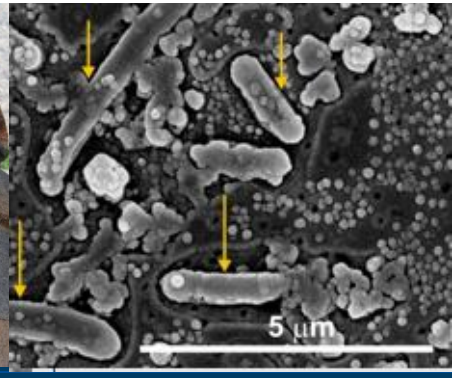
How to avoid corrosion and scaling in ATES systems in Germany?

Hilke Würdemann, Christoph Otten, Beate Dassler, Tobias Lienen, Anne Kleyböcker, Anja Narr, Anke Westphal, Stephanie Lerm and Sebastian Teitz

Hochschule Merseburg





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Microorganisms (MO) vs. technical applications

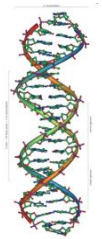
- Development of biofilms → Clogging of pipes, filters, heat exchangers
- Interaction of metal surface, chemical corrosion products, MO, metabolites → Microbial induced/influenced corrosion
- Mineral precipitation → Loss of well injectivity
- Mineral dissolution → Increase in porosity and permeability
- Degradation of scaling inhibitors → Less environmental impact

gefördert vom Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des dt. Bundestags
PtJ Projektträger Jülich Forschungszentrum Jülich

Würdemann *et al.* 2016

Molecular biological analysis: characterization of the microbial community composition and quantification

