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Improving realism and reducing pessimisms in the safety case for geological disposal of ILW

Microbiological FEPs important for ILW

Joe Small

Microbiology FEPs – how represented?

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- Safety cases for geological disposal of ILW recognise that microbial processes may occur in the waste and the barrier system
  - Mostly, no explicit account is taken of the effects of microbes in performance assessment (PA)
- Different treatments/cases:
  - Detailed microbiological processes may be subsumed/simplified within other chemical FEPs
  - Processes have been ignored (where conservative) due to uncertainties or data requirements
  - Some microbiological processes have not been considered because of incorrect assumptions / lack of research

Subsumed/Simplified representation of FEPs

- Microbial effects on speciation, solubility, sorption of redox sensitive radionuclides (e.g. Se, Tc, U)
  - Microbial processes mediate processes governed by thermodynamics
  - Representation by equilibrium models is considered adequate
- Biogeochemical research underpins this simplified approach
  - e.g. examining mechanisms of U and Tc reduction

Conservative representation of Microbiological FEPs

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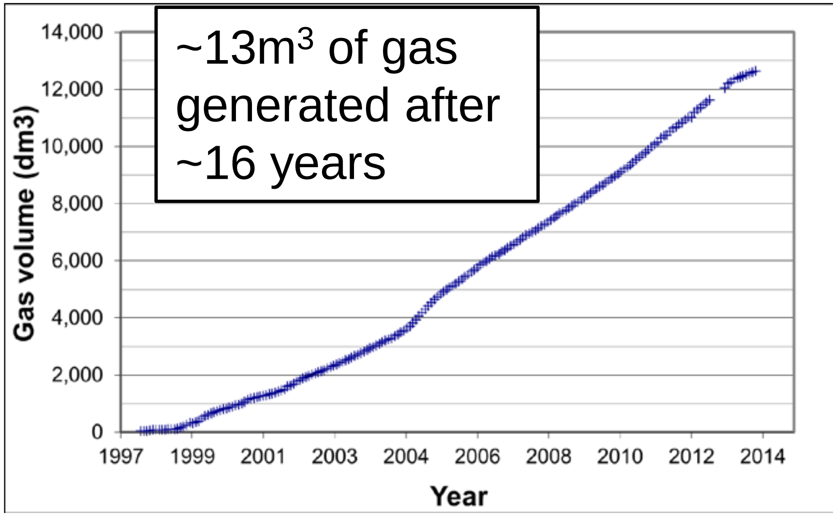
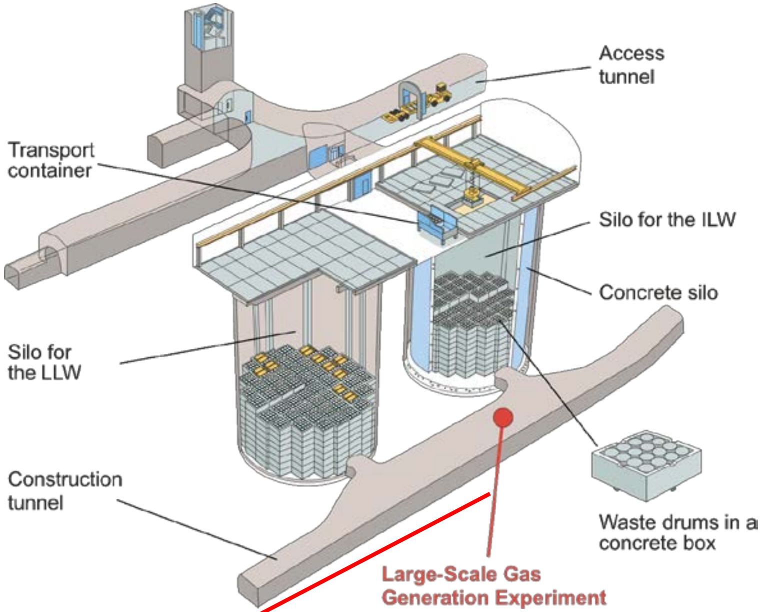
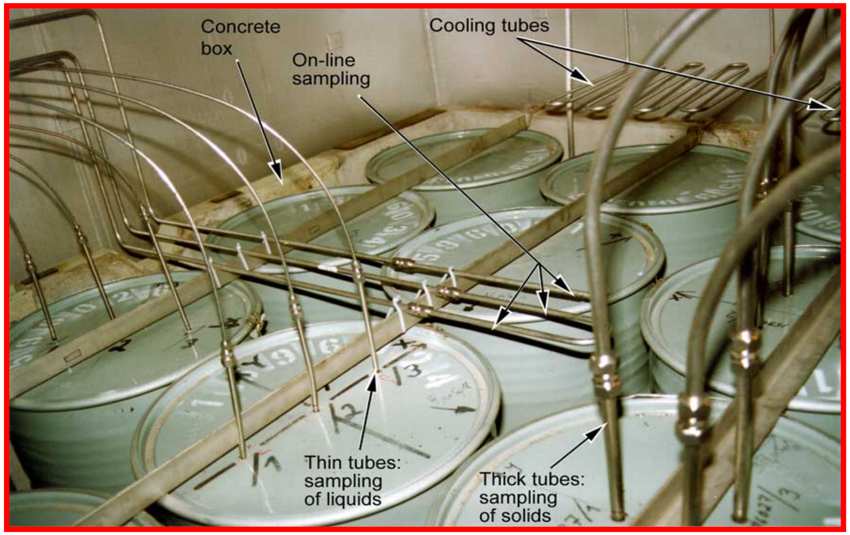
- Effects of alkaline cellulose degradation products (CDPs)
  - Conservative approach ignores biodegradation of CDPs
  - Recent research shows microbial activity at pH 11 (Rizoulis *et al*, 2012) and microbial utilisation of CDPs at pH10 (Bassil *et al*, 2014)
- Potential to reduce significance of CDP / radionuclide transport FEPs
- However, are there other FEPs related to alkaline cellulose biodegradation?

