PRB – established or innovative?

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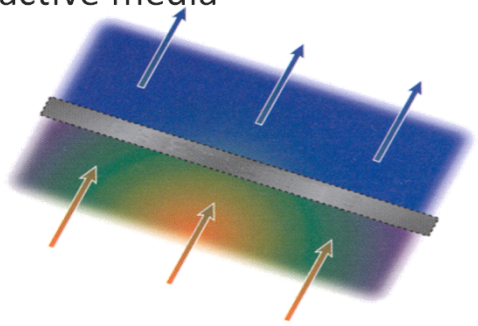
This Presentation

- What is a permeable reactive barrier?
- UK Guidance on use of a PRB
- Technology demonstration in the UK
- Is PRB still an innovative (= uncertain) solution?
  - Publication track record
  - Long-term performance reviews
- Conclusions

Permeable reactive barrier

Reactive zone installed across a groundwater plume to remove or degrade dissolved contaminants as the plume passes through

- Suitable for a wide range of contaminants
- Can use a range of reactive media
- Configuration
- Longevity?
- Green/sustainable?
- Cost effective?



UK guidance

Environment Agency (2002) 'Guidance on the use of permeable reactive barriers for remediating contaminated groundwater'

- Established use in the UK
- Provides staged "how to" guidance

EA/The Queen's University, Belfast 'Guidance on treatability studies for permeable reactive barriers'

- Provides detailed "how to" guidance
- Technical appendices
- Supported by literature review
- Contact me if interested in more info!

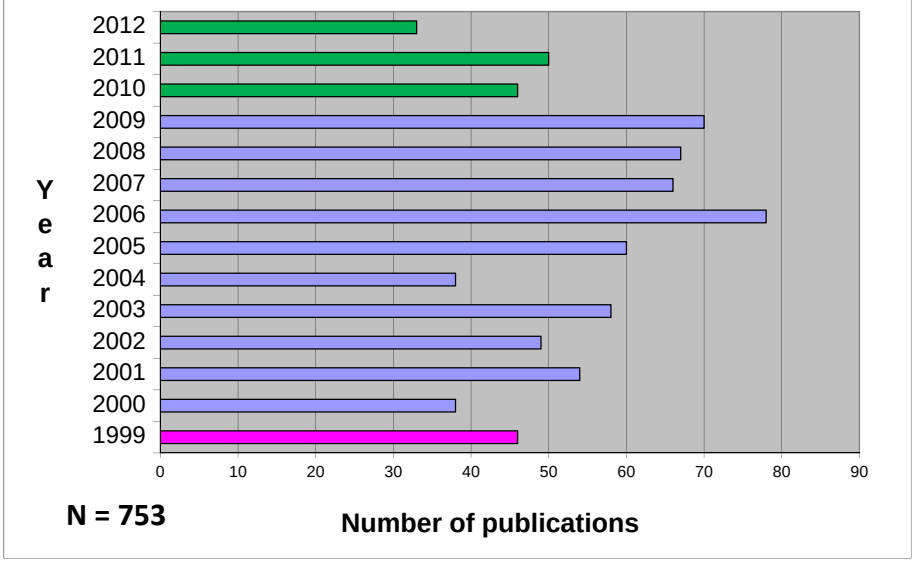
UK Technology Demonstration

TDP 03 (2001) N. Ireland Full-scale iron funnel & gate to treat chlorinated ethenes	TDP 17 (2008) SW England Full-scale sequential biobarrier funnel & gate to treat gasworks plume
CSB 03 (2005) N. Ireland Pilot sequential biobarrier funnel & gate to treat gasworks plume	TDP 20 (2009) NW England Full-scale iron funnel & gate to treat CS_2
TDP 13 (2006) NE. England Full-scale continuous limestone & compost barrier to treat acid rock drainage	TDP 21 (draft) N. Ireland Pilot continuous mulch & gravel biobarrier to treat nitrate. Project completed
CSB 08 (2007) English Midlands Full scale continuous iron barrier to treat CS_2. Communication issues reported	Next TDP?

