Microbiological characterization of European porous storages

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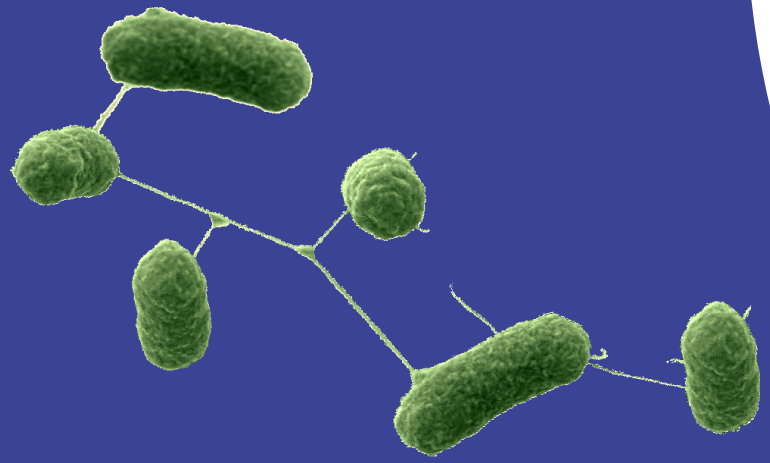

HYSTORIES – FINAL CONFERENCE - MAY 25th 2023

Acknowledgment

The Project is co-founded by European Union

Outline

1. Outline of WP3: „Microbiology“
2. Microbiological characterization of storage reservoir brines
3. Simulation of microbial hydrogen consumption
4. Risk assessment of microbial hydrogen consumption

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Outline of WP3:

Microbiology of porous under-ground storages (UGS) and hydrogen related risks

Microbiology of porous UGS and hydrogen related risks

Objective:

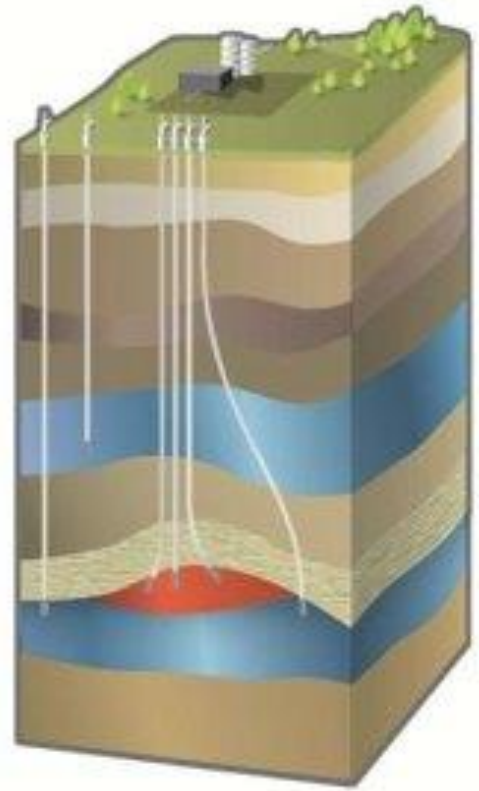
Characterization of the microbial processes and risks associated with hydrogen storage in various porous UGS facilities at European level.

WP3 “Microbiology” included:

1 **WP 3.1**
- Acquisition of representative samples
- Microbiological and molecular-biological characterization

2 **WP 3.2**
- Hydrogen consumption tests under slightly increased and real reservoir pressure
- Test program to determine H_2-stimulation potential

3 **WP 3.3**
- Microbiological risk assessment
- measures to control microbial activities



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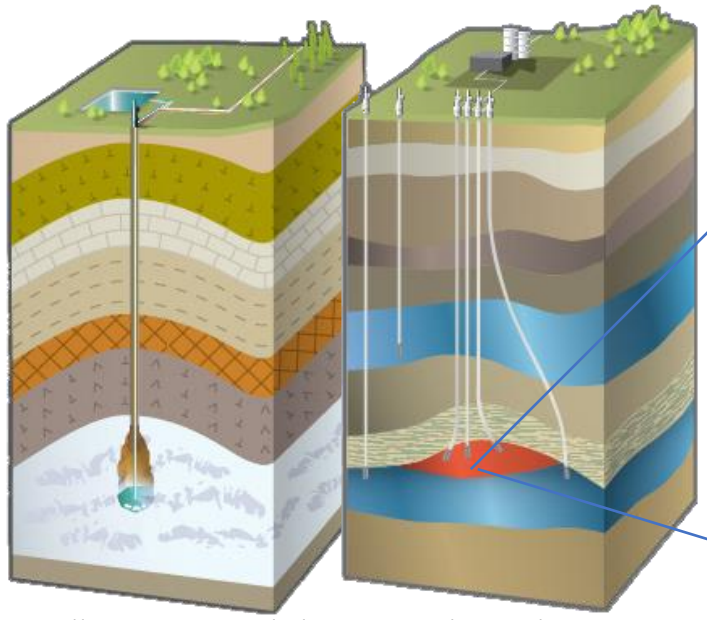
Microbiological characterization of storage reservoir brines

Hydrogen consumption by microorganisms

- Hydrogen can be rapidly consumed also under anaerobic conditions (= Hydrogenotrophs)
- Use of hydrogen as energy source is widespread



