

# Enhancing the Efficacy of Permeable Reactive Barriers

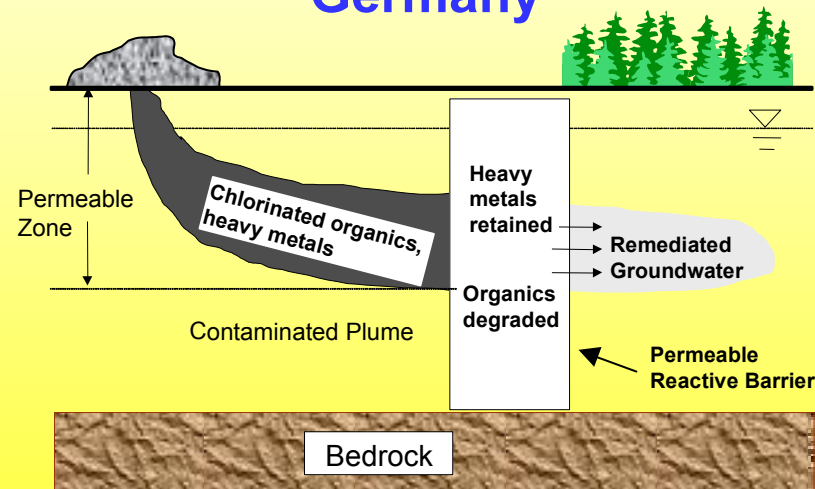
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## **Permeable Reactive Barriers (PRB)**

### **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**

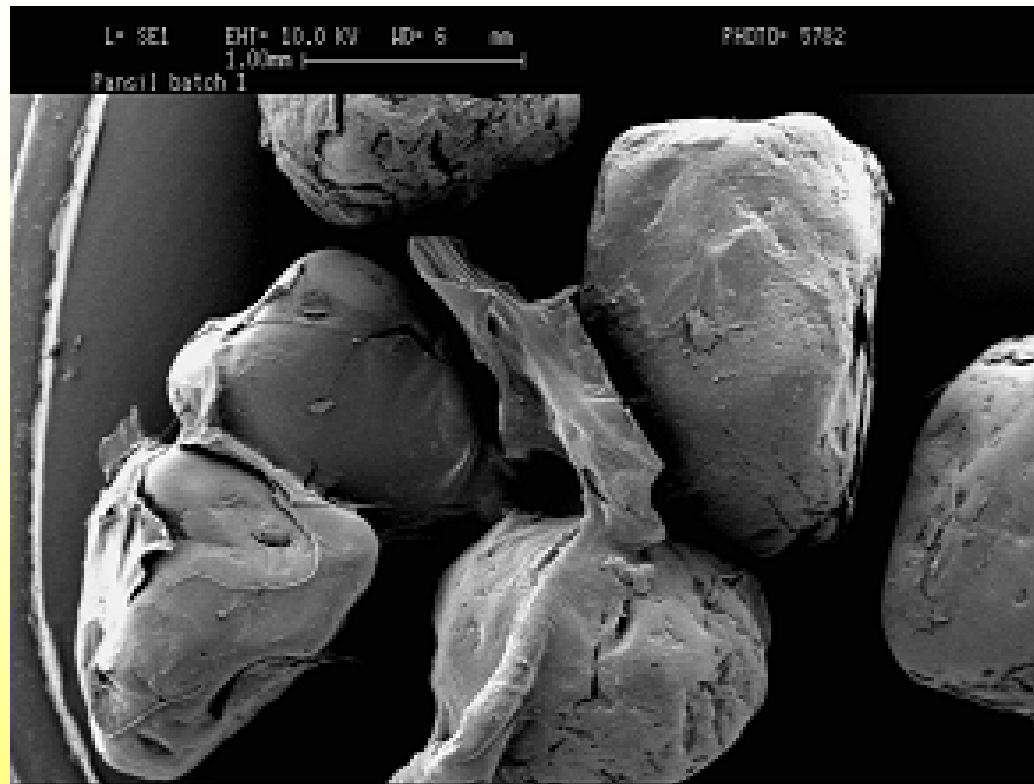
**PANSIL: silica coated with modified polyacrilamidoxime**

