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Mainstreams and Lessons Learned at Nine German PRB Sites Over Five Years – An Interim Report

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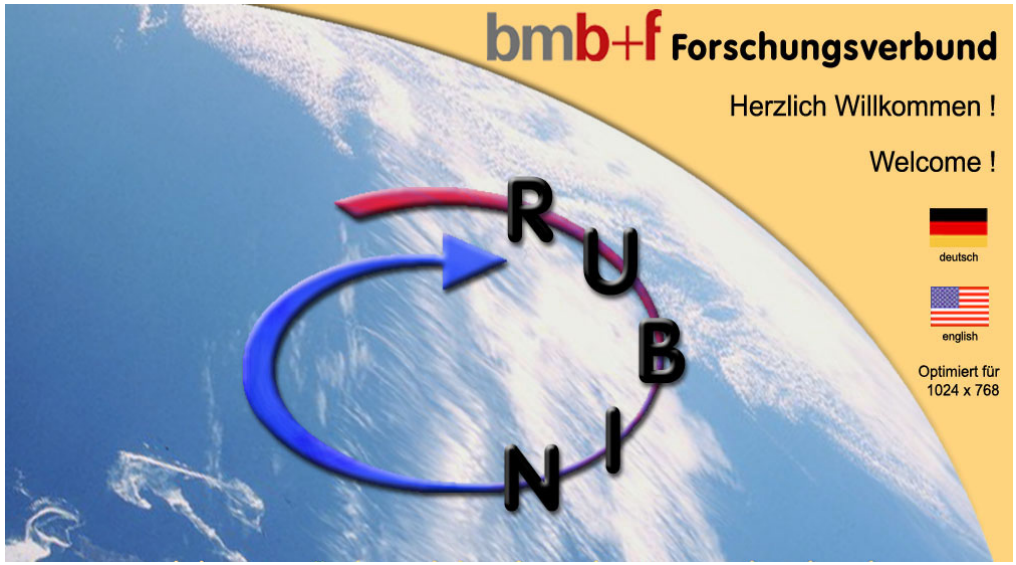


PRBs in Germany

- **Two R&D networks**
  (funded by the Federal Government)

  <u>“SAFIRA“</u> (6 Mio $)

  Basic R&D, semi-technical scale

  reactive materials for cVOCs/chlorobenzenes/PAHs

  <u>“RUBIN“ (4-5 Mio $)</u>

  R&D *and* technical implementation of PRBs at different sites across the country

- **Public funds spent ≈ 14 Mio $**
- **Different private sites ≈ 6 Mio $**

PRBs in Germany (2)

Start up	Site	Contaminants	Status	Construction	Reactor	Total Costs
May 98	**Edenkoben**, industrial plant, supplier for car manufacturers	cVOCs (cDCE, 1,1,1-TCA,TCE, PCE)	Pilot-scale	F&G, length 30 m, depth 15 m, 1 gate	ZVI (filings), 2 chamber system, vertical flow	350,000 €
Feb. 01			Full-scale private	F&G, length 440 m, depth 15 m, 6 gates		1,750,000 €
June 98	**Rheine**, former dry cleaner´s	cVOCs (PCE, TCE, cDCE)	Pilot-scale RUBIN project*	CRB, overlapping boreholes diameter 0,9 m, length 22.5 m, depth 6 m	Granular ZVI an iron sponge	170,000 €
Oct. 98	**Tübingen**, former industrial site	cVOCs (TCE, cDCE, MCE)	Full-scale, RUBIN project*	F&G, length 200 m, depth 10 m, 3 gates	ZVI, bore-holes (diameter 0.9-1.8 m), horizontal flow	600,000 €
Oct. 99	**Bitterfeld**, chemical industry	Chlorobenzenes, CHC, phenols	Pilot-scale, R&D only SAFIRA	5 shafts equipped with steel reactors, depth 24 m	GAC, ZVI, ORC, nutrients	6,000,000 €
Jan. 00	**Reichenbach (Fils)**, metal-processing industry	cVOCs (PCE, TCE, cDCE)	Full-scale Private site	CRB, boreholes, two rows	Activated carbon, specially conditioned	200,000 €

PRBs in Germany (3)