Samples

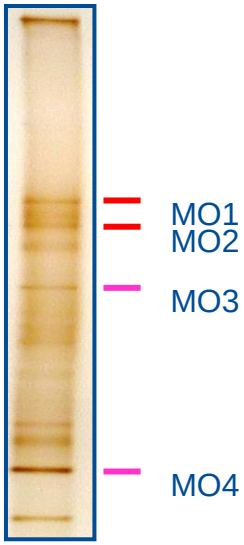


DNA

PCR

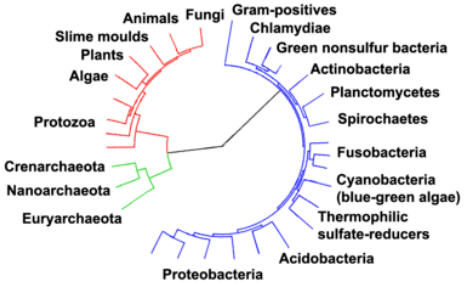
DNA-Fragment Amplification

Genetic Fingerprinting

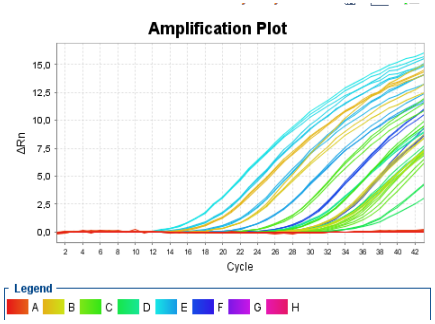


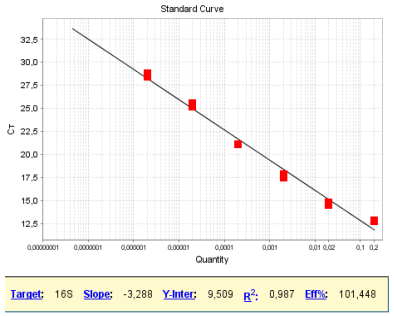
Sequenzing

DNA Data base



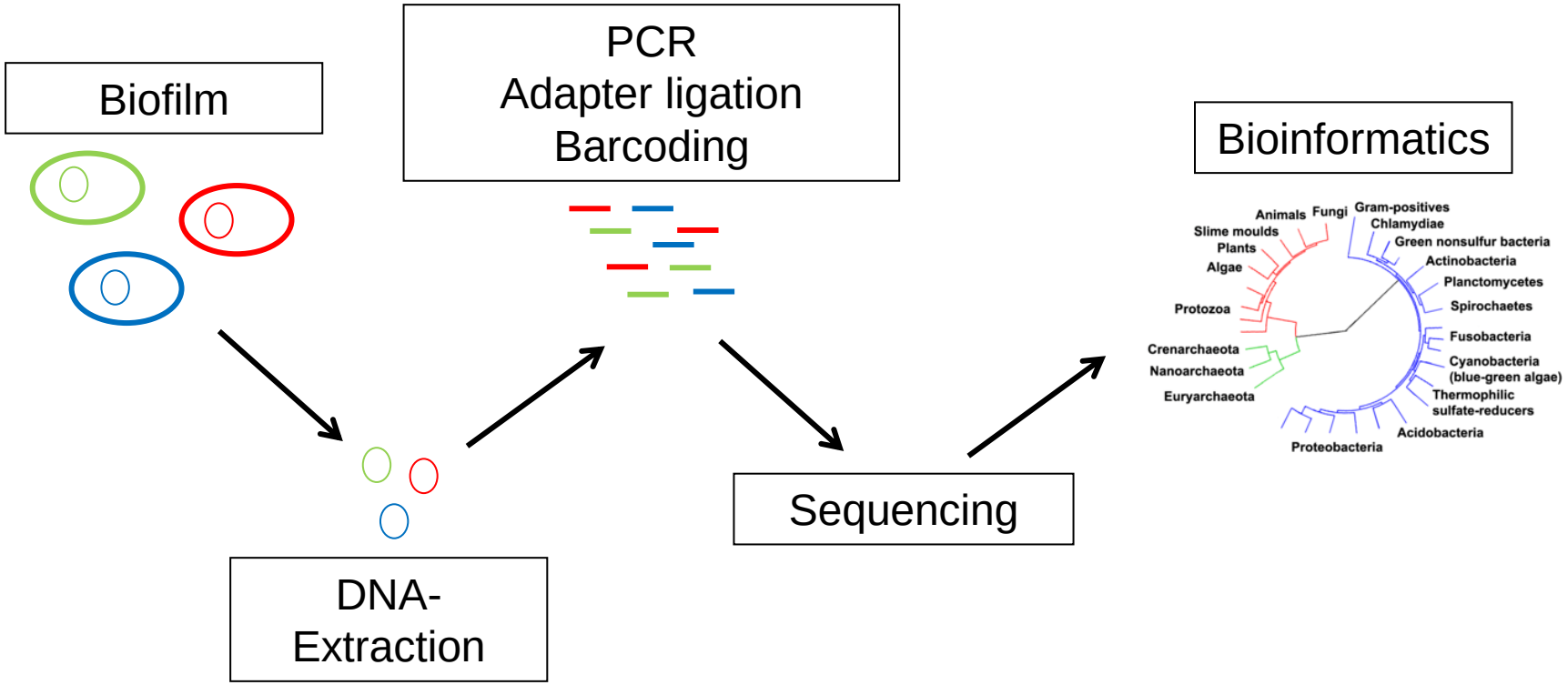
Quantitative real-time PCR





- Relative quantification related to the total community
- Absolute quantification of species or groups

Microbiom analysis of Fluids and Biofilms



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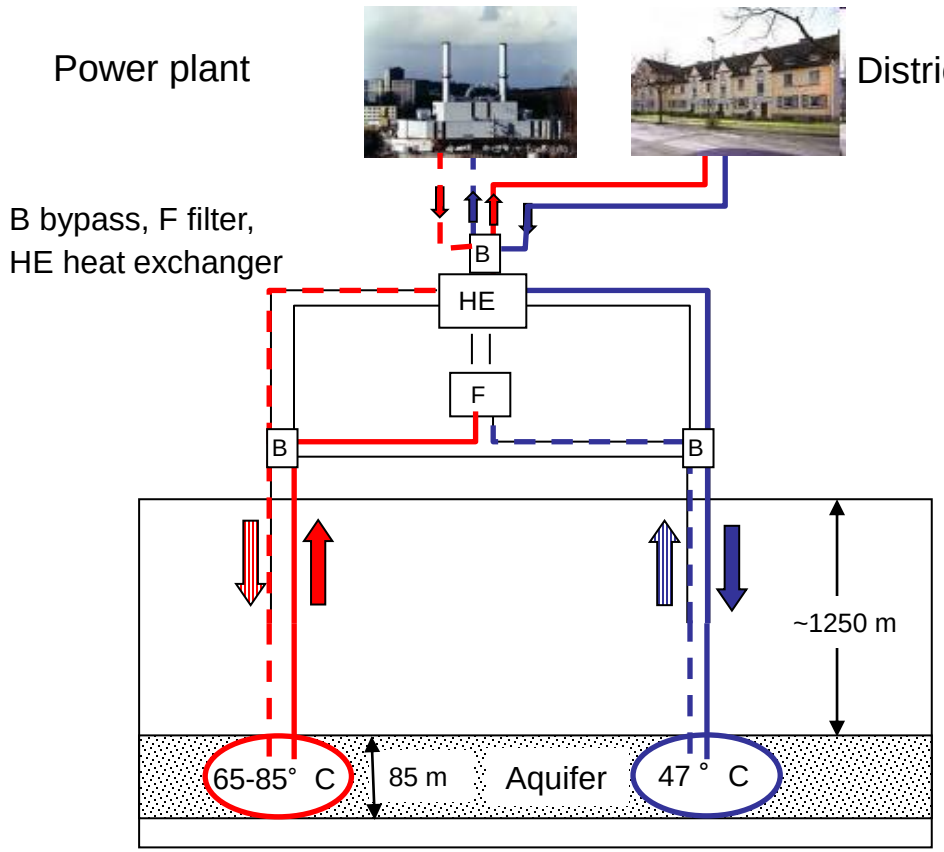
Geothermal Heat Store Neubrandenburg



Schematic illustration

Since 2004 operated in seasonal mode (charge/decharge)

Depth: 1,250 m

Salinity: 130 g/L

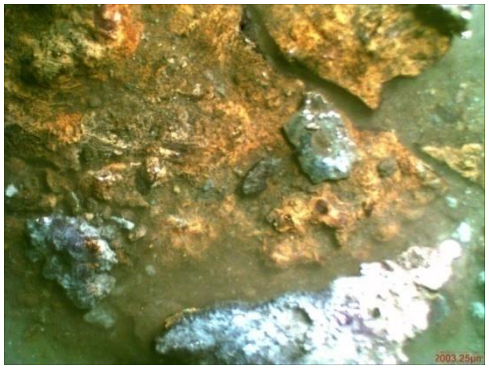
Problems: Corrosion in the "Cold" well

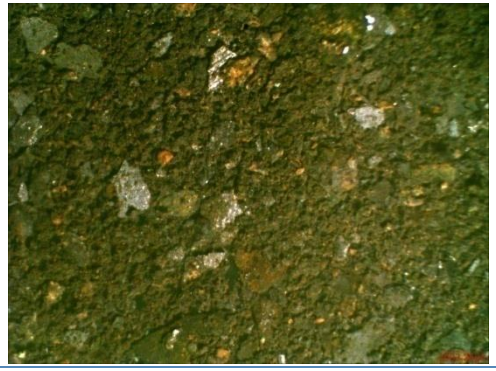
Lerm *et al.* 2014

2007-2011	T [°C]	pH [-]	Na^+ [g l^{-1}]	Cl^- [g l^{-1}]	NO_3^- [mg l^{-1}]	SO_4^{2-} [mg l^{-1}]	Fe^{2+} [mg l^{-1}]
Cold well (CW)	46.7	6.1	47.0	78.5	b.d.l.	912	16.9
Warm well (WW)	73.2	6.0	47.2	78.5	b.d.l.	983	14.7

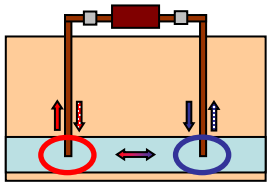
Corrosion and Scaling in the “cold well”

Microorganismen involved?





