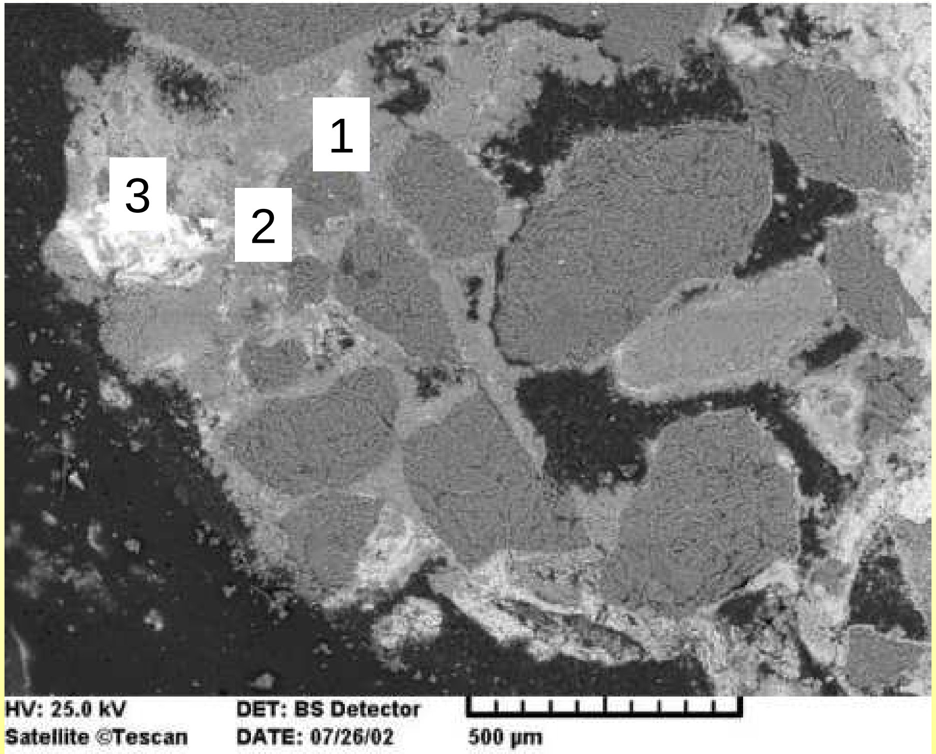


Accelerated test of ageing, pore clogging, BAM, Berlin



Activities measured in the column after various time intervals

BAM



Electron microscopy image of sand/iron mixture.
1: sand particle, 2: precipitated $CaCO_3$, 3: iron particle.
Surface covered with $Fe(OH)_2$ and $FeCO_3$ precipitation.
(Debreczeni & Gombkötő)

BAM

Experimental pilot-scale permeable reactive barrier

Pécs, Southern Hungary:

former uranium mining site

6.8 m x 2.5 m x 3.8 m

38 tonnes of iron

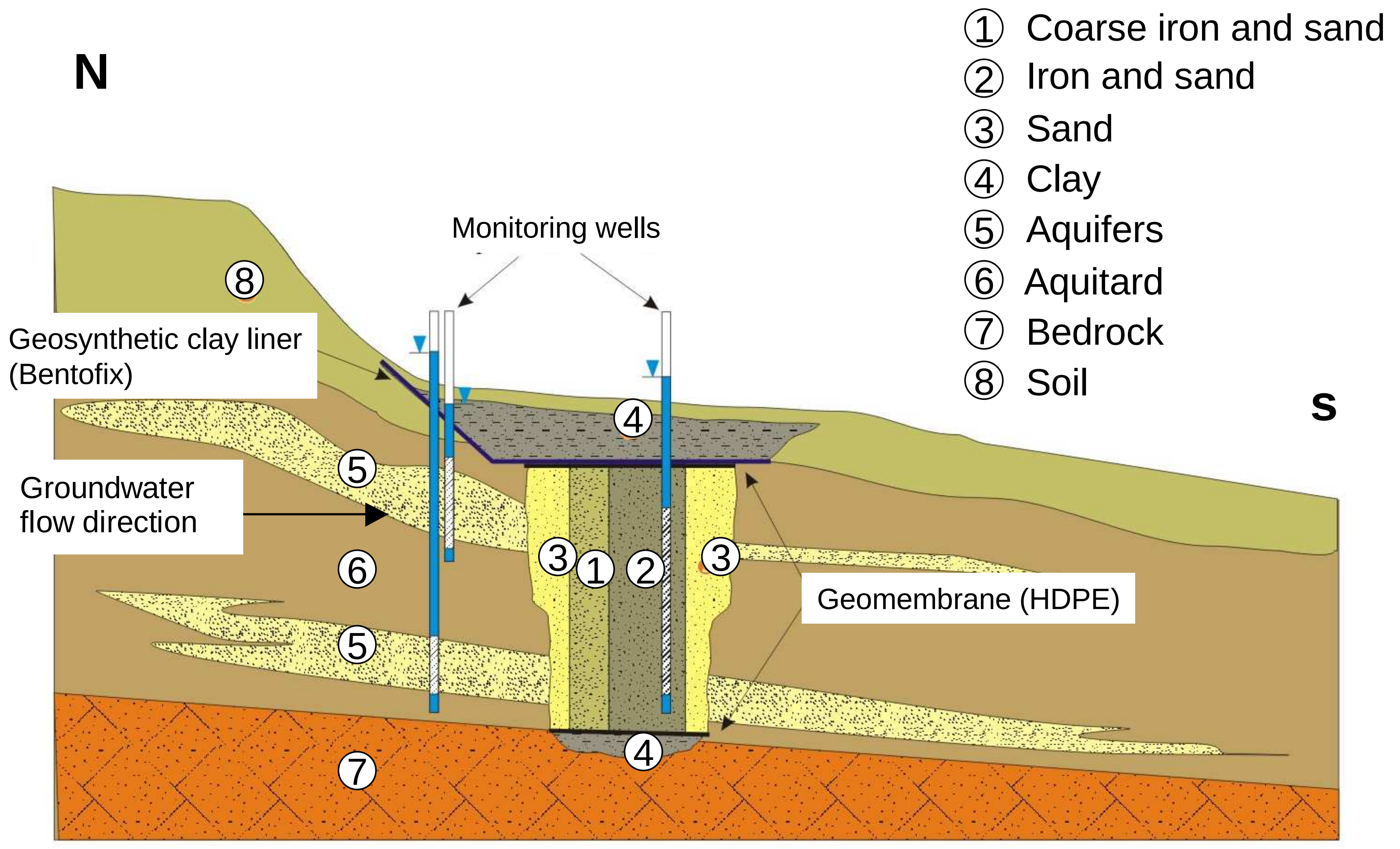
24 monitoring wells

Uranium concentration

Early 2002: 1,000 µg/l

Late 2002: less than 100 µg/l