**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**



## **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**

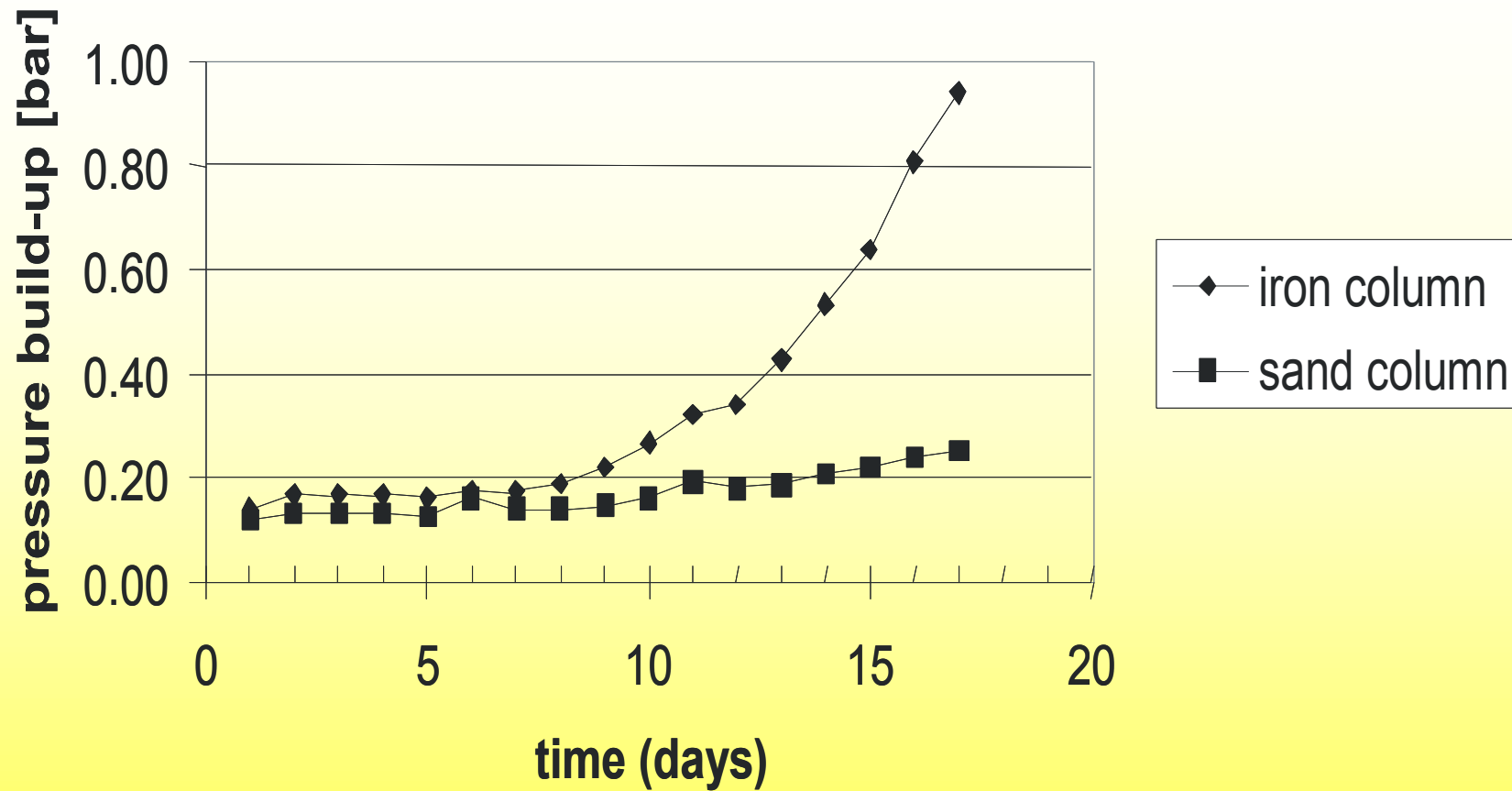
**$^{237}\text{U}$  radioindicator (half-life 6.75 days)**