Gas generation experiment, VLJ Repository, Olkiluoto

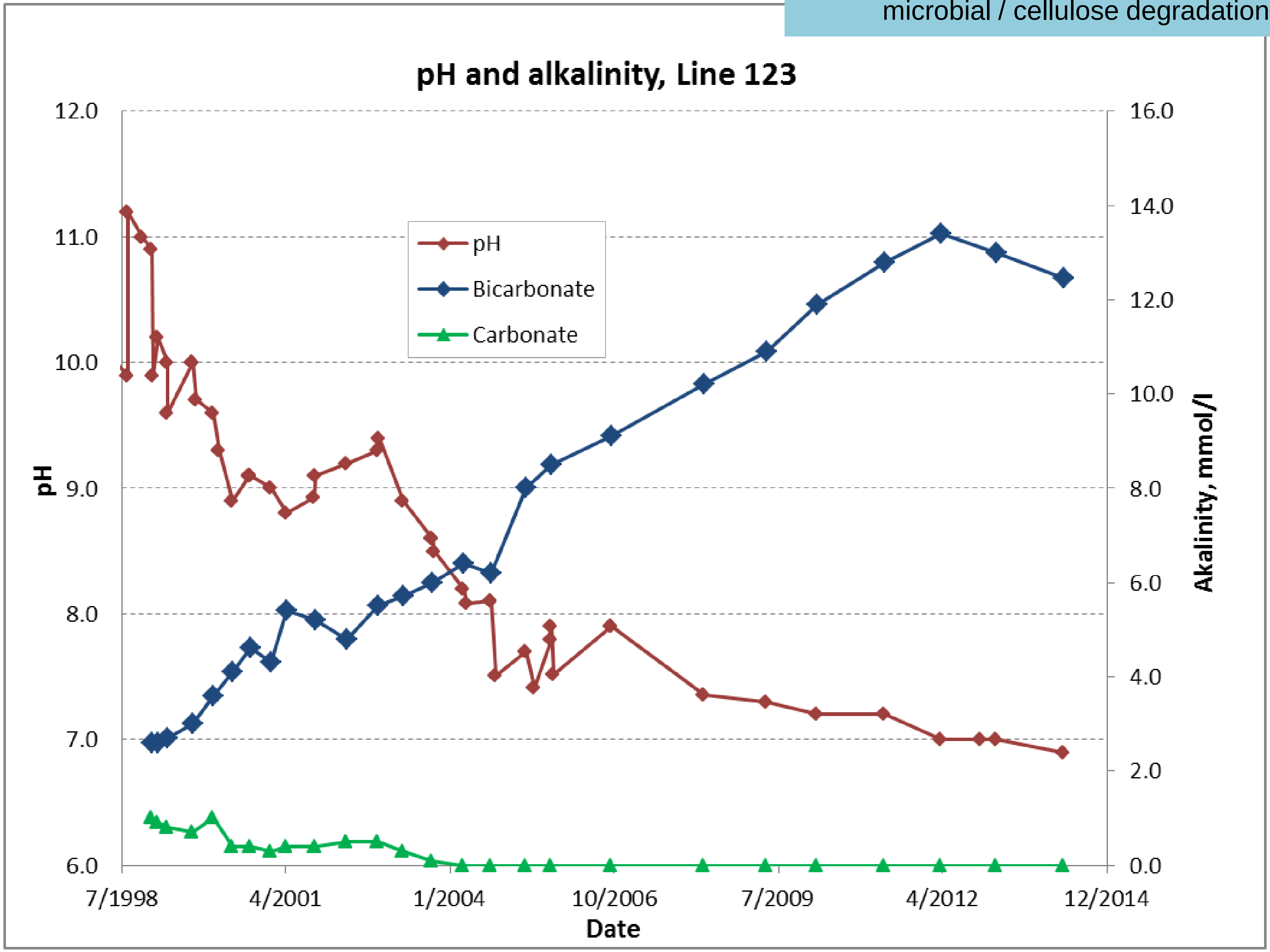






Celluose biodegradation - effect on pH and bicarbonate

- The VLJ repository design has a small pH buffering capacity
  - Small amount of concrete
  - High water content
- However, it improves understanding of microbial / cellulose degradation FEPs