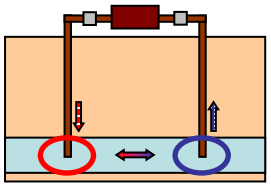
Effects of plant downtime



Causes	Date	Duration days]
Restart after pumping test	Apr 11	6
Technical defect during charge mode	Sept 11	28
Change of operation mode	Mar 12	7
Technical defect during charge mode	Aug 12	19
Change of operation mode	May 13	10
Technical defect during charge mode	Jun 13	32

Westphal *et al.* 2016

Geothermal fluid and mineral properties – during restart –



Measurements after restart after produced volume [m^3]	SO_4^{2-} [mg l^{-1}]	Fe^{2+} [mg l^{-1}]	H_2S [µg l^{-1}]	DOC [mgC l^{-1}]	Particle load [g m^{-3}]	$\delta^{34}S_{SO4}$ (‰CDT)
5-30	1600 ↑↑	22 ↑	375 ↑↑	98.8 ↑↑	50,000 ↑↑	25 ↑
30-490	980	17	180	2.6	0.1	----

↑ **Increased concentrations after downtime**

Westphal *et al.* 2016

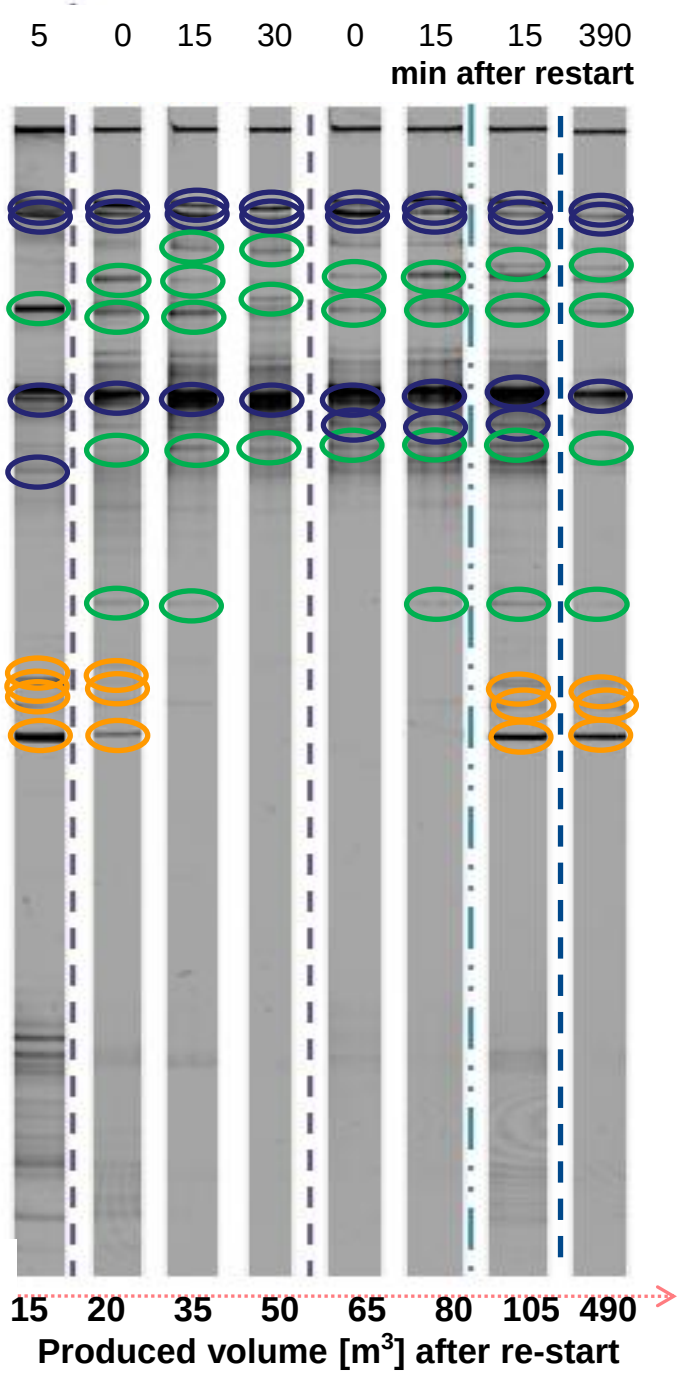
Sulfate reducing and fermentative bacteria dominant members of the microbial community

- Sulfate reducing bacteria (SRB)
- Fermentative bacteria
- Sulfur oxidizing bacteria (SOB)