UK Technology Demonstration

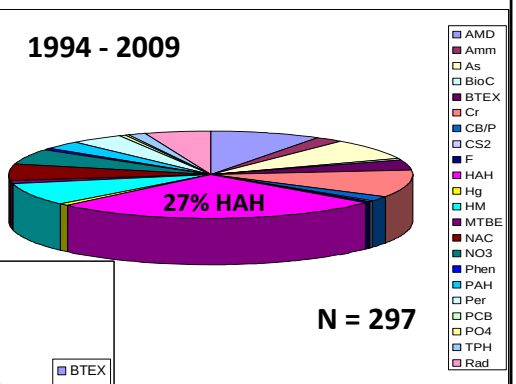
- **TDP 03 Monkstown ZVI PRB**
  - Performance review published 2010
  - > 10 year service
  - Phillips et al. EST 44 (10), 3861-3869
- **TDP 13 Shilbottle compost & limestone PRB**
  - Performance review published 2010
  - 5 year service
  - Caraballo et al. Am. Mineral. 95 (11-12), 1642-1649

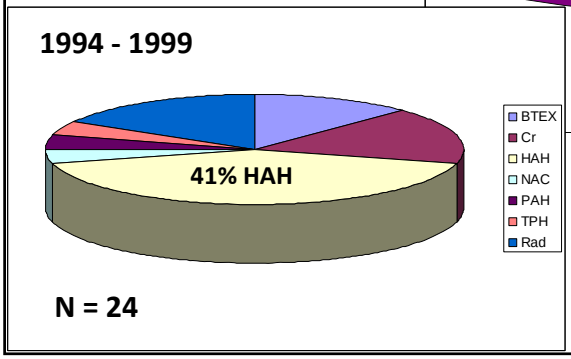
PRB status? Literature review



Contaminants treated in the lab?

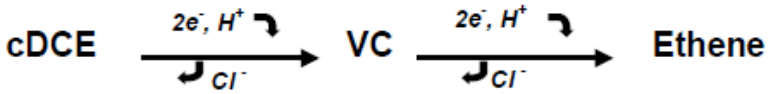
Acid mine/rock drainage, arsenic, BTEX, chromium, halogenated aliphatic hydrocarbons, heavy metals, nitroaromatic compounds, nitrate, perchlorate, radionuclides





Destructive processes

- **Biotic degradation**
  - Anaerobic degradation (perchlorate, nitrate, sulphate)
  - Aerobic degradation of BTEX/MTBE
- **Abiotic degradation**
  - Reductive dechlorination (hydrogenolysis) of chlorinated aliphatic hydrocarbons



  - Reduction of TNT, RDX

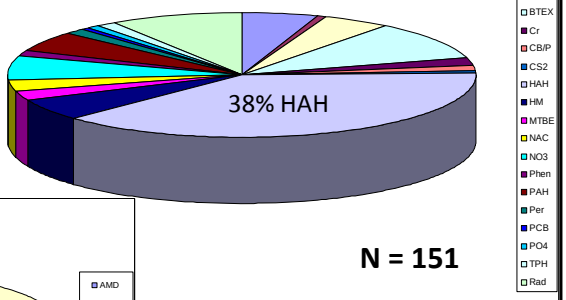
Non-destructive processes

- **Sorption**
  - Adsorption of As to ZVI/slag
  - Adsorption of PAH to GAC
- **Ion exchange**
  - Sr^{90} to zeolite (clinoptilolite)
  - Pb to (hydroxy)apatite
- **Chemical transformation & precipitation**
  - Reduction of Cr(VI) to Cr(III)

Contaminants treated in the field?

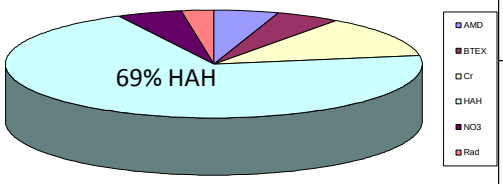
Acid mine/rock drainage, arsenic, BTEX, halogenated aliphatic hydrocarbons, heavy metals, PAH, nitrate, radionuclides

1994 - 2009



N = 151

1994 - 1999

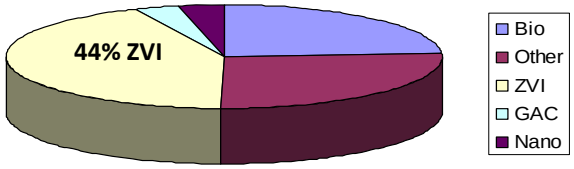


N = 40

Reactive materials used?