Microbial cellulose degradation - further effects

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- Lower pH – effects on radionuclide sorption and solubility
- Aqueous carbonate may act as a complexing ligand e.g. for U(IV)
- Carbonation of cement may
  - Affect flow properties of porous cement backfill
  - Armour/isolate backfill, further reducing pH buffering

Gas FEPs - treatment in the safety case

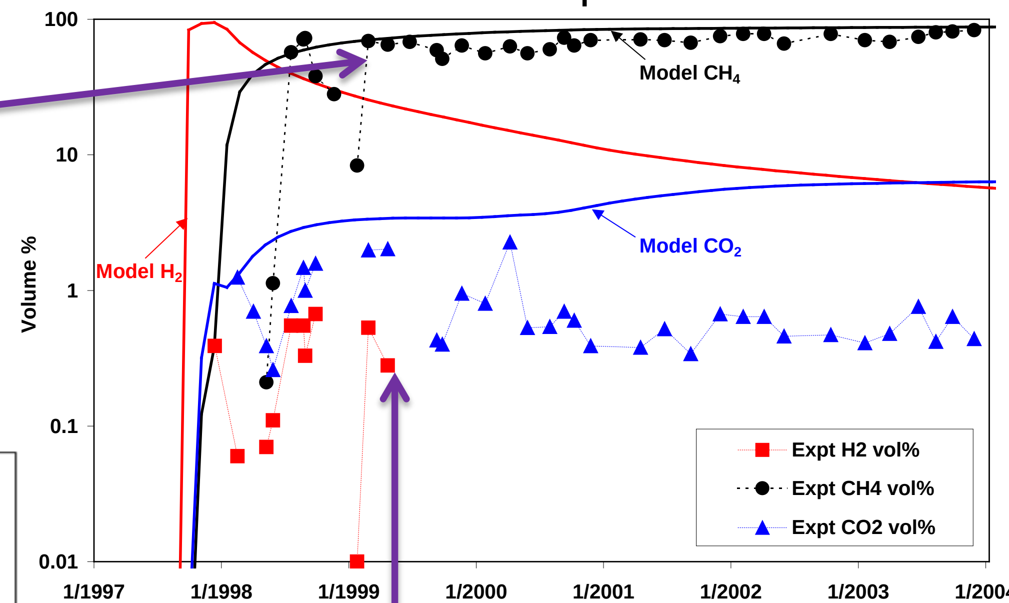
- Generally conservative with respect to CH_4 generation
  - Microbial processes are considered!
  - Assumptions/models vary between WMOs
  - pH limitation, wasteform/pH heterogeneity ?
- H_2 utilisation as electron donor ignored
  - Conservative with respect to H_2 generation by anaerobic corrosion and radiolysis
  - Research now started
- Inconsistent consideration of H_2 in methanogenesis
  - $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$

TVO gas experiment- very limited H_2 production

Sulphate reduction is a key process for ILW

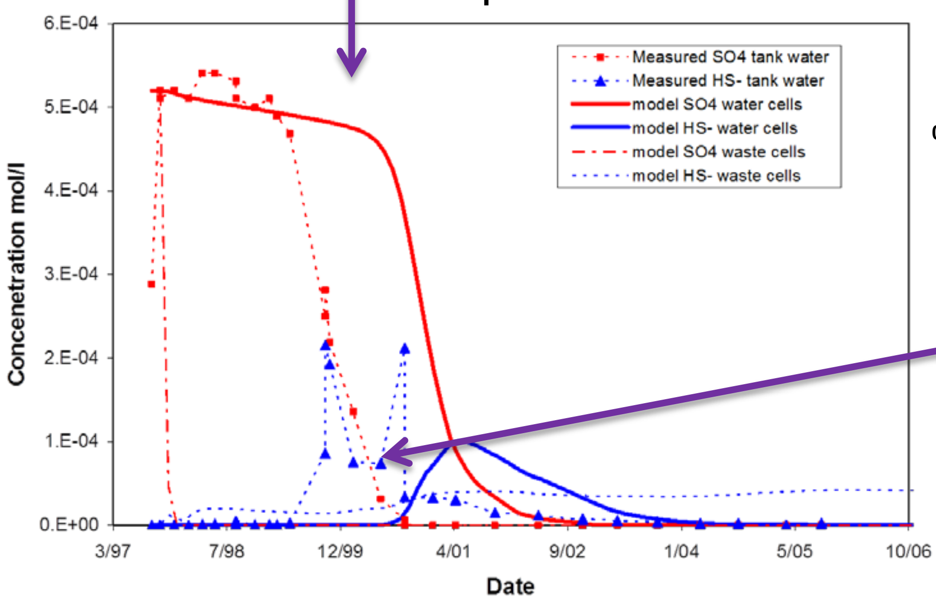
- Outcompetes (limits) methanogenesis
- Main sink for H_2