→ Oxygen ingress

→ Sulfur cycling

→ Increased corrosion rates

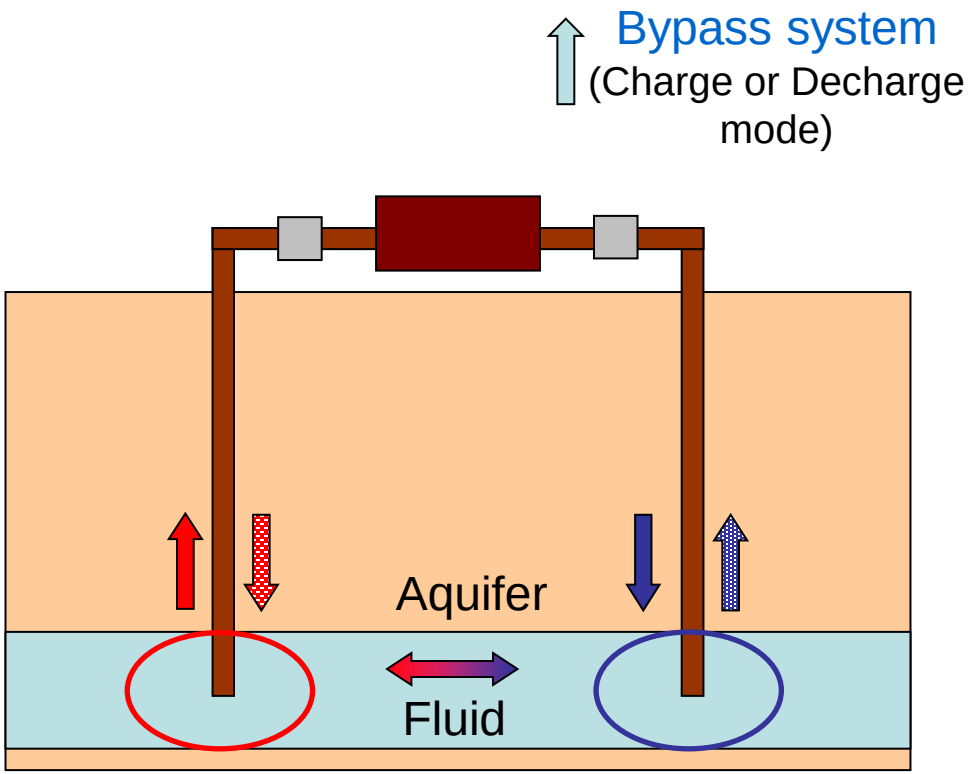


Short stop of operation (< 3h)

Long stop of operation (19h)

Westphal *et al.* 2016

Geothermal Heat Store Neubrandenburg



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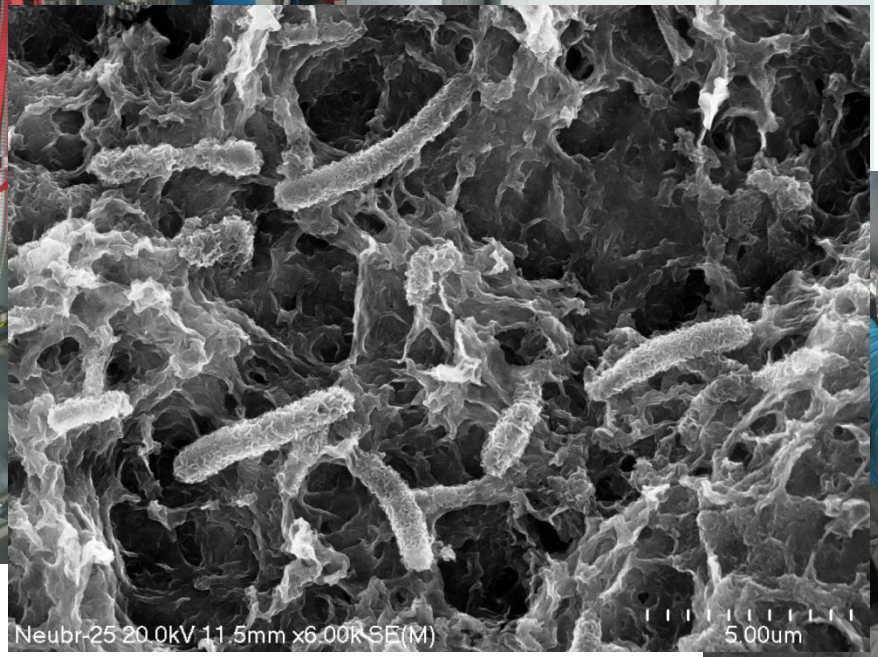
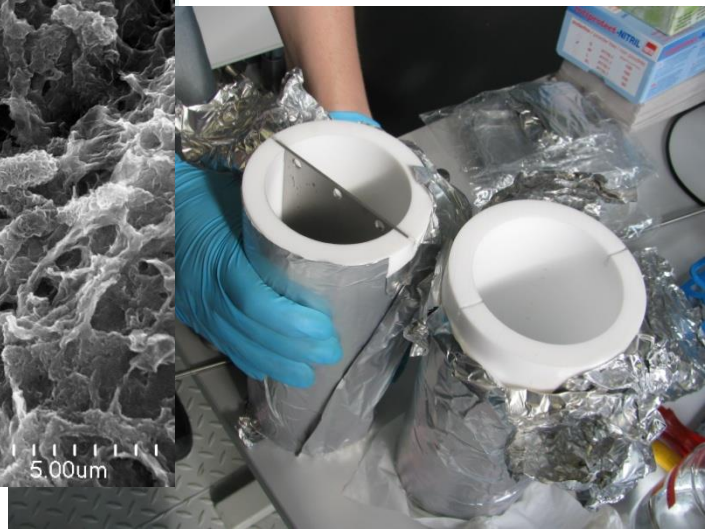
Warm well (WW)	73.2	6.0	47.2	78.5	b.d.l.	983	14.7