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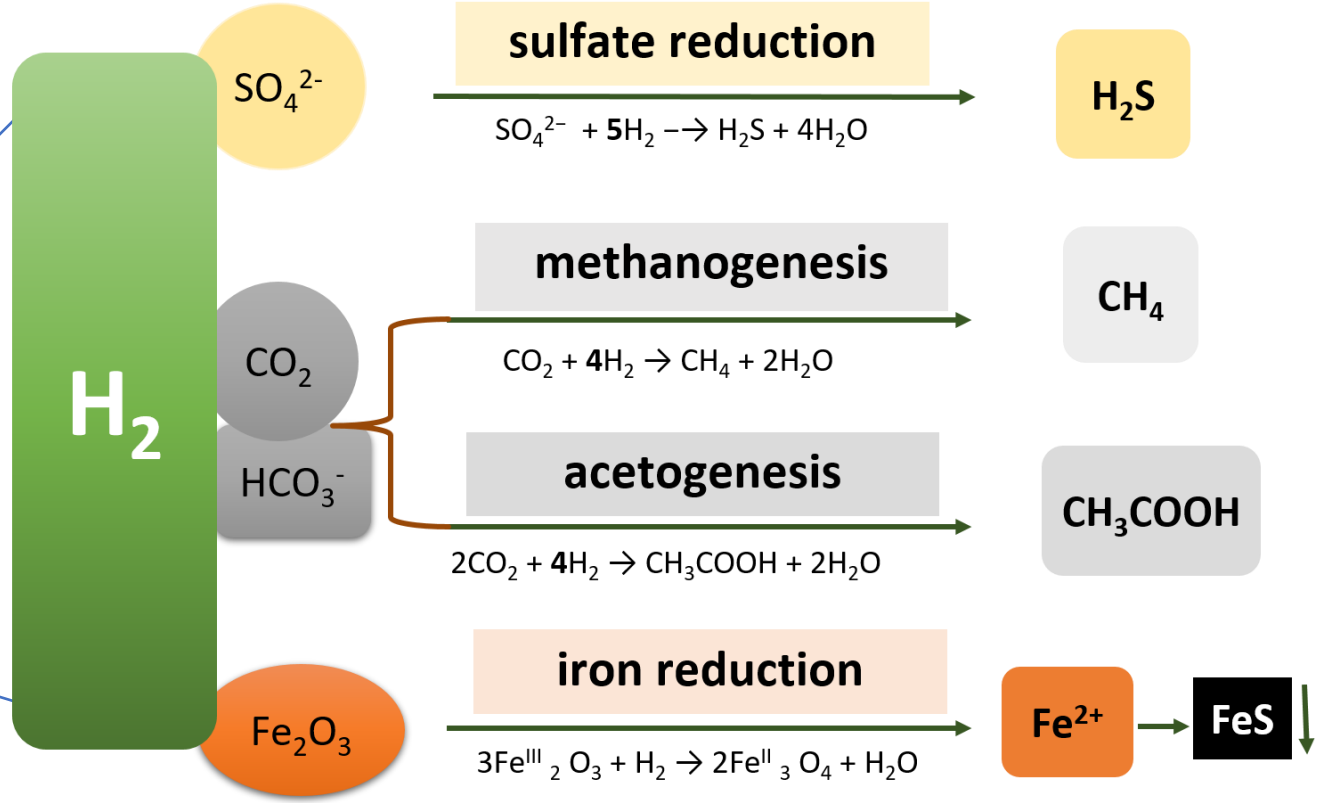
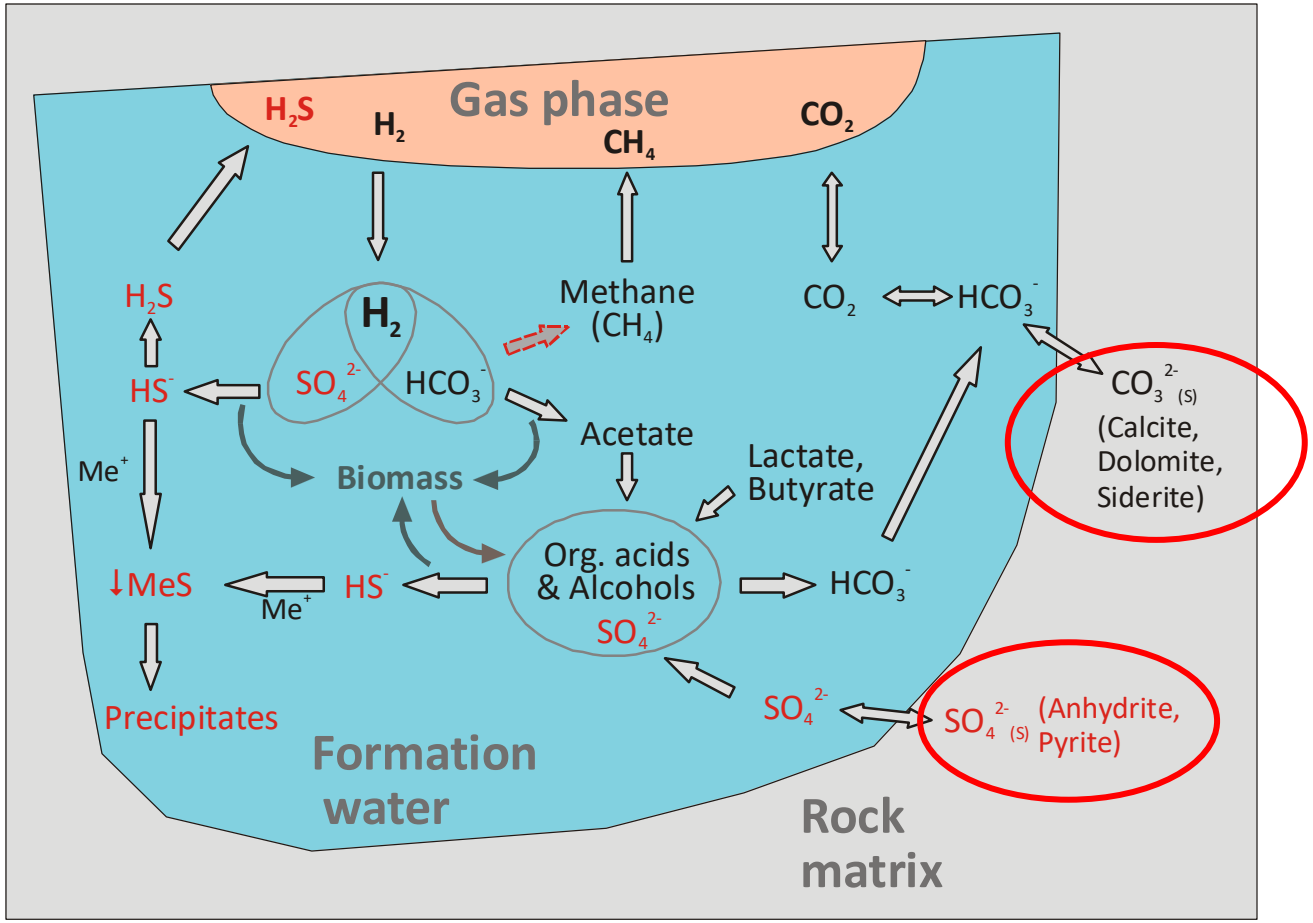
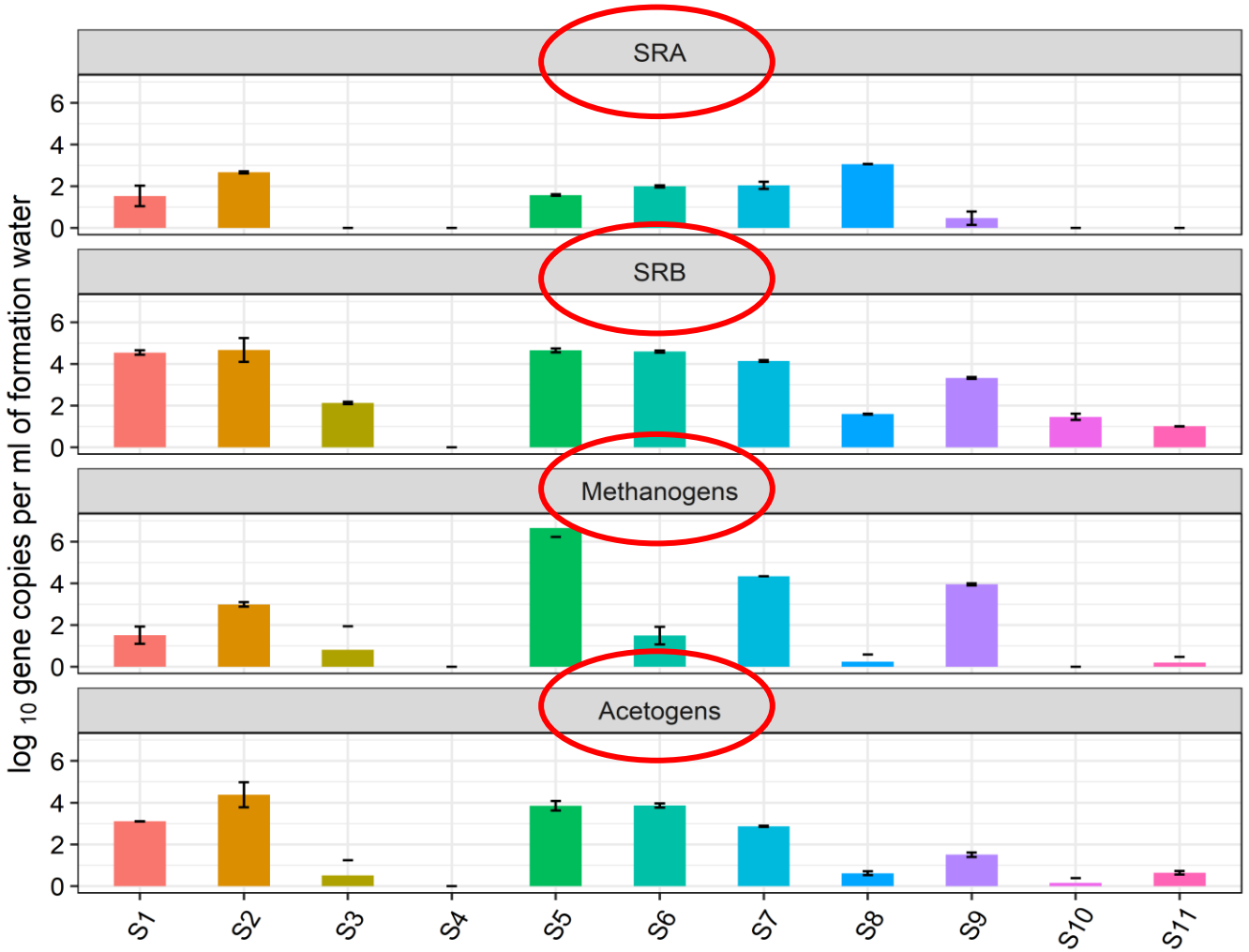


Potential H_2- pathways in porous storages

The availability of carbonate and sulfate in many geologic formations can promote microbial activity.



