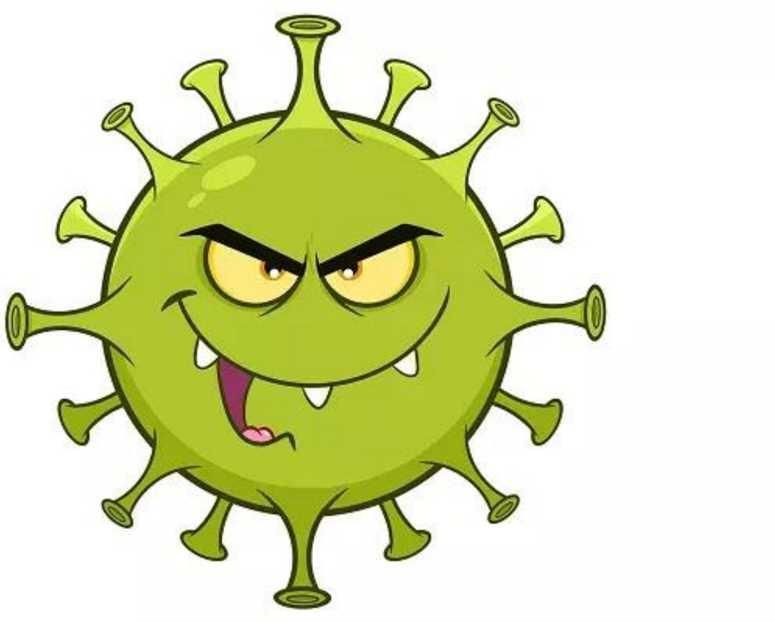


Microbiology in Dutch Geothermal Systems

DAP Symposium
15 October 2021
Ayla Reerink

VEEGEO
Geothermal Energy

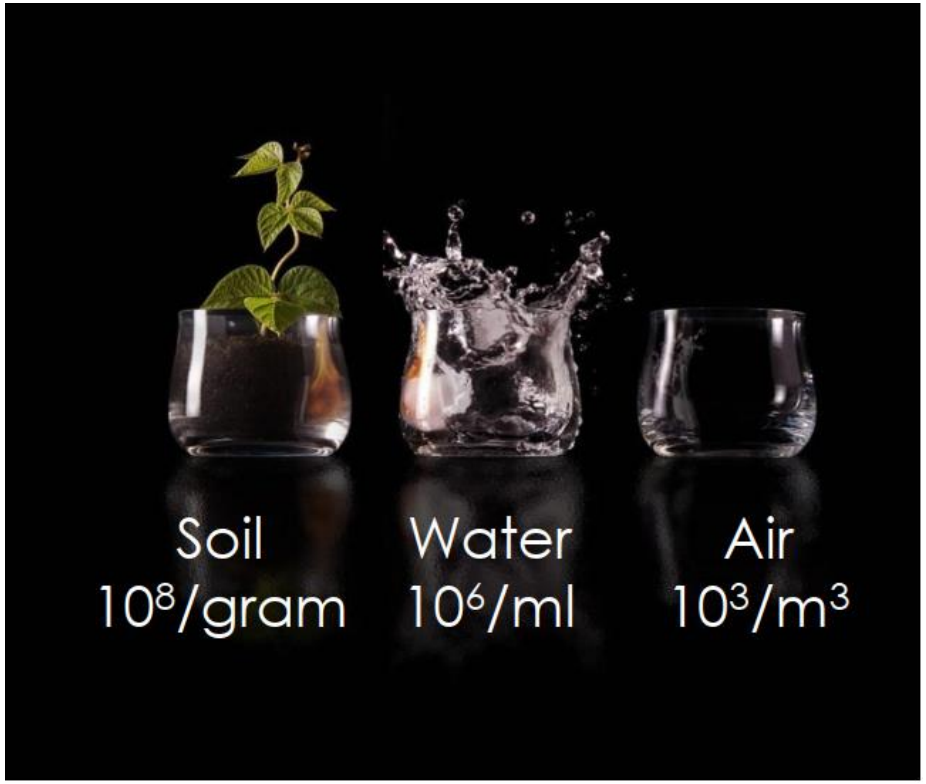
Introduction

- All Dutch geothermal systems contain bacteria
- Presence of bacteria can have a major impact
  - Surface installation & Well integrity issues
    - Microbiological induced corrosion (MIC)
  - Injectivity decline
    - Biofouling
    - Scaling through SRP's
  - Reservoir souring
    - Sulphate reducing Prokarioten
    - Forms Sulphides and H_2S