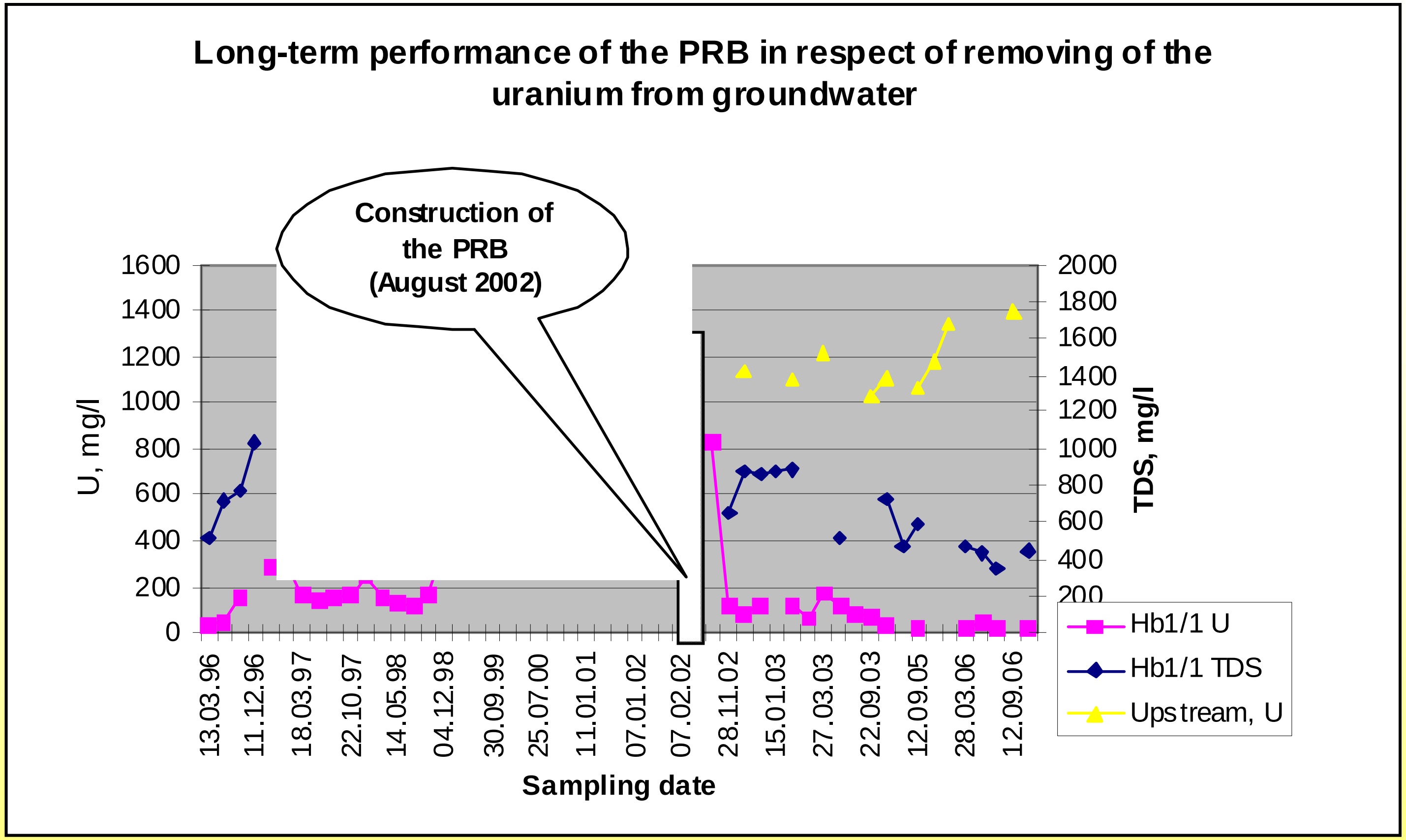
BAM



Experimental permeable reactive barrier near Pécs, Hungary (Csővári et al.)

View of the experimental permeable reactive barrier with monitoring wells (Csővári et al.)