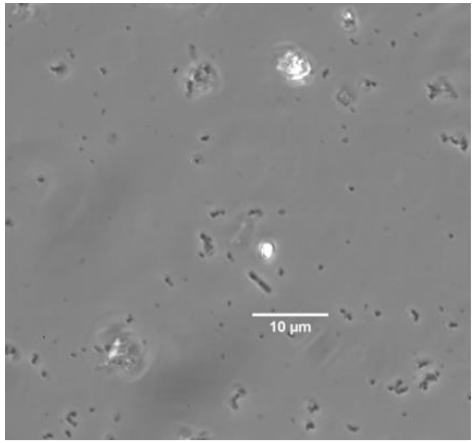
Molecular-biological analysis of H_2-specific gene markers



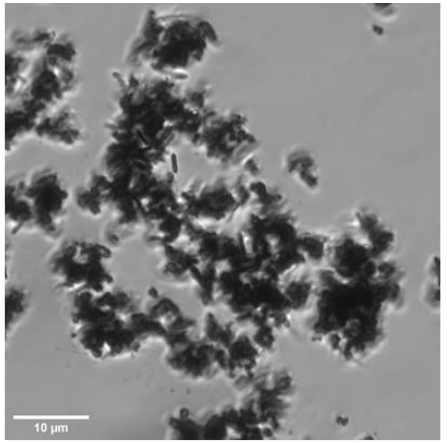
- The proportion of major hydrogen consuming microorganisms varies significantly between different formation water samples.
- In 7 formation water samples all 4 major hydrogen-related gene markers were detected
- 3 storages contain low cell numbers, but at least one H_2-consuming group is almost always present

Enrichment cultures of microorganisms

Formation water sample	Salinity (equivalent to % NaCl (w/v))	Temperature (°C)	pH	Hydrogenotrophic microorganisms relative cell number / group of MO	
1	1.5	49	6.8	+++	Methanogens, Acetogens, SRB, TRB, IR
2	4.8	60	7.4	+/-	Methanogens, TRB
3	1.7	60	5.8	+++	Methanogens, Acetogens, SRB, TRB, IR
4	0.1	66	6.2	+++	Methanogens, Acetogens, SRB, TRB
5	1.4	91	10.2	+	IR
6	0.1	34	7.8	+++	Methanogens, Acetogens, SRB, TRB
7	6.0	48	6.45	++	Methanogens, TRP, IR
8	10.0	64	5.9	+/-	Acetogens
9	0.6	64	6.0	+/-	Acetogens, SRB
10	2.8	40	6.5	+++	Methanogens, TRB
11	16.3	88.3	5.7	-	negative



Original formation water



Enrichment of SRB

→ 6 reservoirs are massively contaminated with active H_2-consuming microorganisms, although H_2 has never been injected.

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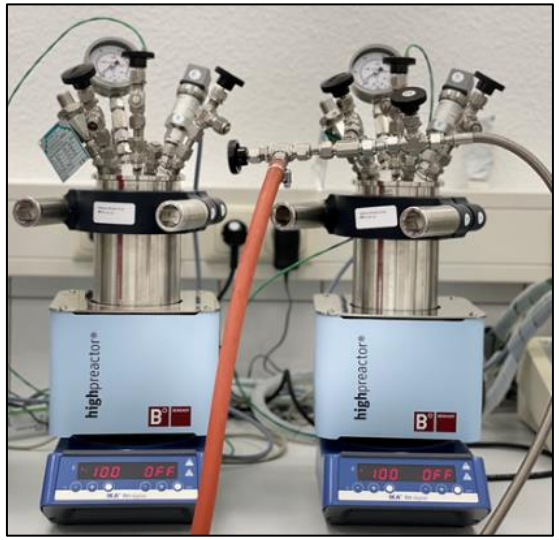
Simulation of microbial hydrogen consumption

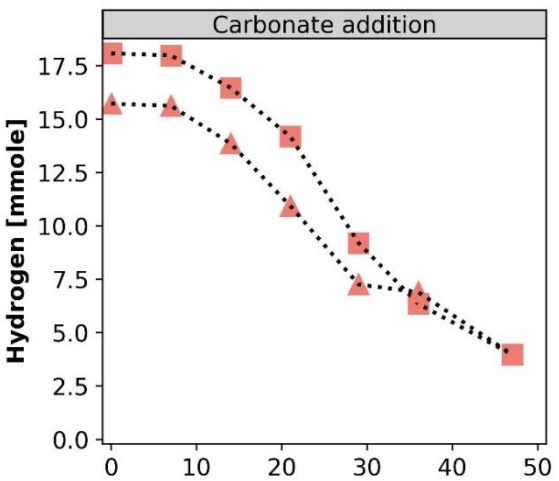
Hydrogen conversion tests

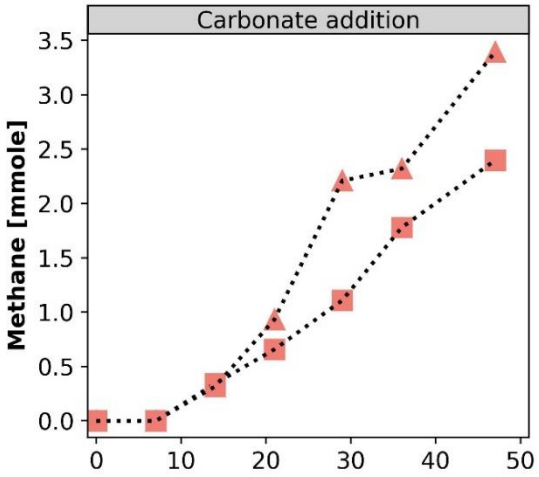


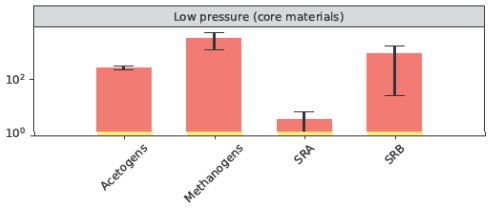
High pressure test	Slight over-pressure test
• **Microorganisms**: enrichment cultures	
• **Gas phase**: 100 % H_2	
• **Fluid**: formation water	
• carbon source: - core materials (original or artificial)	• carbon source: - core materials; - carbonate (HCO_3^- or $CaCO_3$)
• pressure: UGS conditions	• pressure: < 3 bar

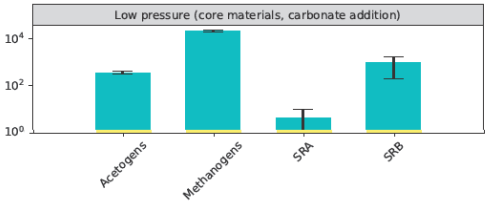
Hydrogen conversion at low pressure

Carbonate ($NaHCO_3$)