**Understanding the uranium uptake capacity**

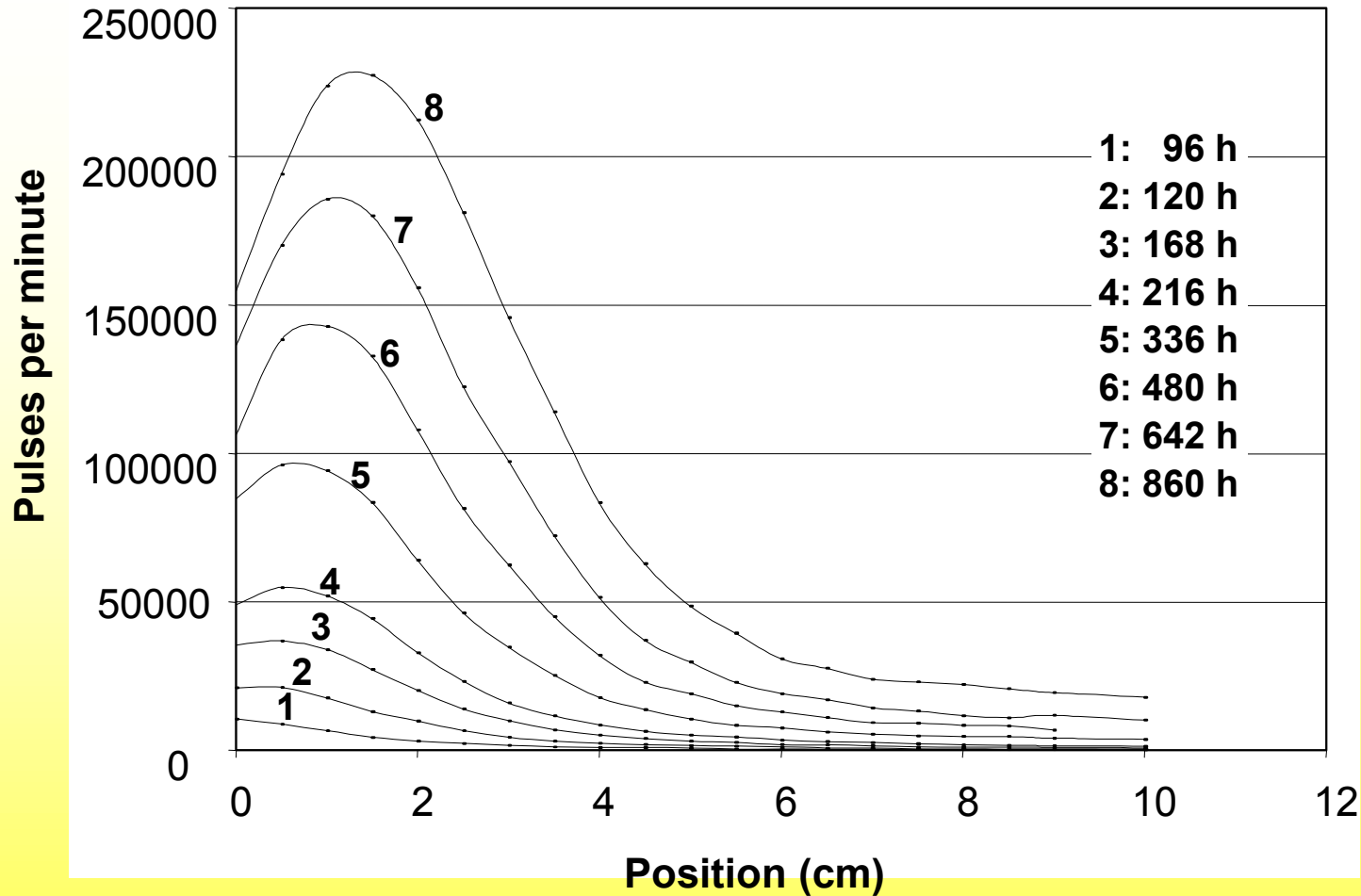
**Flow velocity: 2.5 times natural GW flow velocity**