Bypass system to study temperature effects on corrosion rate



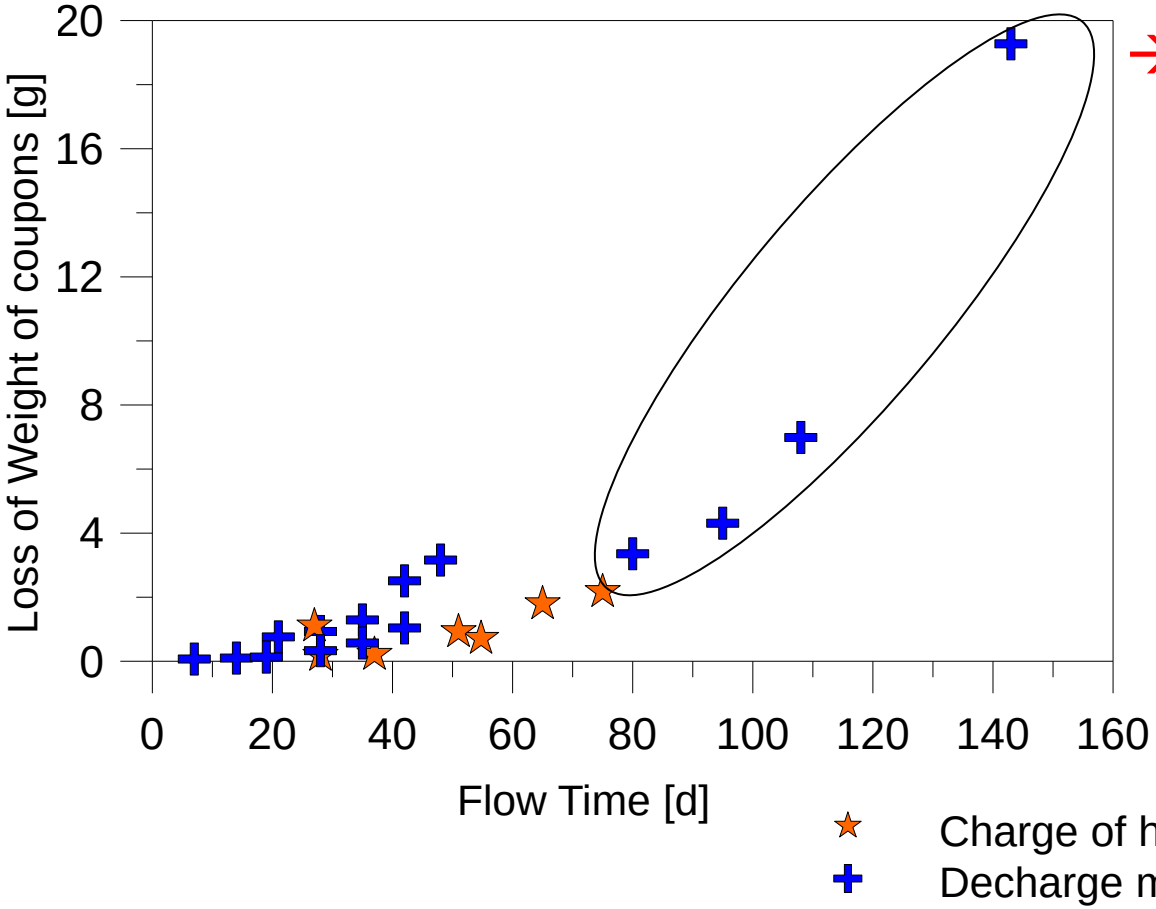


Cooling capacity:

50 kW

Kleyböcker *et al.* 2017

Corrosion over Exposure Time (Flow Time)



→ Change of flow direction and different plant down times

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Coupons exposed to geothermal fluid (59 days) in the bypass system: - Effect of heat shock -

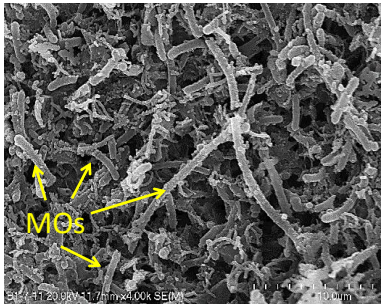
Vessel A:
Coupons: 2
Temperature: 40 ^{o}C

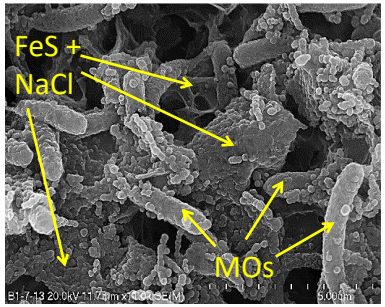
Vessel B:
Coupons: 2
Temperature: 40 ^{o}C & every 14 days: 78 ^{o}C (6 h)

Kleyböcker *et al.* 2017

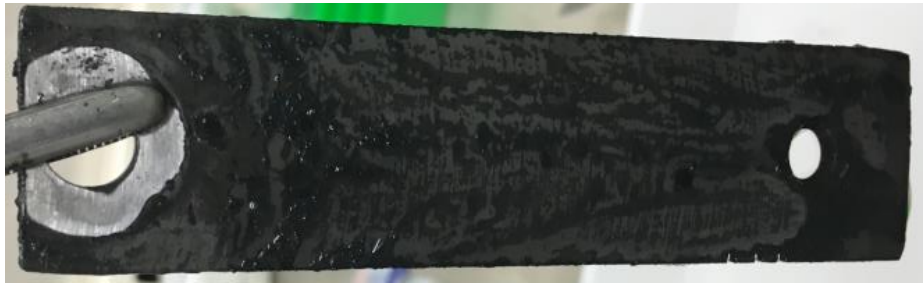
Temperature experiment (59 days): Shock temperature every 14 days

Vessel 1: T= 40 °C





Vessel 2: T= 40 °C & 78 °C (6 h)



→ Thinner biofilm layer after shock temperature

Kleyböcker *et al.* 2017

Summary - Heat Store Neubrandenburg

- Growth of SOB indicates oxygen ingress during the downtime phase. The fast decline of SOB after plant restart indicates the exclusive affection of the well.
- Interaction of SRB and SOB might have enhanced the corrosion processes occurring in the geothermal plant.
- Heat shock is a promising procedure to reduce biofilms and corrosion.