Gas composition



Methanogenesis after sulphate reduction

Sulphate reduction



No H_2 after sulphate reduction established ~year 1999/2000

Mont Terri URL – H_2 studies

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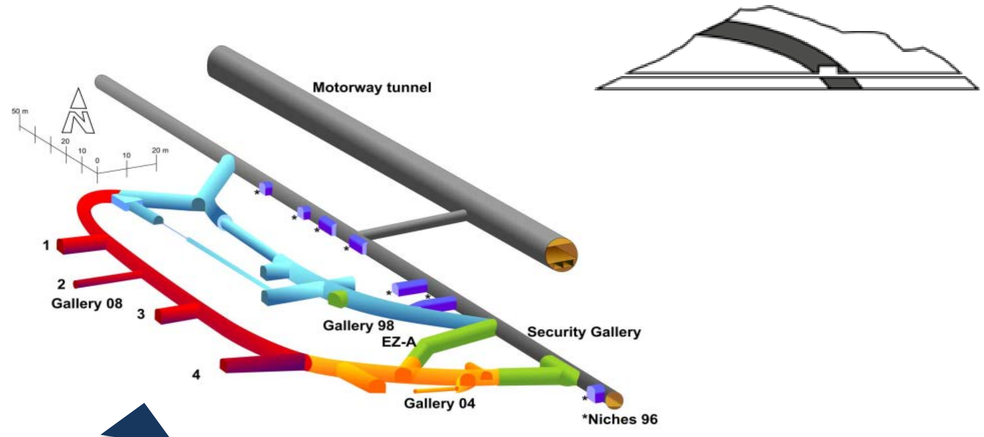

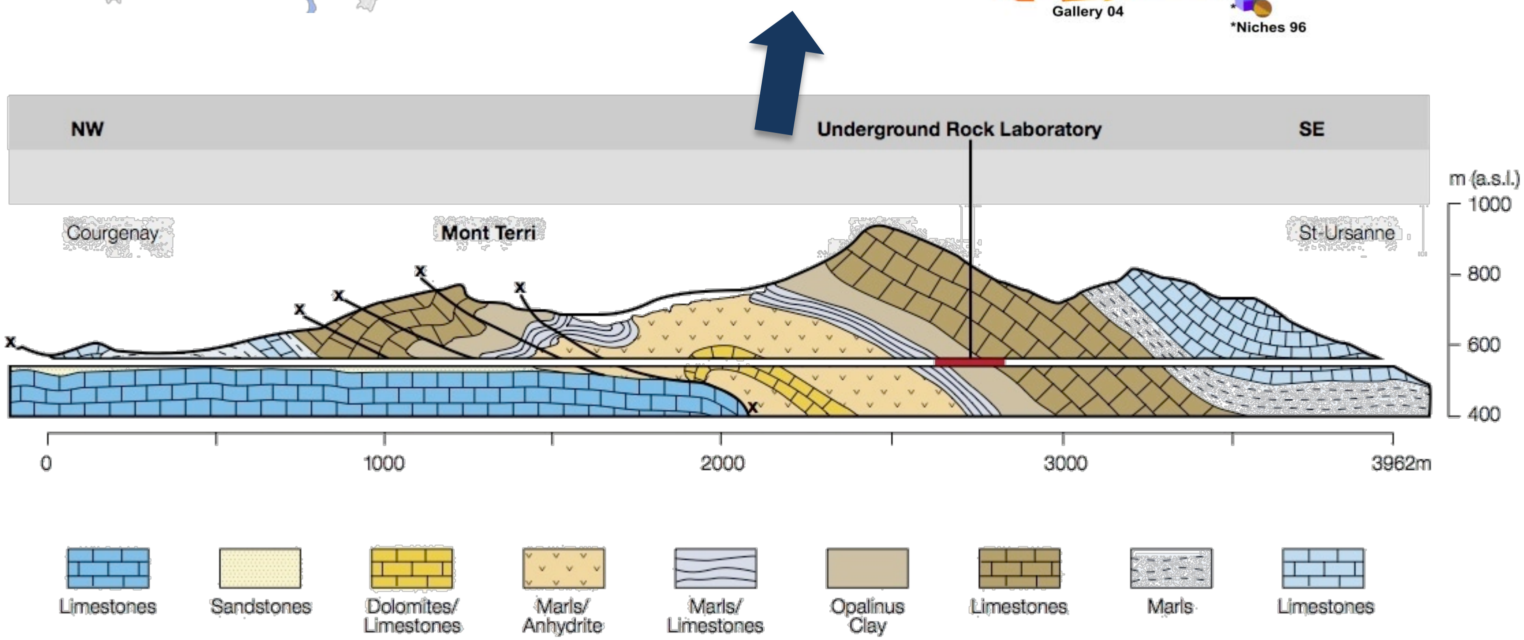

Hydrogen Transfer (HT) Experiment
Agnes Vinsot *et al*, 2014

Clays in Natural and Engineered Barriers for Radioactive Waste Confinement.
Geological Society, London, Special Publications, **400**