Start up	Site	Contaminants	Status	Construction	Reactor	Total Costs
Jan. 01	**Karlsruhe**, former gas works plant	PAHs, VC	Full-scale, private site	F&G, 8 gates	GAC	4,000,000 €
Aug. 01	**Denkendorf**, trading estate	cVOCs (PCE, TCE, 1,1,1-TCA, cDCE, VC)	Full-scale	Drain-and-gate, 1 gate designed as a shaft	Activated carbon	Not available
Sep. 01		mainly VC is targeted	Small pilot-scale, treatability/ feasibility study, RUBIN project	Columns (column experiments using a bypass stream diverted in front of the entry of the fullscale reactor)	Palladium on zeolites	120,000 €
Sep. 01	**Bernau**, former dry cleaner´s (military site)	cVOCs (TCE), very high concentrations in 2 aquifers	Pilot-Scale, mainly R&D, RUBIN project	Special F&G design capturing 2 contaminated aquifers, closed funnel, partly operated actively (pumping)	Granular ZVI	1,500,000 €
Jan. 02	**Oberursel**, industry	cVOCs	Full-scale, private	F&G	Granular ZVI	Not available

PRBs in Germany (4)

Start up	Site	Contaminants	Status	Construction	Reactor	Total Costs
May 2002 (set-up 2003)	**Offenbach**	PAHs, BTEX	Full-scale, RUBIN project	F&G	Microbiology, GAC	Not available yet
May 2002	**Wiesbaden**	Arsenic	R&D; later full scale, RUBIN project	Reactive zone plus F&G	Sulphide emitting/ generating phases (microbiology), granular ZVI, iron oxides/hydoxides	Not available yet

* For extended monitoring only; PRB had been set up before RUBIN was launched

Conclusions

- 2003: Germany – 9 PRBs, 4 planned (Offenbach, Wiesbaden, Wörth, Stuttgart);
PRBs with “directed GW flow“ prevail (7 in total, F&G, “drain-and-gate“ and modified F&G systems (partly applying pumping))
- Reactors/gates often installed/accessible nearby the surface – Germans “love control“?!
- Iron (ZVI) and activated carbon (AC): preferred reactive materials

- The need for new materials to meet the removal of complex pollutant mixtures is an important issue; novel media and combinations of known materials are therefore intensively investigated
  - Ceramic Sorbents (Alkaline/Earth Alkaline Oxides)
  - Zeolites (natural, synthetic, modified)
  - Lignite, peat alone/in combination with iron
  - ZVI and AC, AC and microbiology
  - ZVI and ORC
  - Palladium (Pd) on zeolite or embedded in silicone polymer

- Some German PRBs do not meet remediation goals (e.g., 10 µg/L cVOCs) due to several reasons (single or in combination)
  - ➢ GW by-passes and/or over-/underflows the PRB
  - ➢ The iron bed has been clogged by precipitations (carbonates, biofouling)
  - ➢ There are preferential flow paths thru the iron zone due to heterogeneously settled iron after installing the wall, especially when iron/pea gravel mixtures were employed
  - ➢ Potential failures during the installation period (damages at the construction, monitoring wells etc)

- Iron sponge performs better than iron granules regarding the dehalogenation of PCE or TCE, probably due to its special composition/production process
- If hydrogen – produced by the abiotic corrosion of iron – is not consumed by microbes or safely released by gas pipes, a serious pressure build-up can occur, causing a blocking of the iron bed
- Some German PRBs are facing *special* hydraulic problems (after 2-3 years of operation) due to unexpectedly risen GW levels

RUBIN

- Palladium on solid supports or embedded in a three-dimensional, molecular matrix such as silicone polymer may be poisoned by GW ingredients swiftly, too, like „conventional“ Pd!