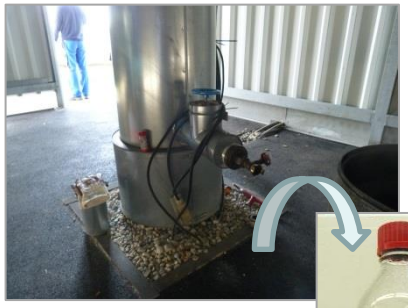
Geothermal Plant Unterhaching

Use of a scaling inhibitor to avoid scaling

Production well

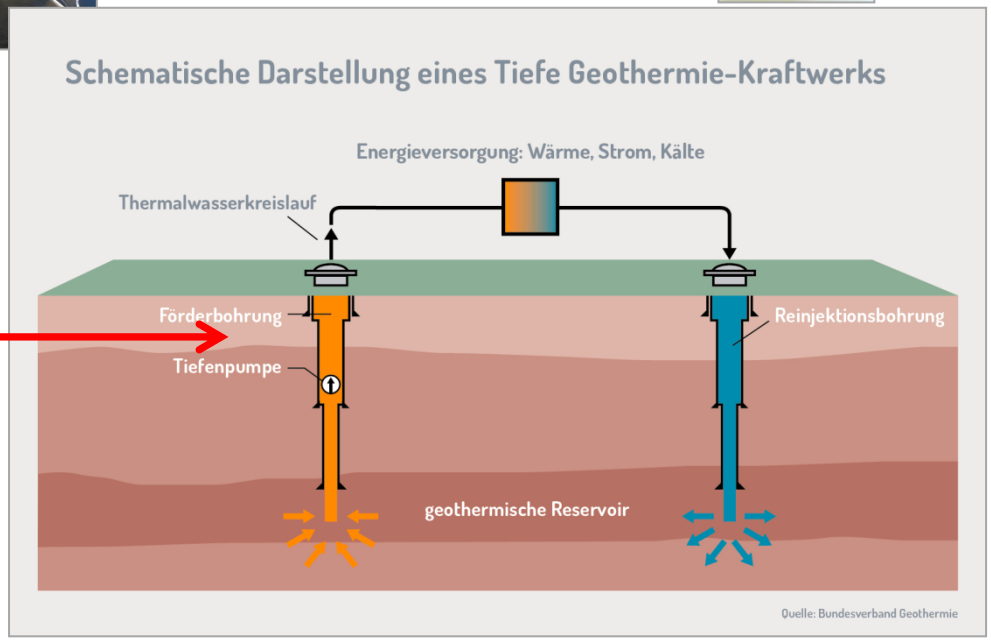
After heat exchanger

Injection well



Dosage of Inhibitor

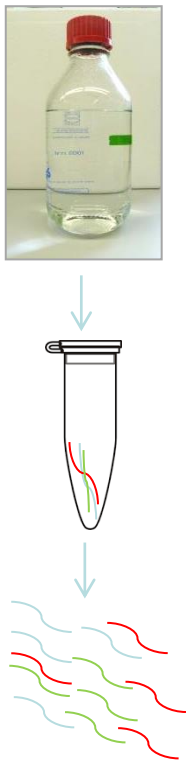
- NC47.1 B
- Polycarboxylat
- Since August 2017
- 5 mg/L -10 mg/L