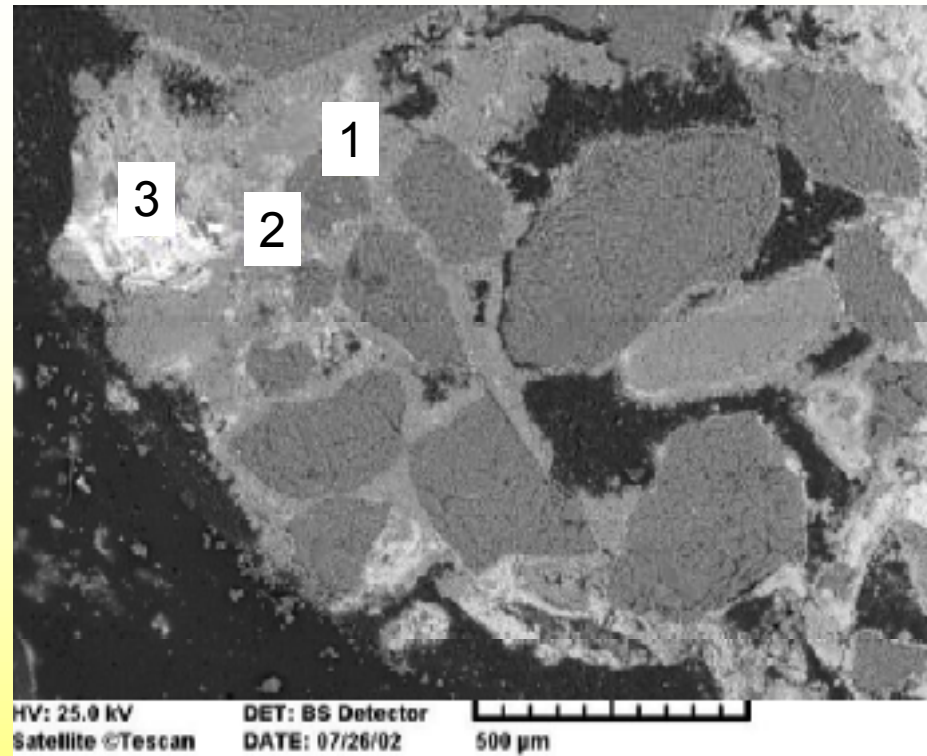
## Accelerated test of ageing: pore clogging, BAM, Berlin



## Accelerated test of ageing, pore clogging, BAM, Berlin



## Activities measured in the column after various time intervals



**Electron microscopy image of sand/iron mixture.  
1: sand particle, 2: precipitated  $\text{CaCO}_3$ , 3: iron particle.  
Surface covered with  $\text{Fe}(\text{OH})_2$  and  $\text{FeCO}_3$  precipitation.  
(Debreczeni & Gombkötő)**

# Experimental pilot-scale permeable reactive barrier

Pécs, Southern Hungary:

former uranium mining site

6.8 m x 2.5 m x 3.8 m

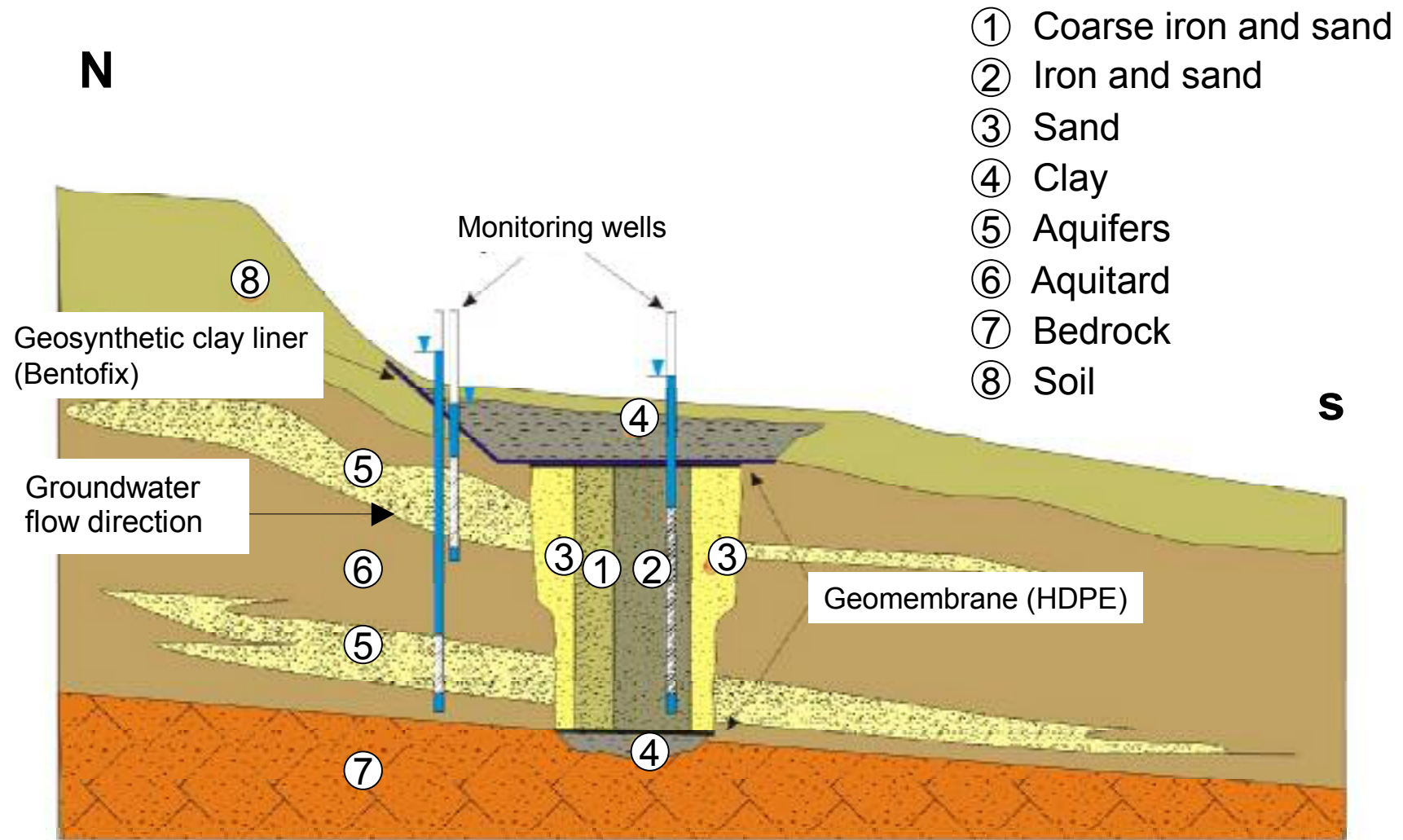
38 tonnes of iron

24 monitoring wells

Uranium concentration

Early 2002: 1,000  $\mu\text{g/l}$