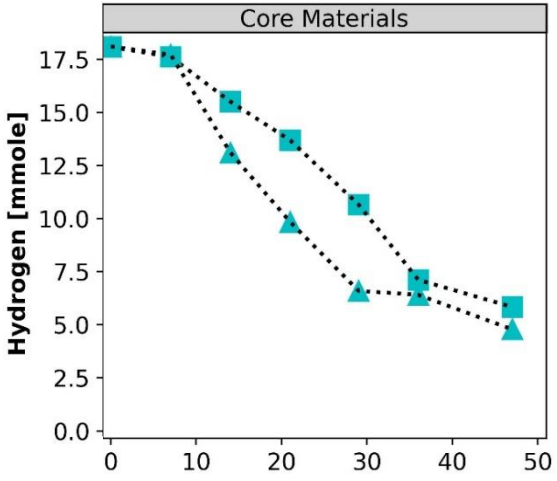


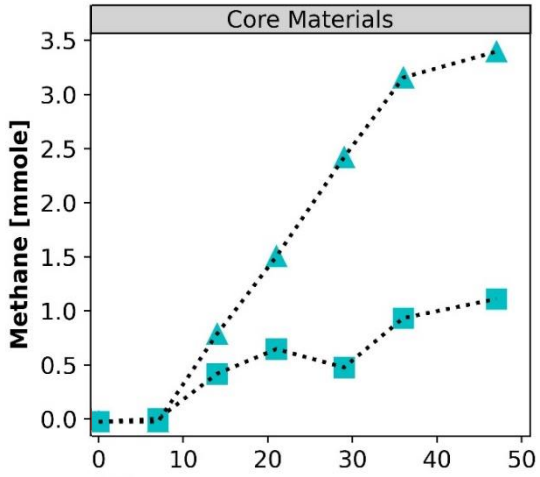


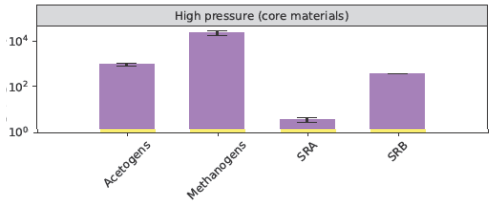


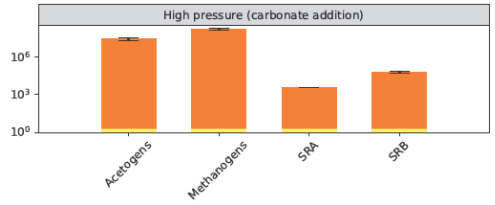


Core material

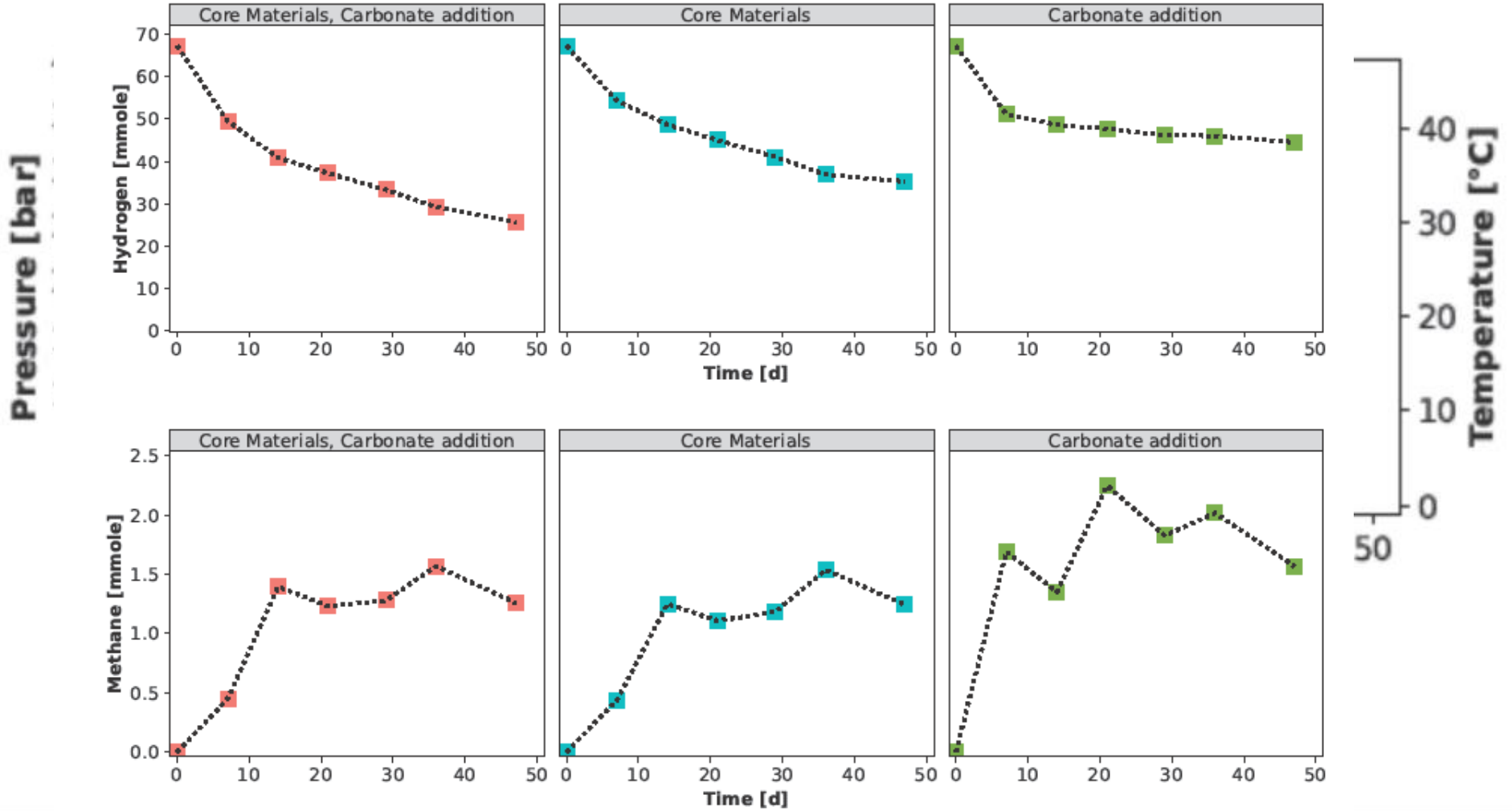






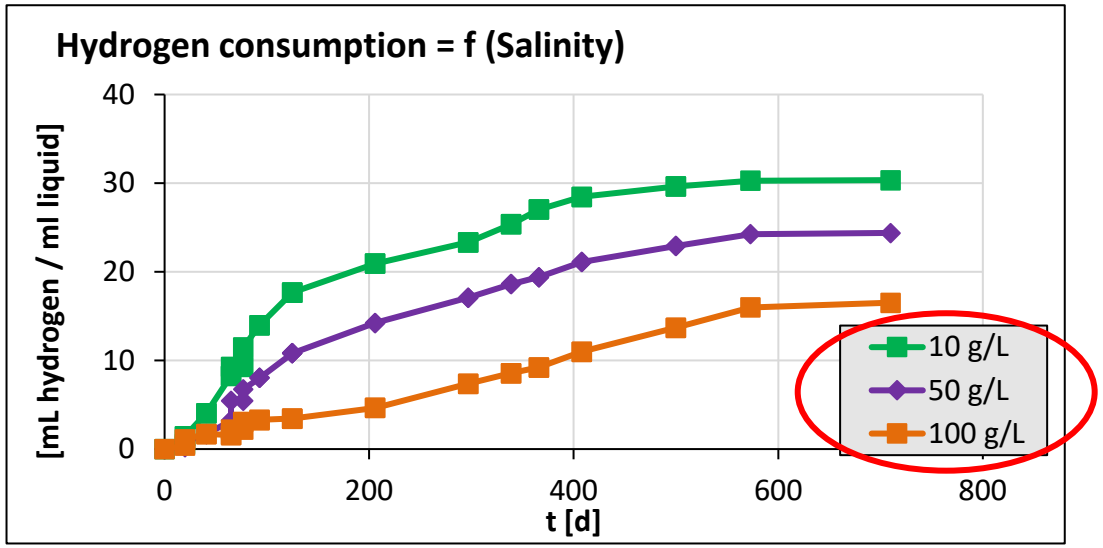


Simulation tests at reservoir pressure



Hydrogen consumption at high salinities

Methanogenesis



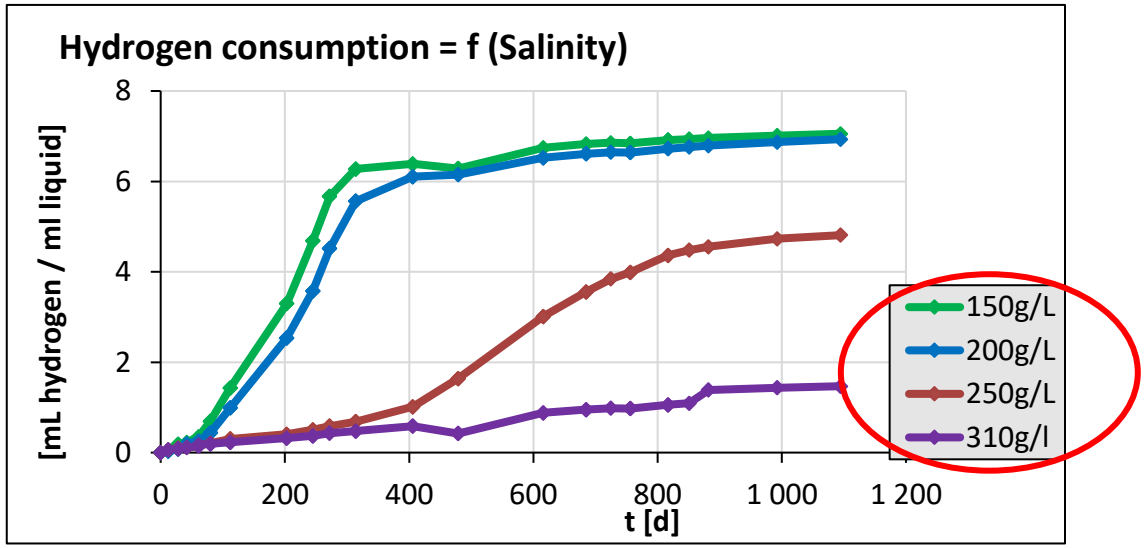
H_2-consumption per month and m³ formation water:

10 g/L: 2 m³ H_2

50 g/L: 1.5 m³ H_2

100 g/L: 0.75 m³ H_2

Sulfate reduction



0 g/L: 9 m³ H_2 (not shown)

20 g/L: 2.2 m³ H_2 (not shown)

150 g/L: 0.75 m³ H_2

200 g/L: 0.67 m³ H_2

250 g/L: 0.25 m³ H_2

310 g/L: 0.05 m³ H_2

What hydrogen conversion rates can be expected?

Conversion rates strongly depend on storage conditions and composition of microbial population