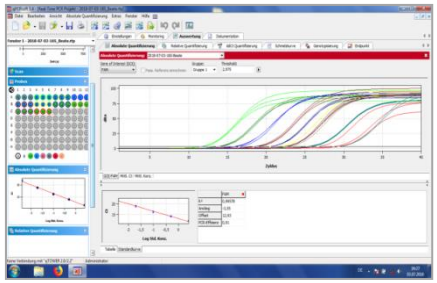


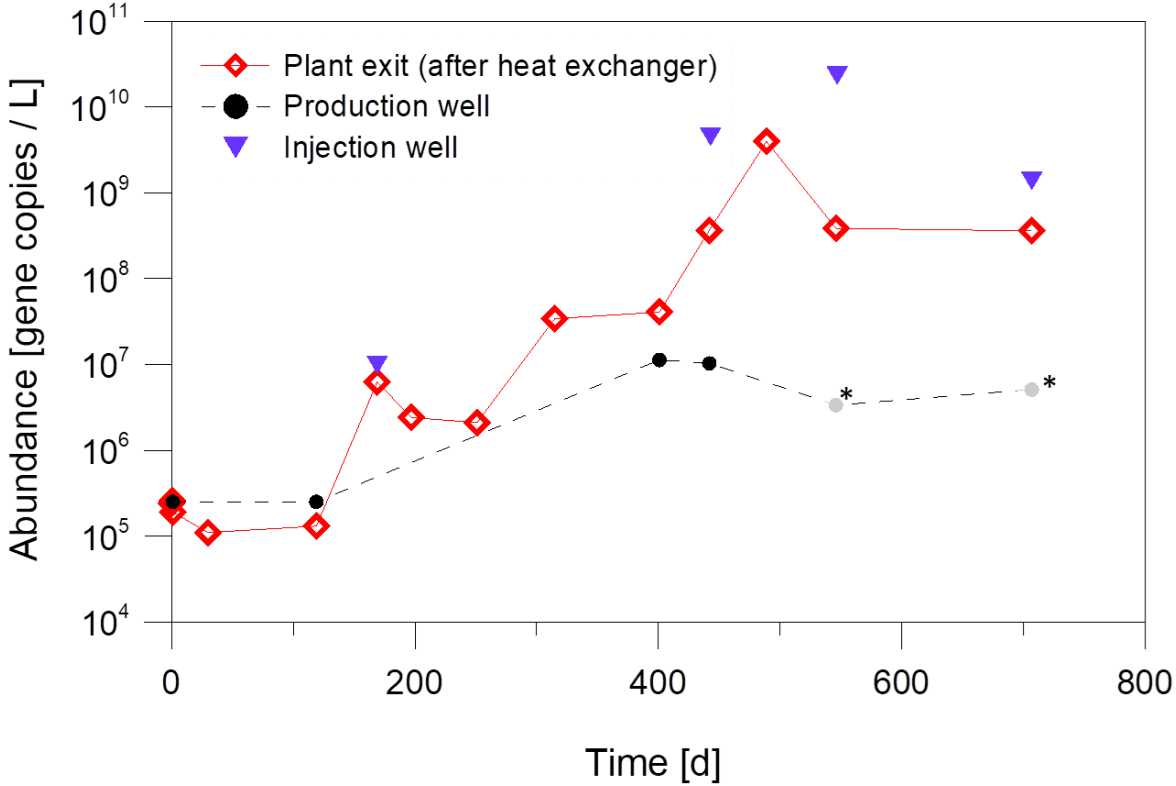
Otten *et al.* 2021

Increase of bacteria after heat extraction and inhibitor dosage

quantitative PCR (16S rRNA Bacteria)







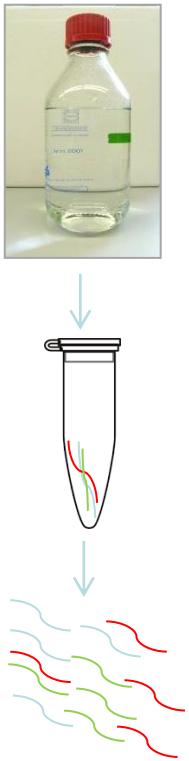
Increase of *Bacteria* due to inhibitor dosage in fluid samples from different sampling sites at the geothermal plant Unterhaching over a monitoring since 700 days of inhibitor dosage.

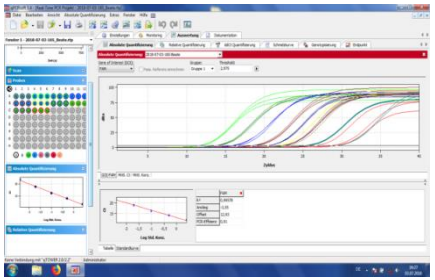
* below the sample specific detection limit

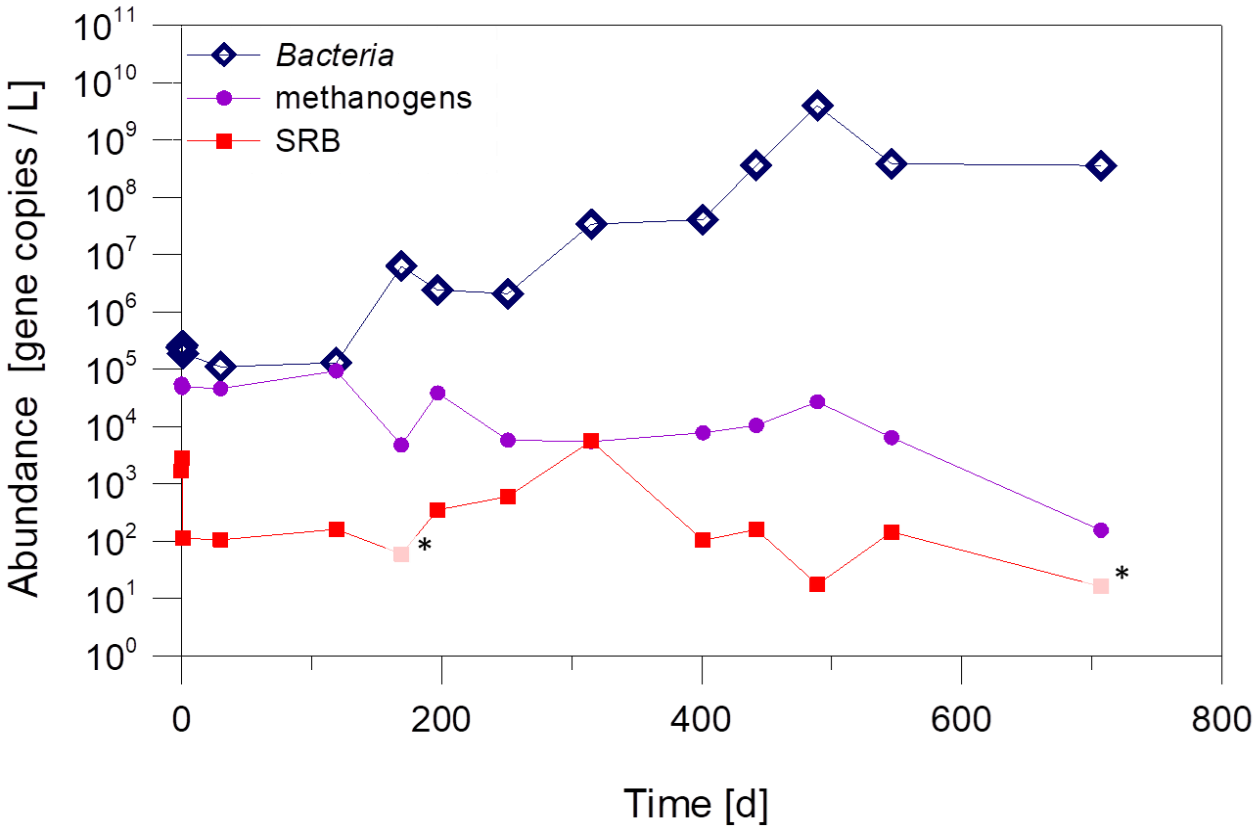
Otten *et al.* 2021

Increase of bacteria after heat extraction and inhibitor dosage

(qPCR of Bacteria, Sulfate-reducing bacteria and Archea)







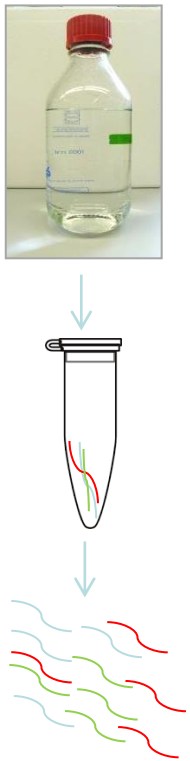
Quantification with qPCR with primers for the 16S rRNA gene (*Bacteria* and methanogenic archaea) and the *dsrA*-gene for sulfate-reducing bacteria.