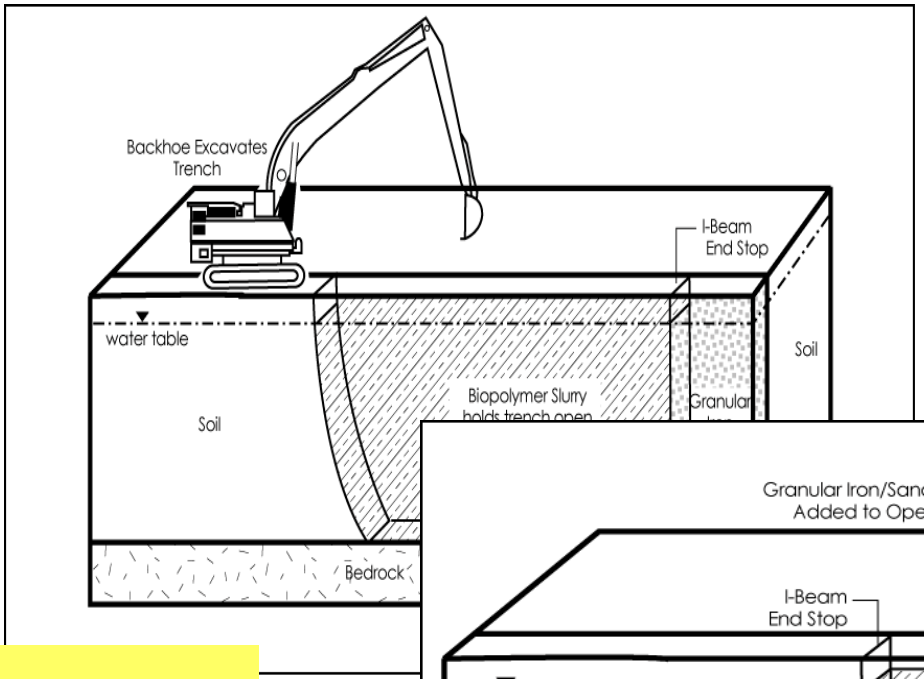
However, stripping the contaminated GW and dehalogenating the contaminants in the gaseous phase at 200-300 °C using Pd/zeolite is a powerful tool, which can be deployed efficiently

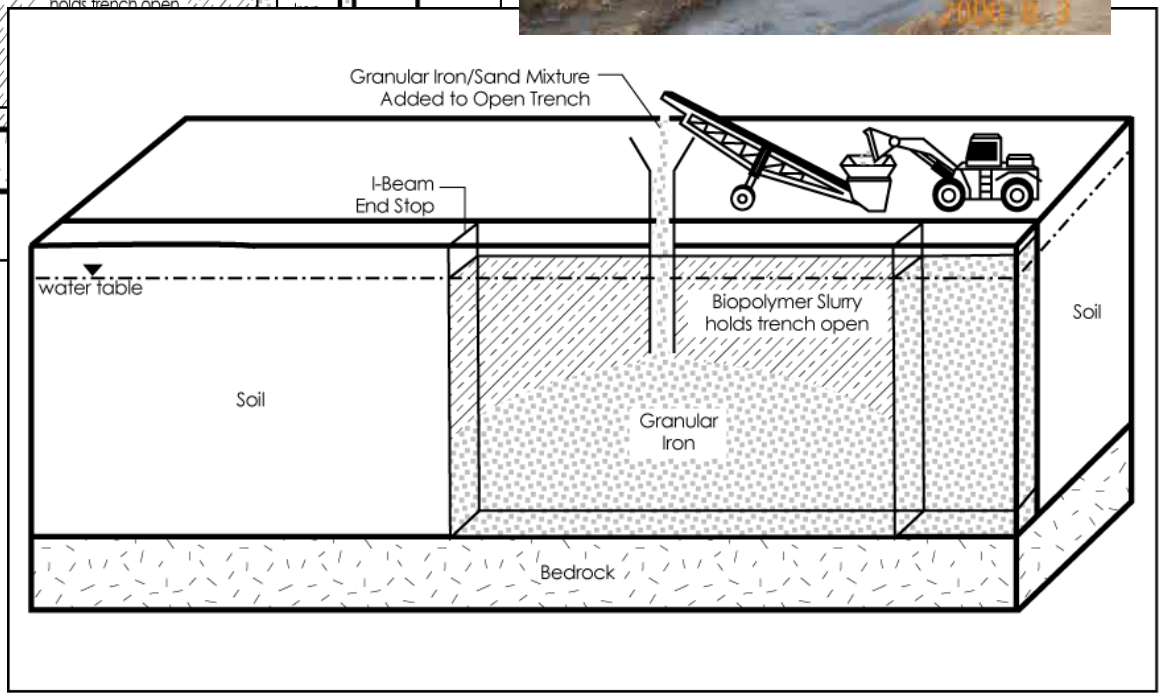
No *passive, in-situ* feature any longer, but successful pilot testing in several cases already done!

PRB – International Development

- Apparent tendency (mainly in the U.S.):
  - ***Less*** funnel-and-gate systems (F&G)
  - ***More*** continuous reactive barriers (CRB) (e.g., Somersworth Superfund Site)
  - Driven by: 1. cost
    2. hydraulic issues
  - ***Significantly low number*** of systems designed/equipped with devices for an enhanced control/controllability/with a strongly directed GW flow: GeoSyphon™, shafts equipped with inserted reactors, „trench-and-gate“ – however, *systems seem to work perfectly!*

Somersworth Sanitary Landfill, 2000, CRB, Fe/Biopolymer Trench





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