Sulfate reducing microorganisms: up to ~500 mM/h

Methanogens: up to ~30 mM/h

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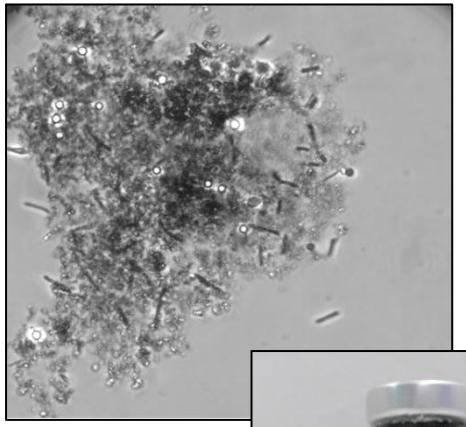
Risk assessment of microbial hydrogen consumption

Risks associated with microbial H_2-consumption

- Quantitative **loss of hydrogen**
- Deterioration of gas quality due to **hydrogen sulfide formation (H_2S)**
- Risk of permeability reduction und **well bore plugging** due to FeS, biofilms
- Chemical **changes of formation water** (pH, solution of minerals, FeS, $CaCO_3$)
- Increase of degradable **organic acids** for secondary processes

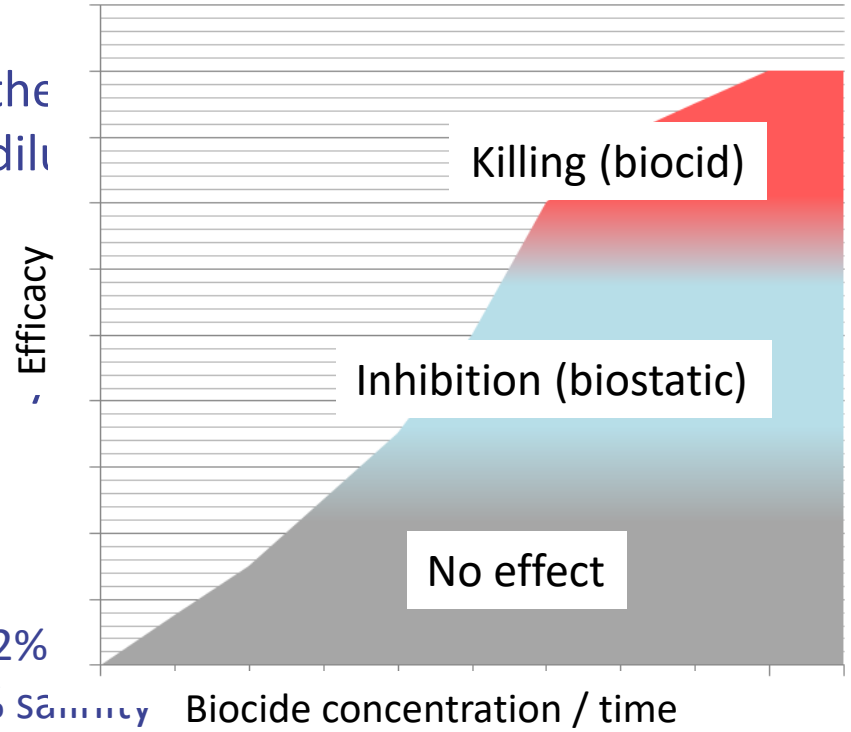


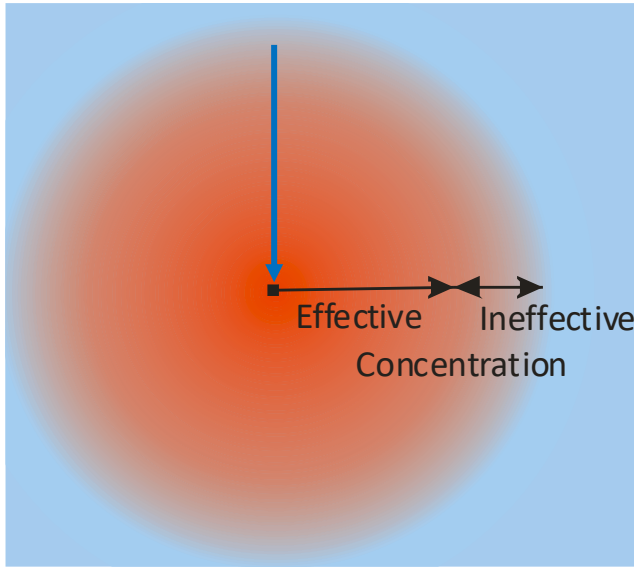
- Sulphate-reducing MO: Deterioration of gas quality (H_2S) and FeS precipitation
  Corrosion (MIC)
  Acidification by H_2S, CO_2 and organic acids