Late 2002: less than 100  $\mu\text{g/l}$



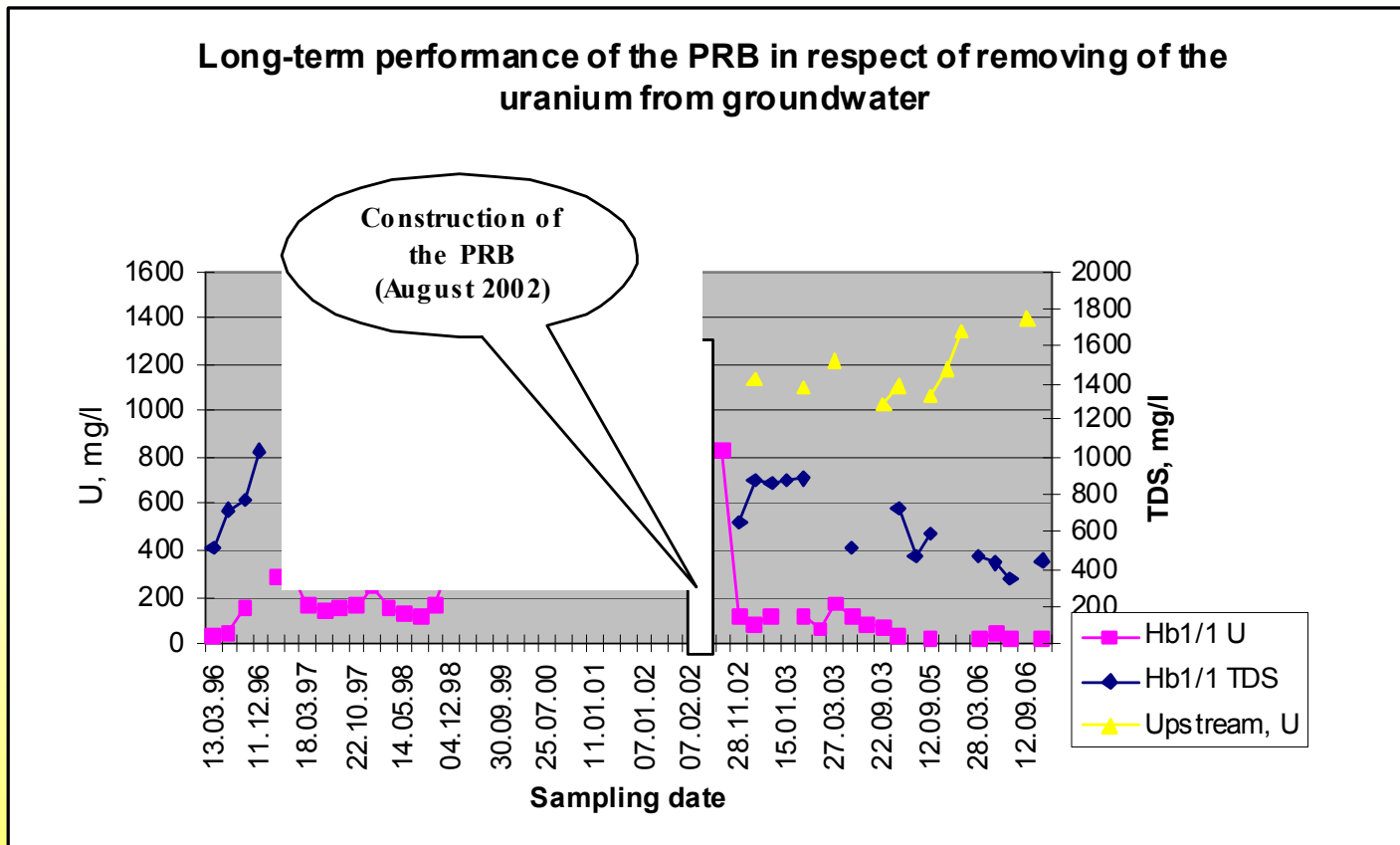
## Experimental permeable reactive barrier near Pécs, Hungary (Csöväri et al.)