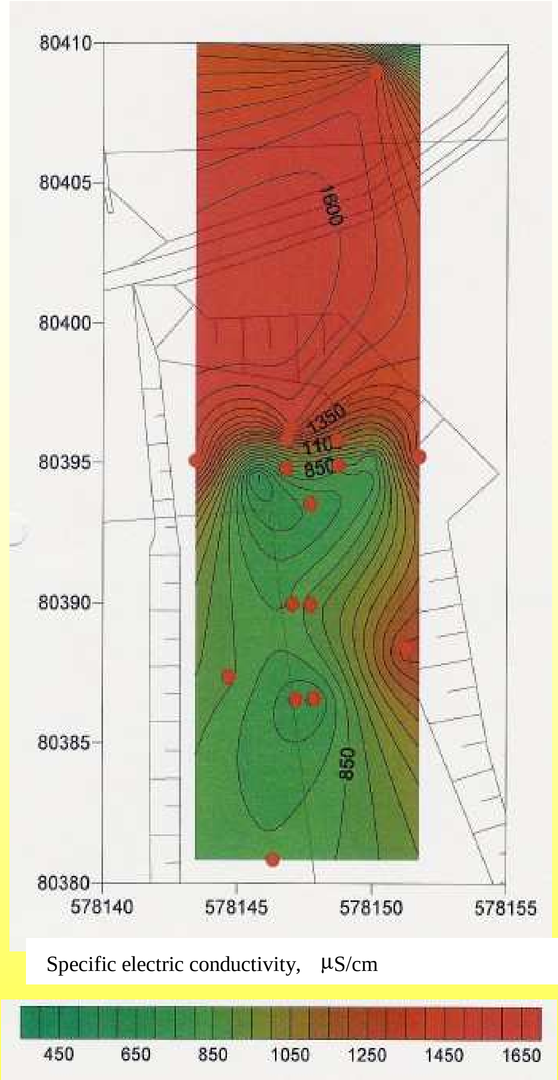
BAM

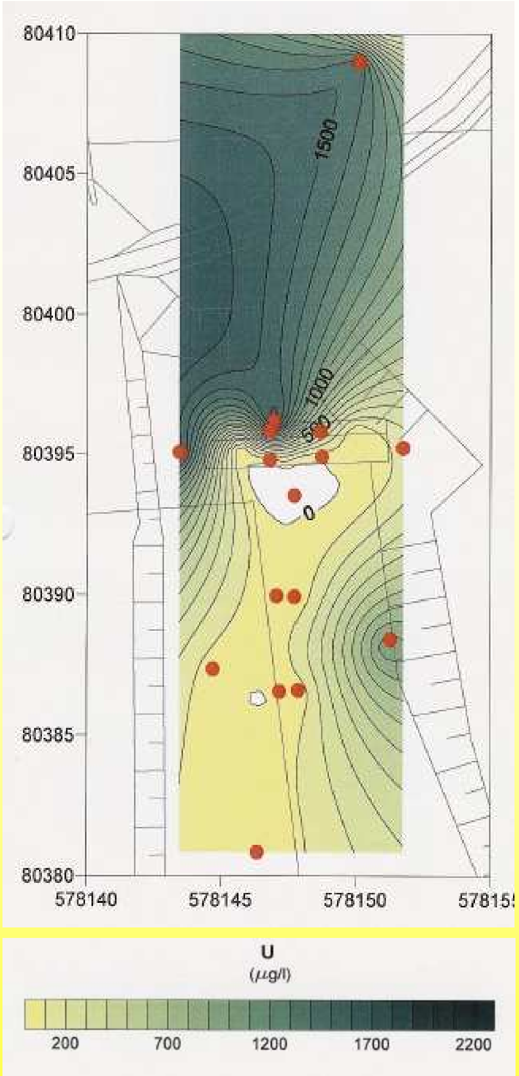


Uranium concentration and total dissolved solids (TDS) U/S and in a D/S monitoring well near the PRB

BAM

Uranium concentration and electric conductivity in groundwater





Monitoring wells

Life span calculation (example)

Criterion: loss of porosity due to precipitation

Fe: electron donor > formation of OH^- > increase in pH

Decrease in solubility of carbonates

700 mg of carbonates precipitation for every litre that passes through PRB

Flow rate 750 m^3/y > 525 kg/y precipitate (2.75 g/cm^3) > 0.192 m^3/y precipitate

PRB volume: 6.8 m x 1.5 m x 3.8 m = 38.8 m^3

Pore volume: 38.8 x 0.3 = 11.6 m^3

11.6 m^3 / 0.192 m^3/y = **60 years**

BAM

Book:

Roehl, Meggyes, Simon, Stewart (eds): Long-term Performance of Permeable Reactive Barriers
published by Elsevier in the series
J.O. Nriagu (series ed): Trace Elements and Other Contaminants in the Environment
http://www.elsevier.com/locate/isbn/0444515364

PEREBAR project website:
http://www.perebar.bam.de/