* below the sample specific detection limit

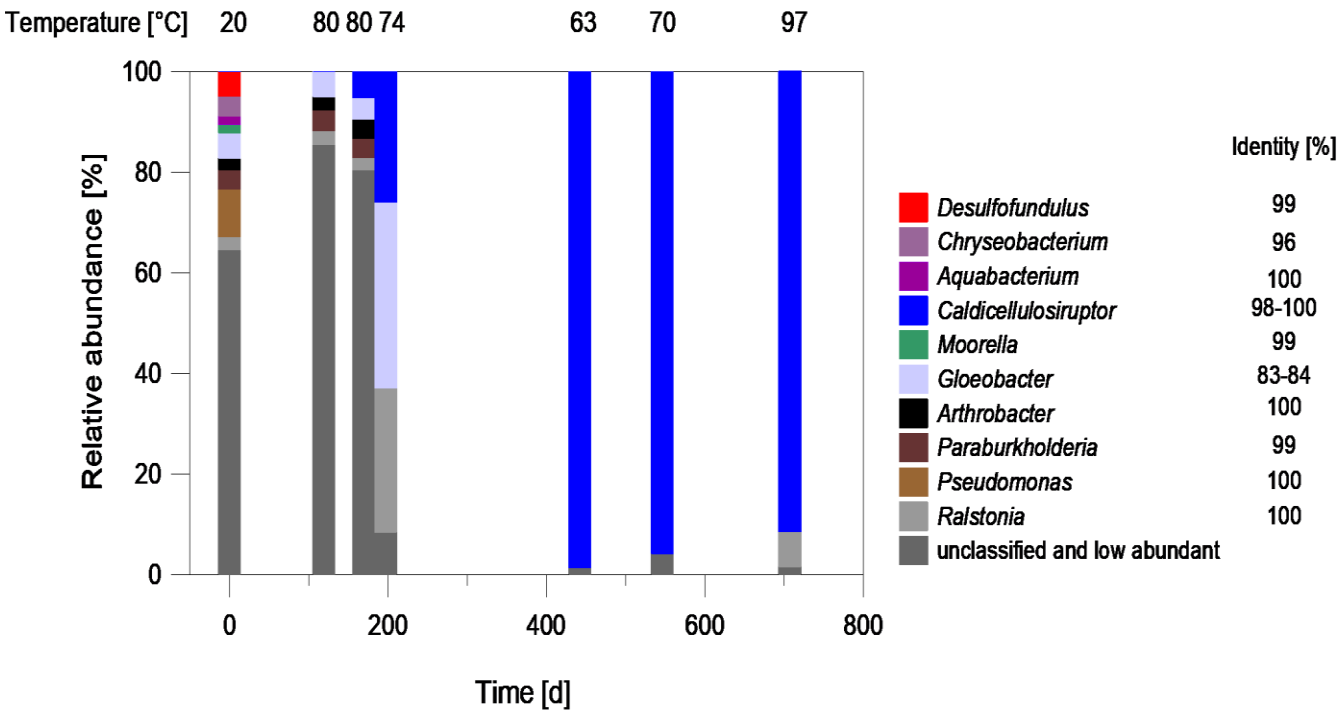
Otten *et al.* 2021

Change of the microbial community composition

(Microbiome analysis)



Microbiome analysis



Characterization of the bacterial biocenosis of fluid samples from the plant exit at the geothermal plant Unterhaching since 700 days inhibitor dosage.

Blue: fermentative bacteria,
Red sulfate-reducing bacteria

Otten *et al.* 2021

Projektträger Jülich
Forschungszentrum Jülich

Gefördert durch:

Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

Many thanks for your attention

GFZ Helmholtz-Zentrum Potsdam
HoME Hochschule Merseburg University of Applied Sciences – Fachbereich Ingenieur- und Naturwissenschaften
TU berlin
SWM Stadtwerke München
GTN Ingenieure & Geologe
BWG Geochemische Beratung GmbH – zur Untersuchung von Wasser und Gas
neu.sw
THEISEN Versorgungstechnik
KSB

Literature

Lerm, S., Westphal, A., Miethling-Graff, R., Alawi, M., Seibt, A., Wolfgramm, M., Würdemann, H. (2013). Thermal effects on microbial composition and microbiologically induced corrosion and mineral precipitation affecting operation of a geothermal plant in a deep saline aquifer. Extremophiles. Volume 17, Issue 2, Page 311-327.

Westphal et al. (2016). Effects of plant downtime on the microbial community composition in the highly saline brine of a geothermal plant in the North German Basin. Appl Microbiol Biotechnol 100(7):3277-3290.

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Kleyböcker, A., Lienen, T., Kasina, M., Westphal, A., Teitz, S., Eichinger, F., Seibt, A., Wolfgramm, M., Würdemann, H. (2017). Effects of heat shocks on biofilm formation and the influence on corrosion and scaling in a geothermal plant in the North German Basin Energy Procedia, Energy Procedia 125 (2017) 268–272. 10.1016/j.egypro.2017.08.173.

Otten *et al.* (2021). Interactions between the calcium scaling inhibitor NC47.1 B, geothermal fluids, and microorganisms – Results of in situ monitoring in the Bavarian Molasse Basin (Germany) and accompanying laboratory experiments. Adv. Geoscience in print.