Strategies to inhibit microbial activity: Biocides

Biocides in porous reservoirs:

- are diluted in porous storages with increasing distance from the injection well
- become ineffective if the e
  concentration due to dilu
- can be degraded or ev
- do not distribute ideal
  migrate evenly in the





Biocide tests for:

- SRP: at 0.1; 15 and 32%
- Methanogens at 0.1% sa
- In-house agent

Mitigation strategies: Biocide tests with SRP

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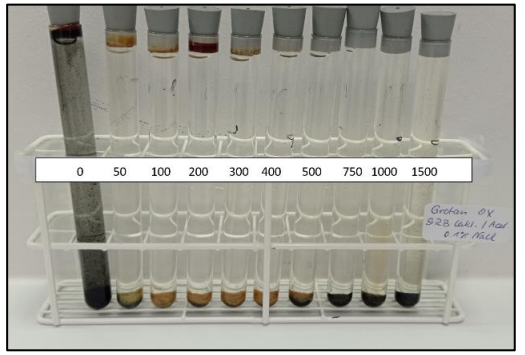
Hydrogen Storage in European Subsurface

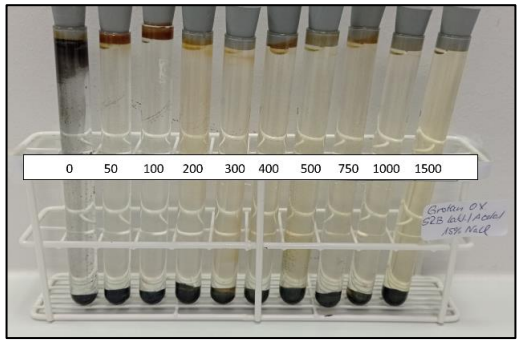
0.1% salinity

	Test concentration (ppm)											
Biocide:	0	50	100	200	300	400	500	750	1000	1500	2000	control
XC82681	+++	+-	-	-	-	-	-	-	-	-	-	-
XC82205	+++	-	-	-	-	-	-	-	-	-	-	-
Grotan OX	+++	-	-	-	-	-	-	-	-	-	-	-



15% salinity

	Test concentration (ppm)											
Biocide:	0	50	100	200	300	400	500	750	1000	1500	2000	control
XC82681	+	-	-	-	-	-	-	-	-	-	-	-
XC82205	+	-	-	-	-	-	-	-	-	-	-	-
Grotan OX	+	-	-	-	-	-	-	-	-	-	-	-



32% salinity

	Test concentration (ppm)															
Biocide	0	10	20	30	40	50	75	100	200	300	400	500	750	1000	1500	control
XC82681	++	+-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
XC82205	++	++	++	++	++	++	++	++	-	-	-	-	-	-	-	-
Grotan OX	++	++	++	++	++	++	++	++	-	-	-	-	-	-	-	-
In-house agent	++	++	-	-	-	-	-	-	-	-	-	-		-	-	-

Strategies to inhibit microbial activity

Storage conditions that influence microbes:

Temperature

Pressure

pH-Value

Salinity

Hydrocarbons

Carbonate

VFAs
(organic acids, etc.)

Sulfate

Metal ions

Nitrate

CO_2

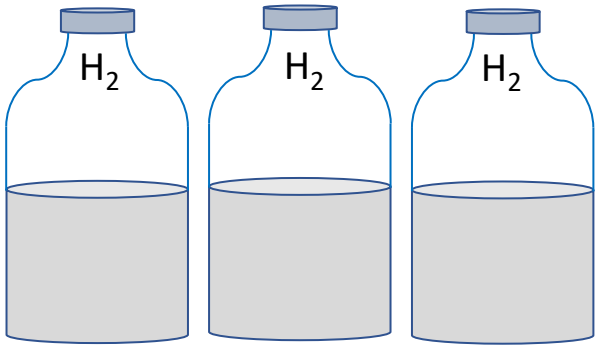
Chemicals
(Scavengers, Drilling fluids,
Hydrate inhibitors)

Composition of
rock matrix

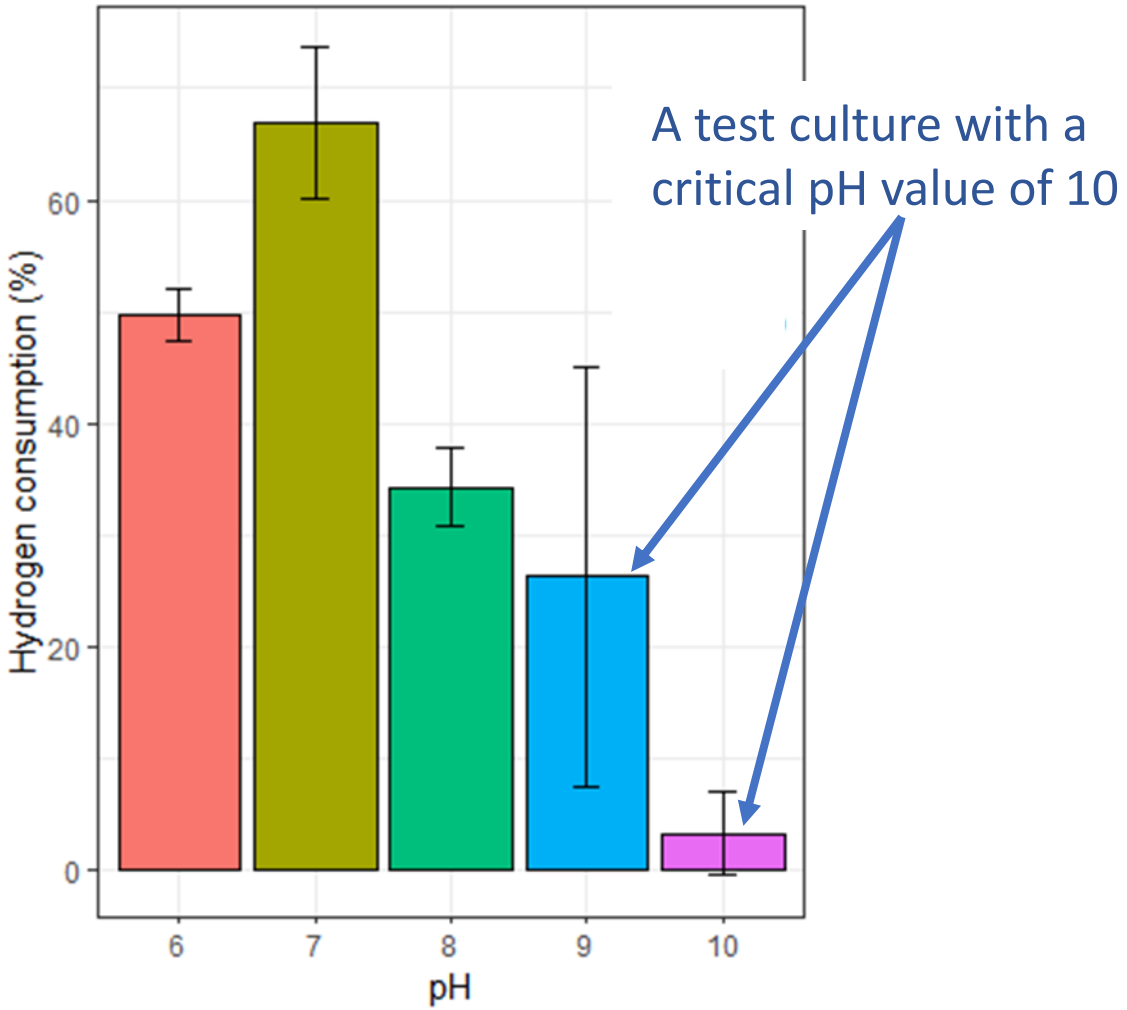
Mitigation strategies: extreme pH

Model experiments with pH Value test series

- Temperature: 50 °C
- Salinity: 0.1 %
- Microorganisms: mix of methanogens and SRB
- Carbon source: HCO_3^-