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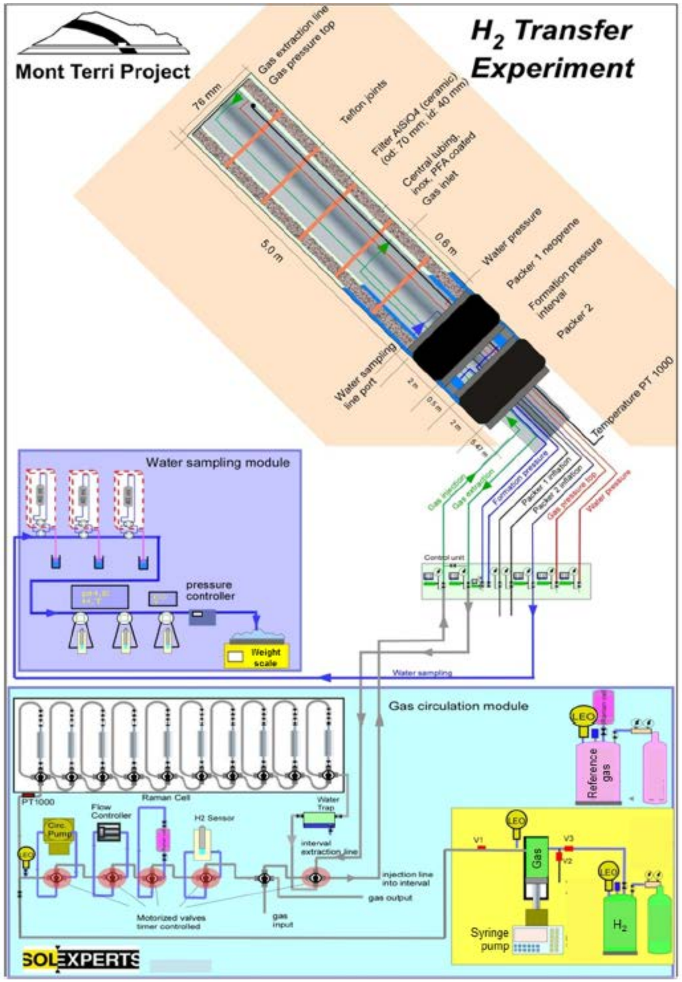


Loss of H_2 due to reaction with Fe(III) or SO_4^2 ?
(Vinsot *et al*)