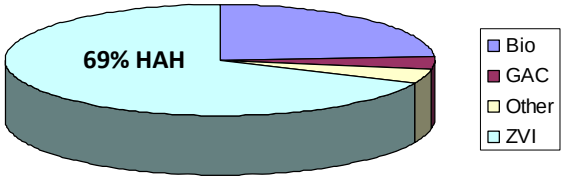
Bio = biological systems
ZVI = zero valent iron (Fe(0))
GAC = granular activated carbon
Nano = nanoparticles (undifferentiated)

Lab 1994 - 2009



N = 297

Field 1994 - 2009



N = 141

Other = mainly ion exchange and adsorption media, including zeolites, hydroxyapitite, coal fly ash, slags, scrap steel, iron compounds, shredded tyres, coal/peat

Field evidence - summary

- Estimated >(>?)200 PRBs installed worldwide
- Papers related to at least 148 installed up to 2007
- Antarctica, Australia, Belgium, Canada, Czech Rep., Denmark, Germany, Hungary, Italy, Japan, Switzerland, UK
- But the majority of published sites are in the USA
- Performance review 10 years (ITRC 2005)

  "thorough site characterisation is the best insurance against future PRB failure"
- Performance review 15 years (ITRC 2011)

  "15 years later, hundreds of applications of PRBs composed of many different reactive media for many different contaminants have been successfully deployed"

Long-term performance?

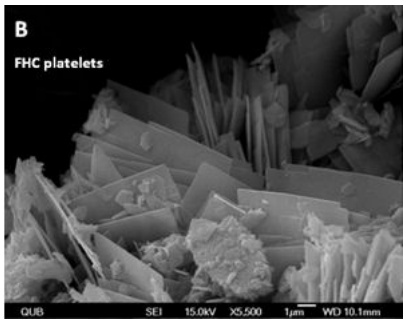
- Review papers/documents
  - USEPA (2003) 'Capstone' report
    - 5 year detailed performance review for 2 iron PRBs
    - Porosity loss estimate > 10 year life
  - Henderson & Demond (2007)
    - Failure fault tree analysis
    - Sufficient data available for only 40 iron PRBs
    - Column studies tend to under-estimate performance
    - Failure mainly due to design error (hydraulic)
  - Performance generally exceeds initial expectations

Monkstown PRB

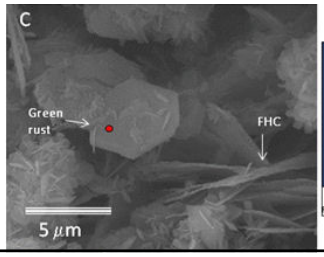
- Funnel & gate, built 1995
- Core sampling in 2006
  - Mineralogy
  - Microbial community
  - Multiple tracer test
  - Groundwater monitoring data review
- Collaboration QUB, Golder, VITO
- Publications
  - Phillips et al. EST 44 (2010)
  - Van Nooten et al. EST 44 (2010)

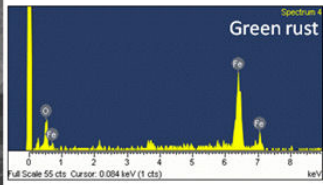
Monkstown PRB – summary findings

- Corrosion of ZVI in upper 25 cm
- Precipitation of carbonates, Fe (hydr)oxides, Fe sulphides, green rust
- Microbial community (DNB, SRB, methanogens)
- Reduced effective porosity & preferential pathways
- Reduced flux
- Remains active
- FeS, green rust and/or bugs?



Thanks to Debra Phillips, QUB for the use of photomicrographs





Long-term performance summary

- Most long-term performance data available from iron PRB
- Many barriers performing well, but long-term performance still not well-understood (prediction?)
- 'Failure' generally related to site characterisation and hydraulic design rather than treatment process
- Iron PRBs expected life of 10-30 years
  - Significantly exceeding original expectations (5-6 yrs)
- Likely shorter life for biobarriers: C-limited, hydraulics
  - Potential +ve effects downgradient (dissolved carbon)

Conclusions?

- Impressive body of literature available on PRB technologies from both lab and field studies
- Dominantly, but not exclusively iron - chlorinated solvent systems
- Increased range of reactive media (incl. waste-derived) and contaminants
- Long-term performance studies (USA, Germany, UK) and reviews leading to improved design guidance
- PRB technology – well-established but continues to innovate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Thank you for listening
Any questions?
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