Reservoir	Sample type	Bacteria present
Triassic	Production water	✓
Delft	Production water	✓
Rotliegend	Production water	✓
Delft	Production water	✓
Rotliegend	Production water	✓
Dinantien	Production water	✓
Brussel	Production water	✓

Ref: Bioclear projectcode 20177513/1987

Introduction

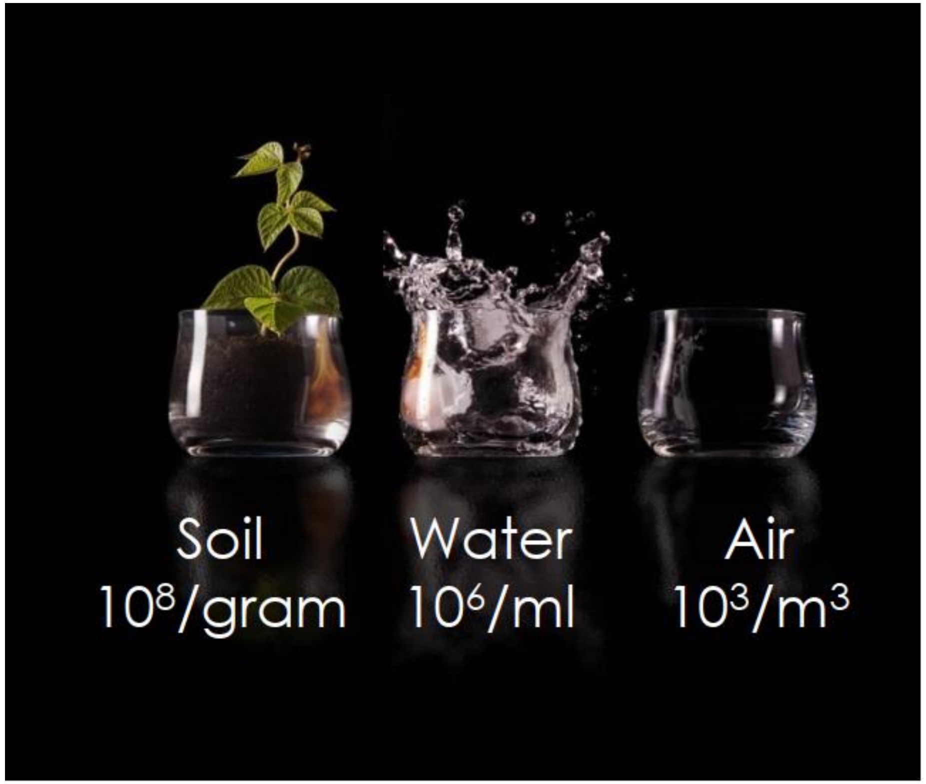


Ref: Bioclear

So how many microbes are in Geothermal Systems?

Introduction

Up to
10^{10}/gram



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Contamination sources & Catalysts