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

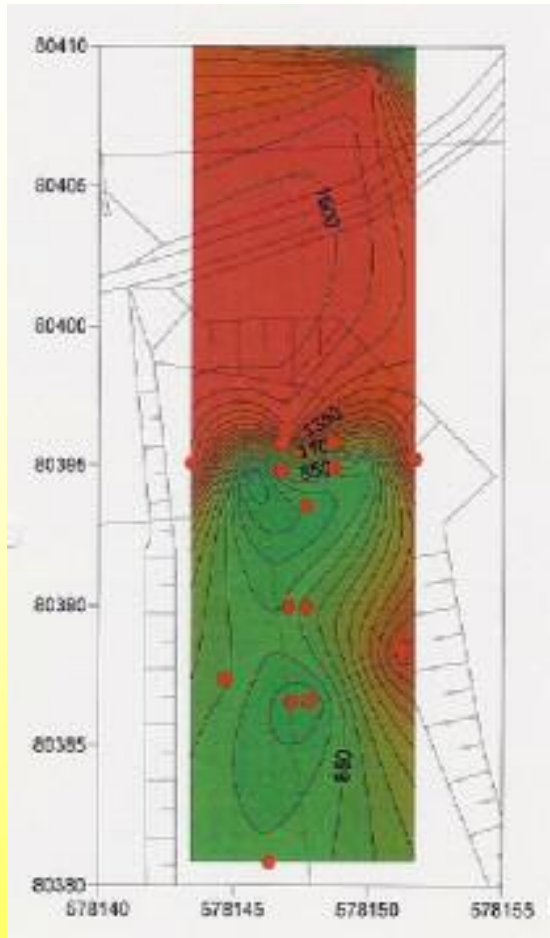


### Long-term performance of the PRB in respect of removing of the uranium from groundwater

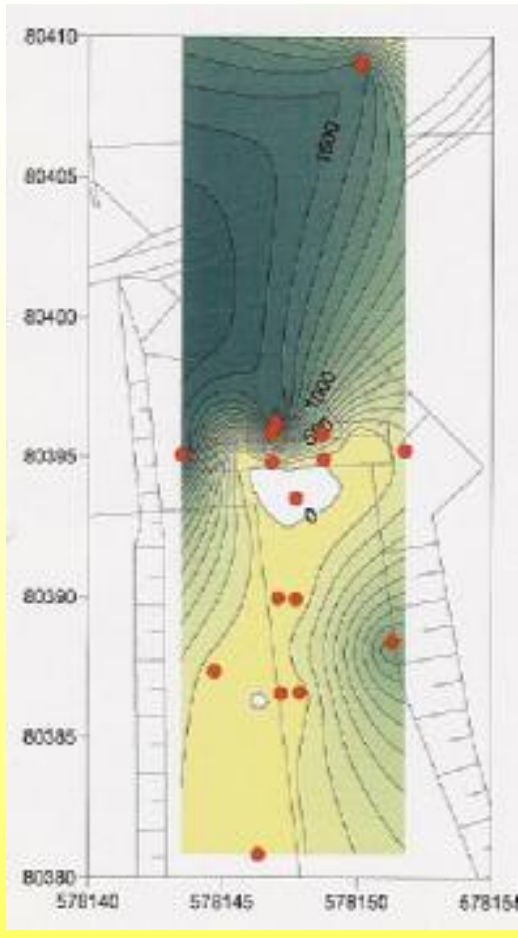


**Uranium concentration and total dissolved solids (TDS) U/S and in a D/S monitoring well near the PRB**

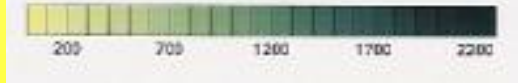




Specific electric conductivity,  $\mu\text{S/cm}$



U  
( $\mu\text{g/l}$ )



Monitoring wells

# Uranium concentration and electric conductivity in groundwater



## Life span calculation (example)

Criterion: loss of porosity due to precipitation

Fe: electron donor > formation of  $\text{OH}^-$  > increase in pH

Decrease in solubility of carbonates

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

Flow rate  $750 \text{ m}^3/\text{y}$  > 525 kg/y precipitate ( $2.75 \text{ g/cm}^3$ ) >  $0.192 \text{ m}^3/\text{y}$  precipitate

PRB volume:  $6.8 \text{ m} \times 1.5 \text{ m} \times 3.8 \text{ m} = 38.8 \text{ m}^3$

Pore volume:  $38.8 \times 0.3 = 11.6 \text{ m}^3$

$11.6 \text{ m}^3 / 0.192 \text{ m}^3/\text{y} = 60 \text{ years}$

## **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/>**