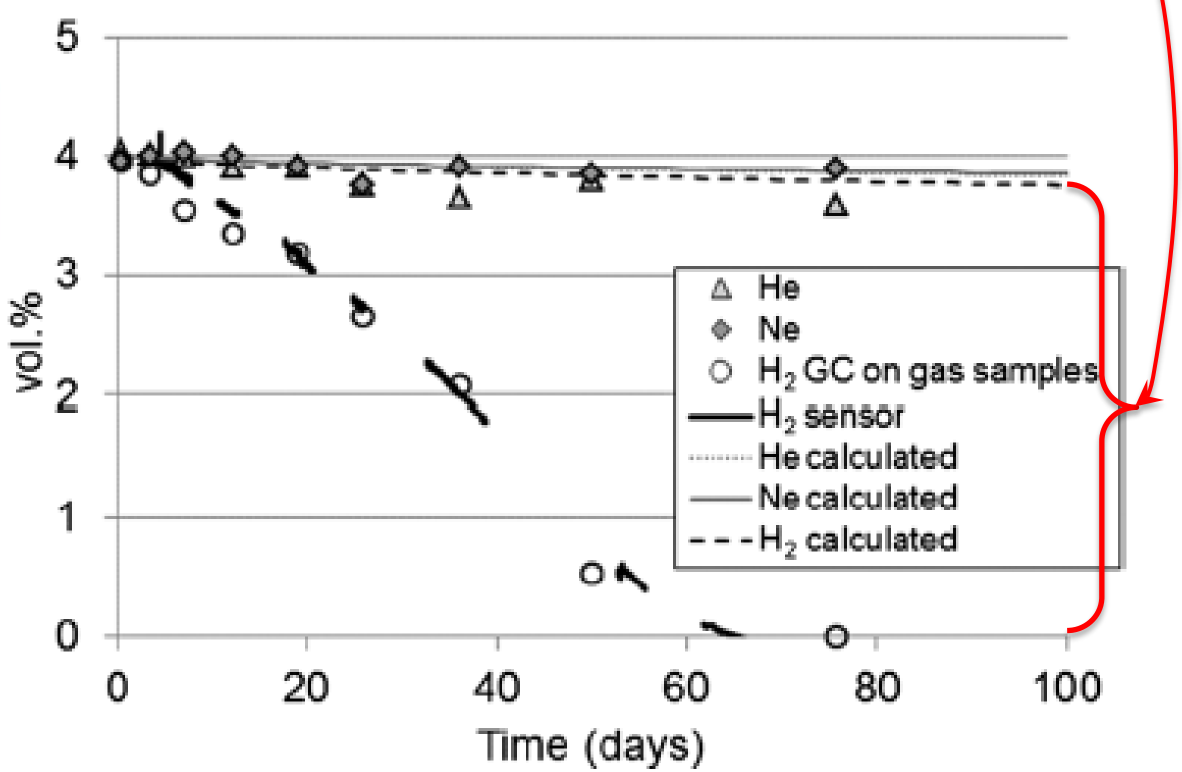
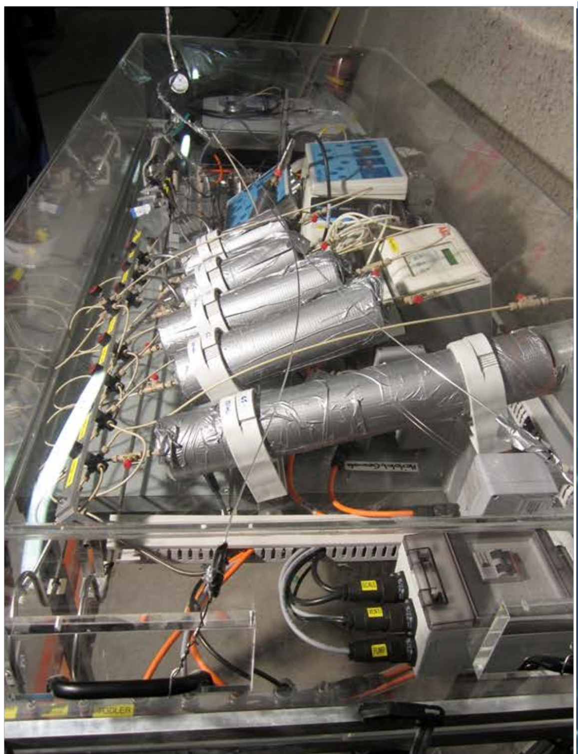


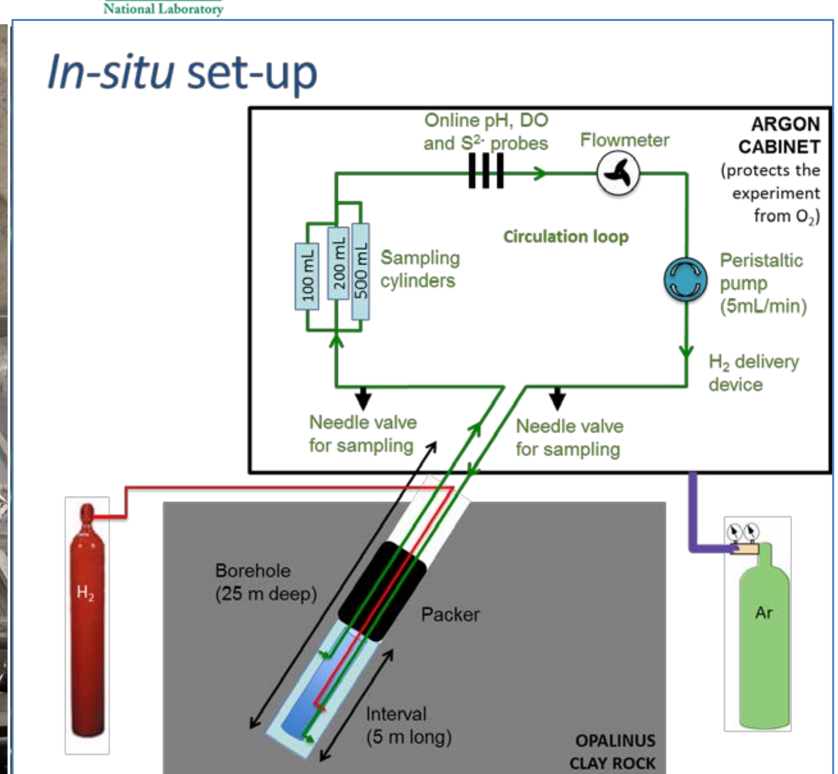
Fig. 9. Observed and calculated evolution of hydrogen, helium and neon over 100 days after the first hydrogen injection.