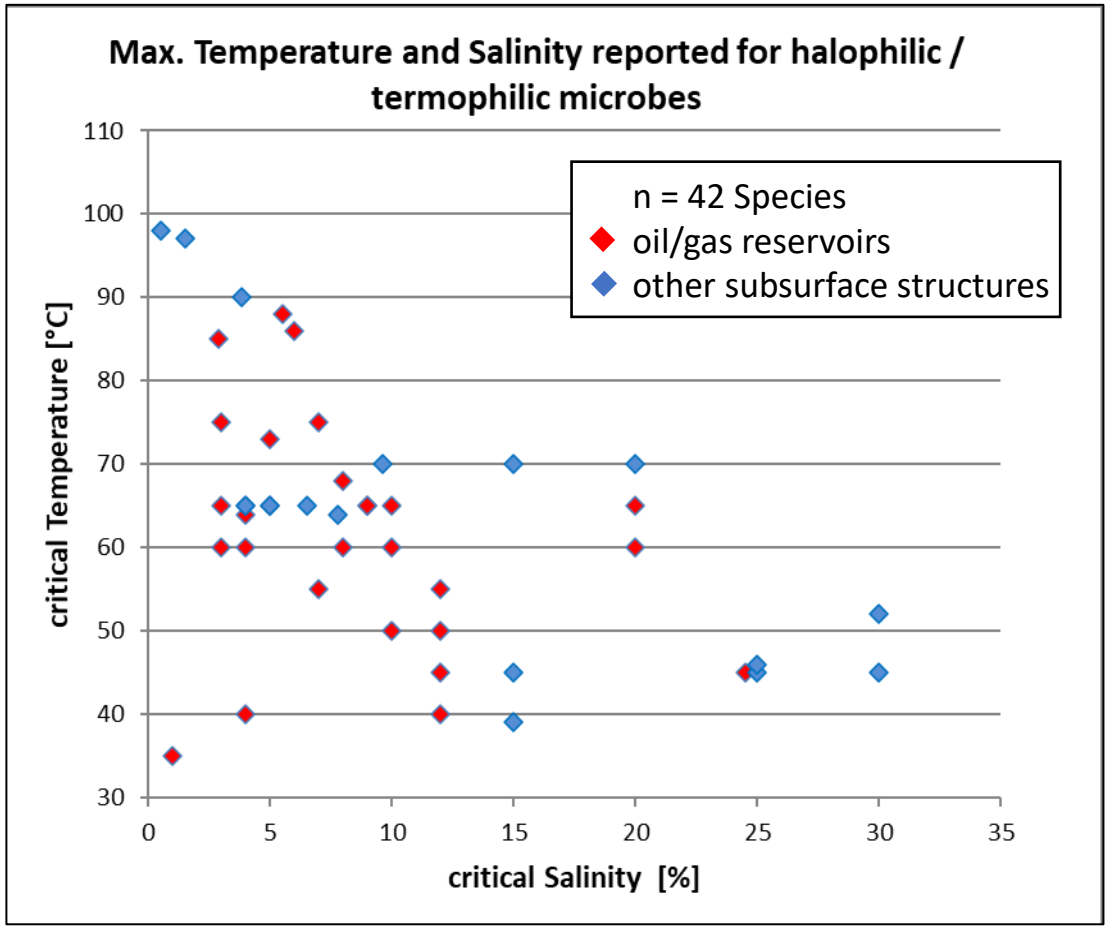


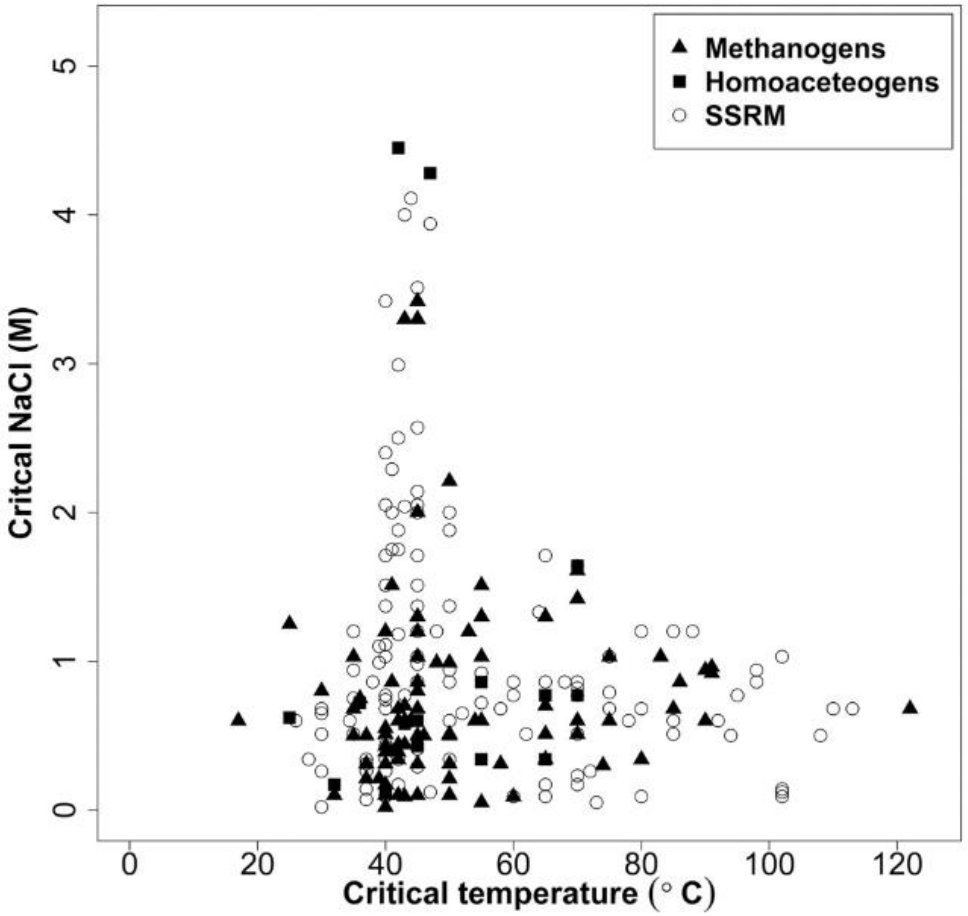
10 days cultivation



A test culture with a critical pH value of 10

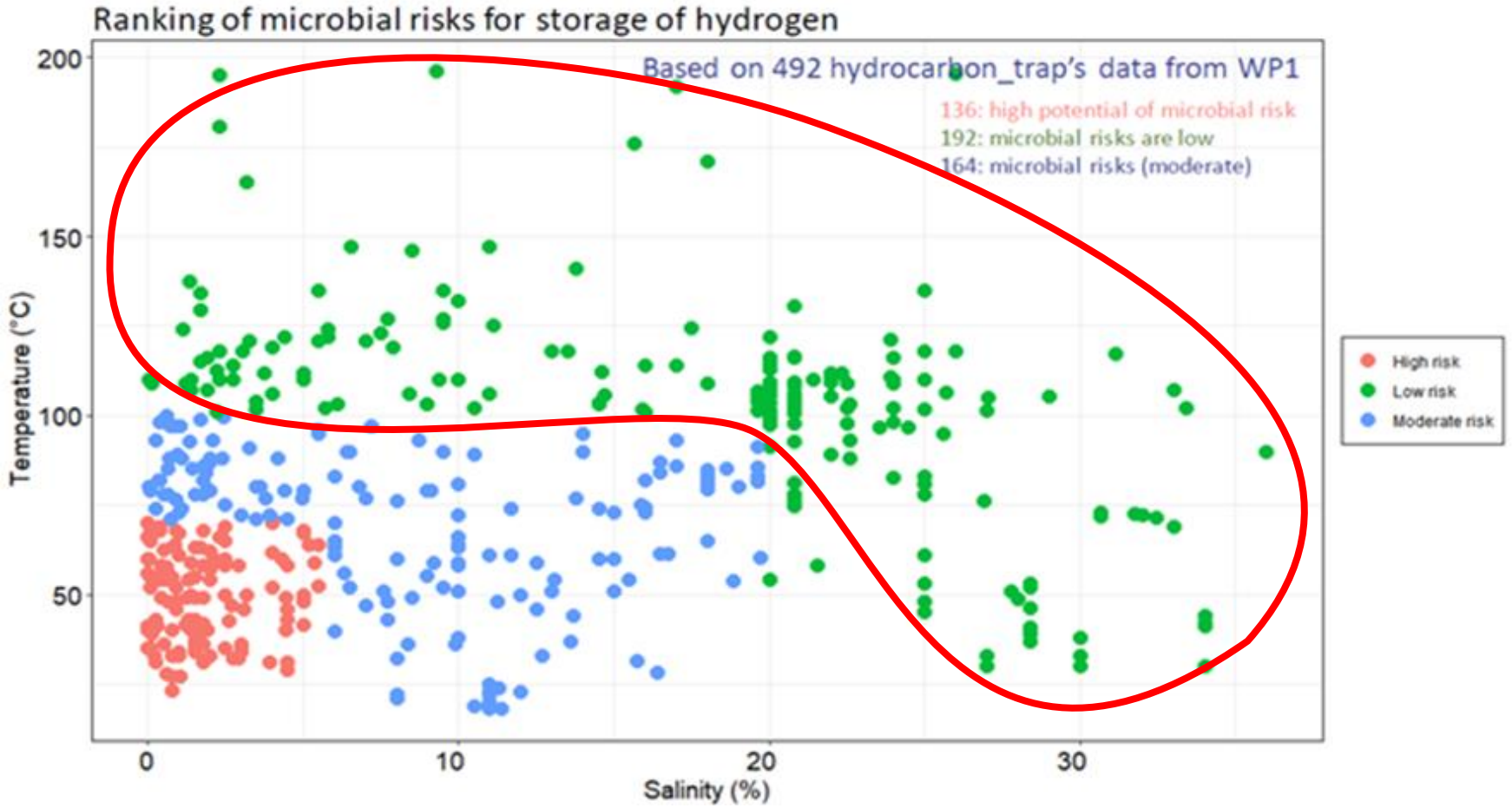
Storage conditions that influence microbes





Thaysen et al_2021_Estimating microbial growth and hydrogen consumption in hydrogen storage in porous media, Renewable and Sustainable Energy Reviews 2021

Storage conditions that influence microbes



Source: HYSTORIES, D7.3

Critical storage parameters to be considered

Temperature

Pressure

Salinity

pH-Value

Hydrocarbons

Carbon source

Sulfate

Metal ions

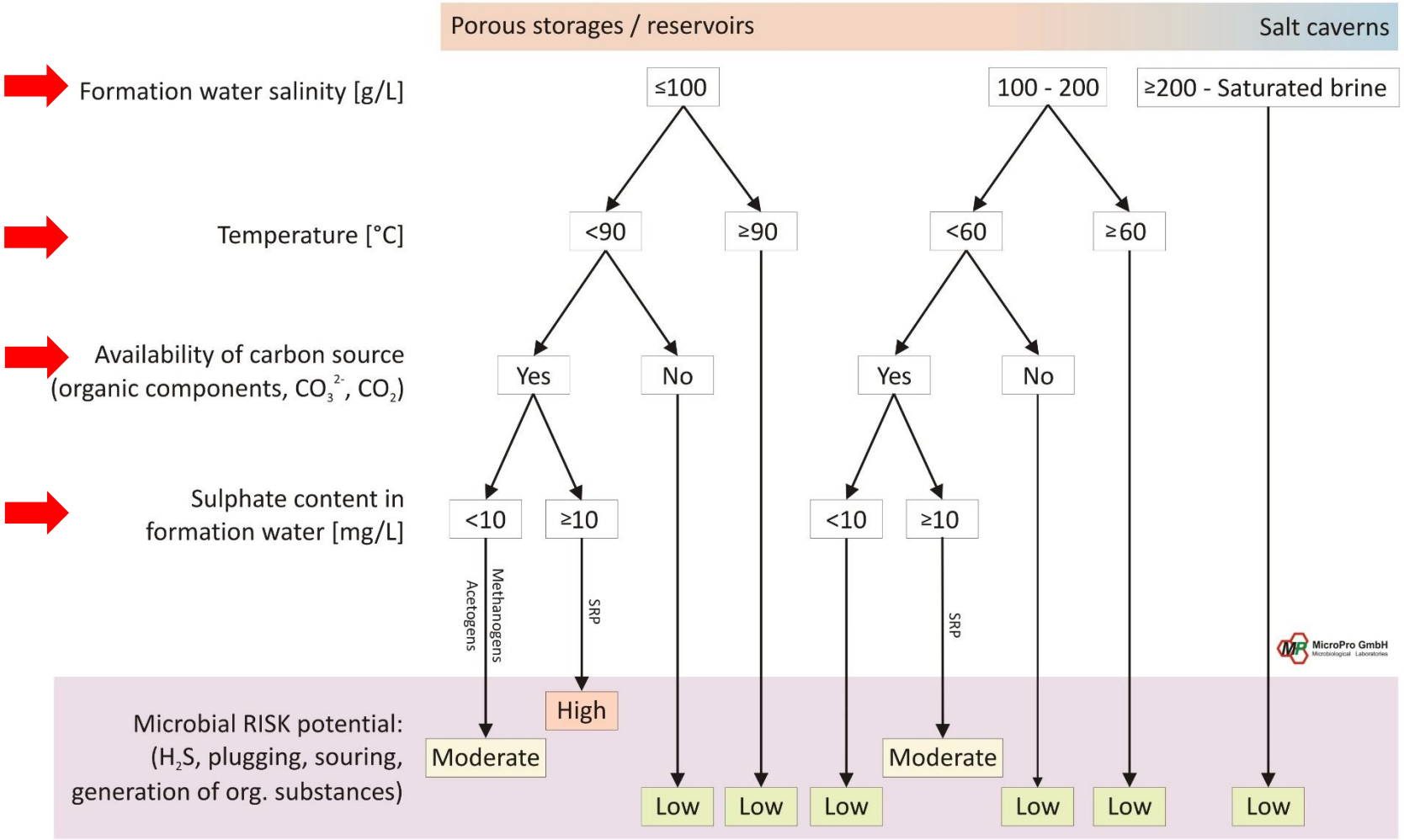
Nitrate

Chemicals
(Scavengers, Drilling fluids,
Hydrate inhibitors)

VFAs
(organic acids, etc.)

Risk assessment

Simplified chart for the assessment of microbial risks



Risk assessment
Low risk (almost no microbial activity or extremely limited)
Moderate risk (though there is inhibition for some microbial groups, there are development of some microorganisms)
High risk (conditions are optimum for many microorganisms in UGS)

Hystories project consortium

GEOSTOCK
GEOSTOCK GREEN STORAGE

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MicroPro GmbH
Microbiological Laboratories

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Clean Hydrogen Partnership

Martin Wagner

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