Microbial Analysis (MA) experiment
Slides from Rizlan Bernier-Latmani

In situ microbial oxidation of H_2

Alexandre Bagnoud, Rizlan Bernier-Latmani [EPFL]
Olivier Leupin, Bernhard Schwyn [NAGRA]
Ino deBruijn, Anders Andersson [SciLifeLab, KTH]
Karuna Chourey, Robert Hettich [ORNL]





H_2 consumption chemistry

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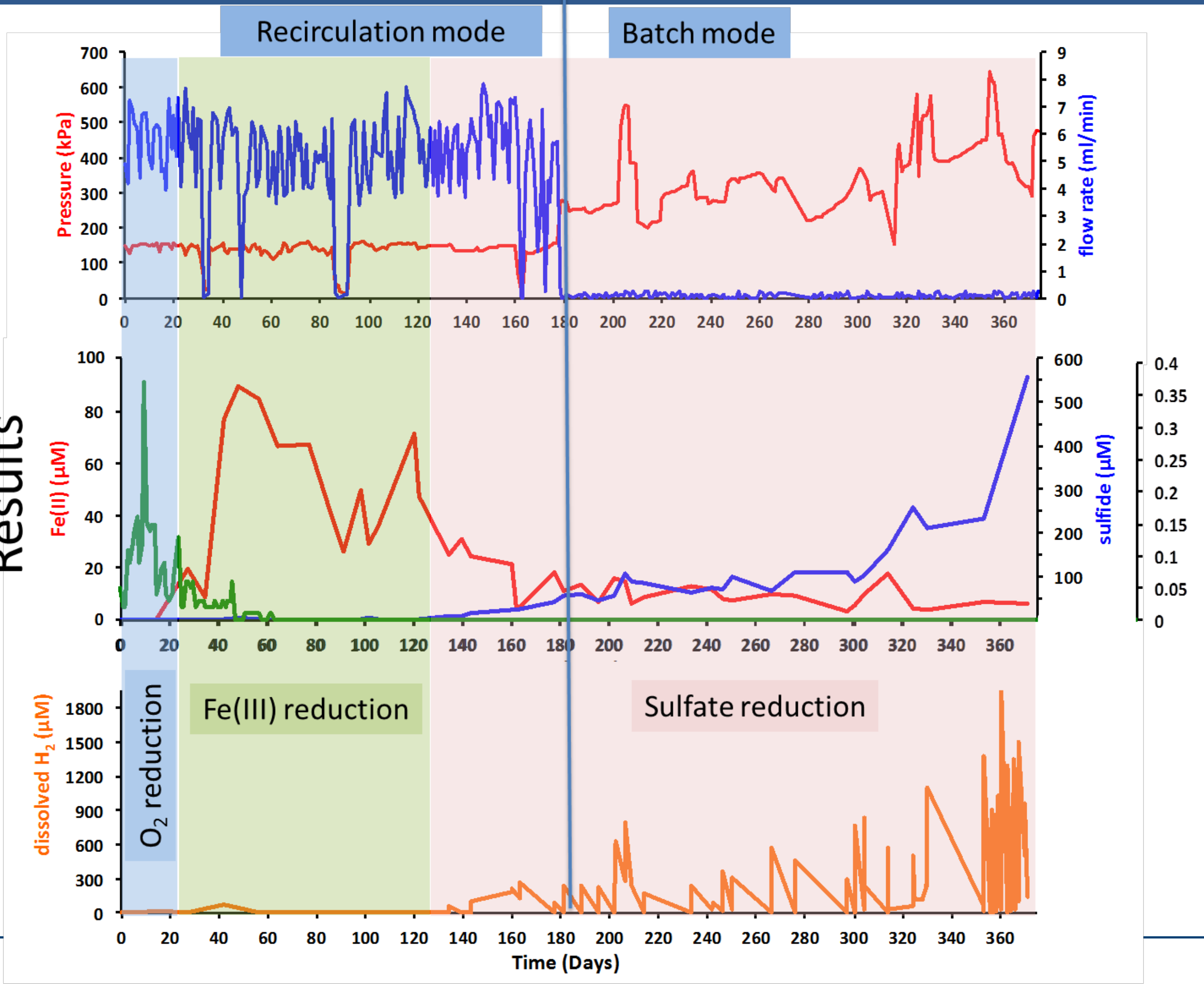
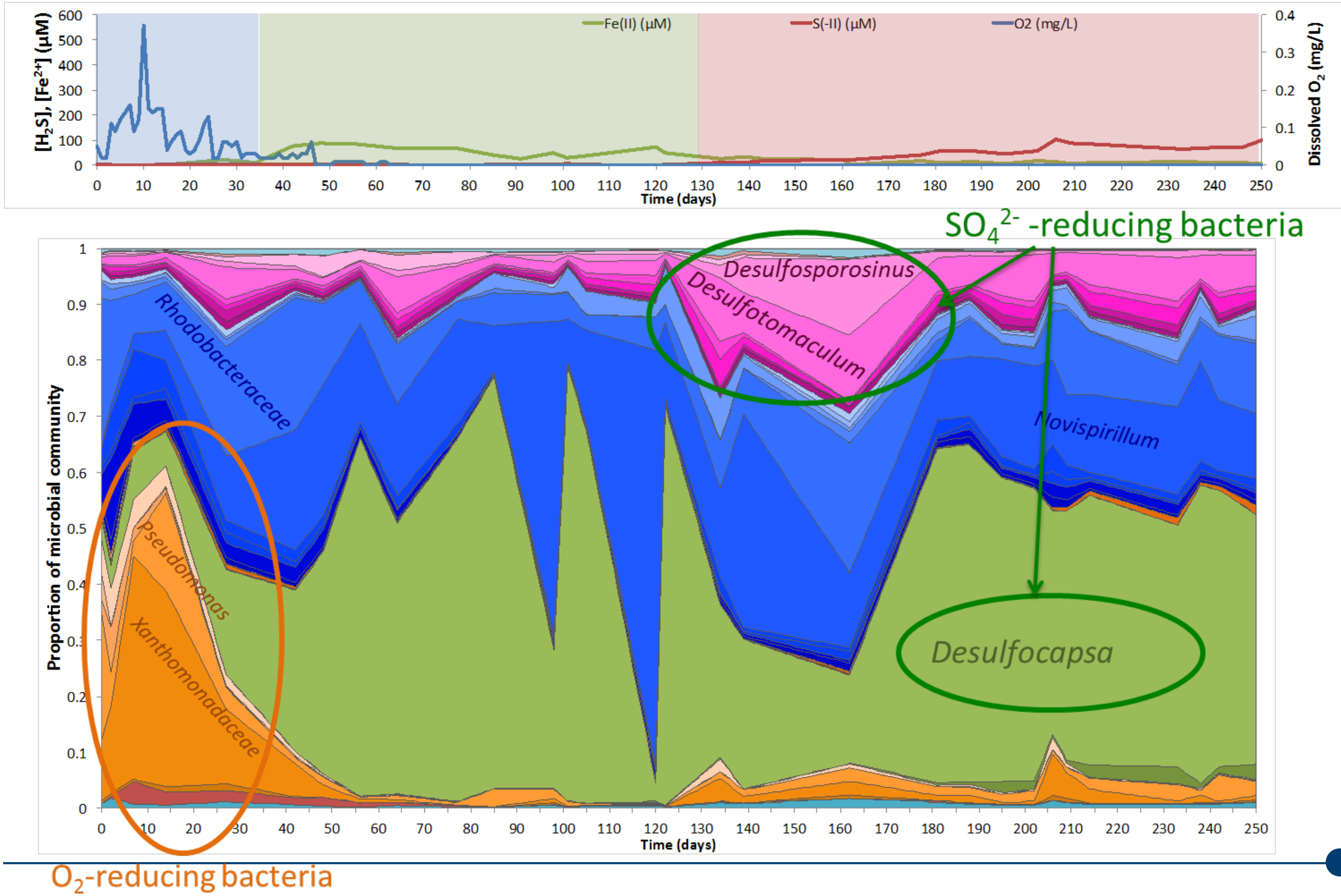
Results



Microbial analysis



Microbial ILW FEP Summary (groundwater)

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- Influence on radionuclide valency / mobility
  - No specific representation needed?
  - Justified by underpinning biogeochemical research
  - More detailed FEP representation unlikely to have significant impact on safety analysis
- Cellulose degradation
  - Scope to reduce radionuclide mobility though degradation of CDPs & other organic complexants
  - Microbial effects on pH & carbonate – complex FEP interactions - could enhance radionuclide mobility
- Other organic polymers
  - Degradation rate and products (including gases) uncertain
  - Combined effects of radiolysis and biodegradation ?

Microbial ILW FEP Summary (gas)

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- Methanogenesis
  - pH limitation / heterogeneity
  - SRB competition
  - Effects could either enhance or reduce CH_4 generation and speciation / mobility of ^{14}C
- Hydrogen utilisation
  - Reduce gas flux and ^{14}C gas release
  - Lower rates of gas generation, beneficial to physical FEPs; pressurisation, cracking, effects on hydrogeology etc
- Sulphate reduction
  - Indirect effects on the above processes involving CH_4 & H_2 gases
  - Also important for organic/groundwater FEPs
- Microbial FEPs need to be considered under *in situ* conditions
  - Need to consider physical constraints on microbial growth
  - Studies to date are mainly in laboratory microcosms or in water filled boreholes
  - Microbial processes within ILW packages (storage & disposal)