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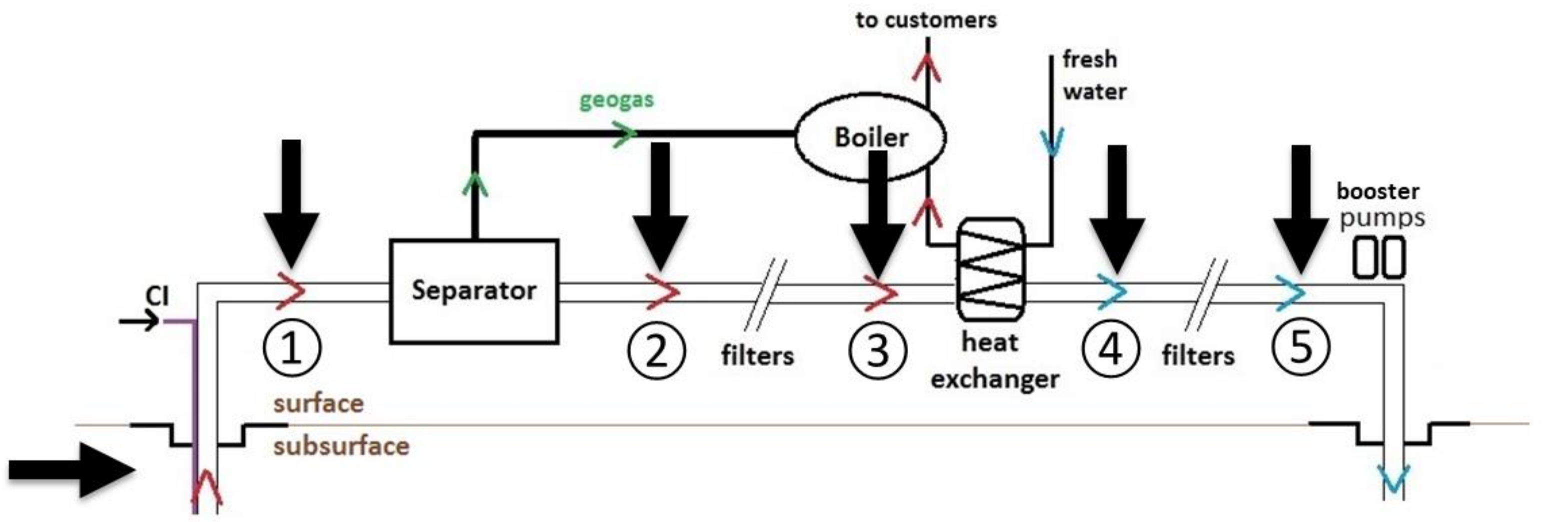
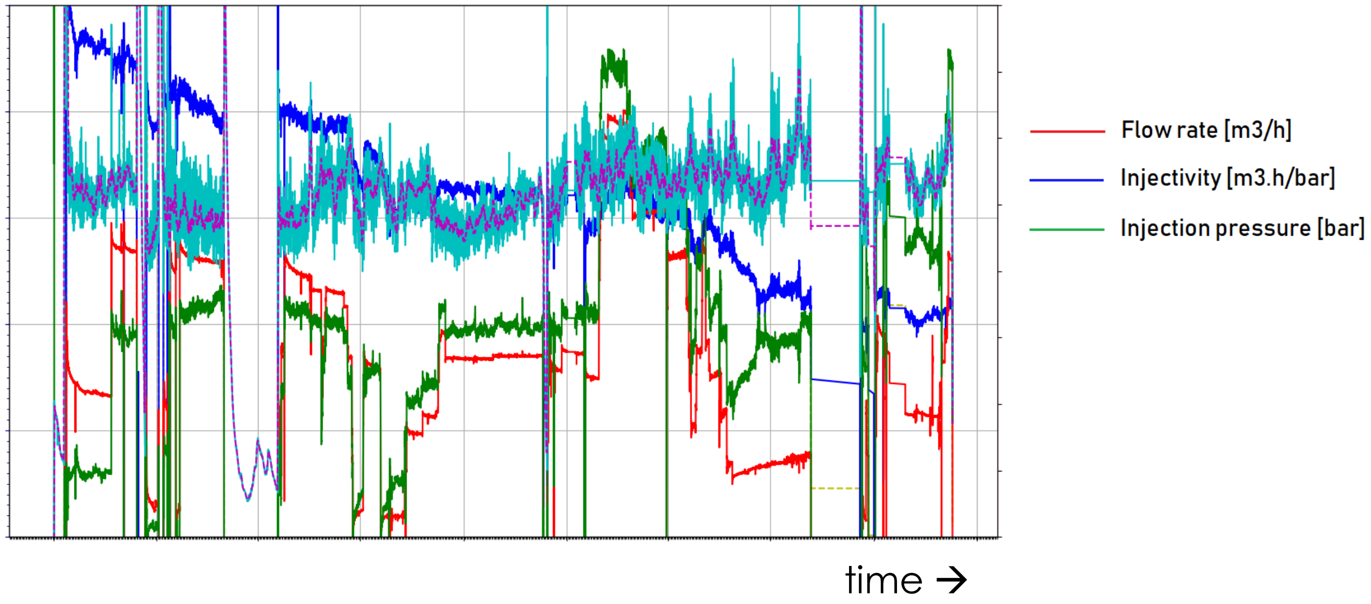
Advise to operators



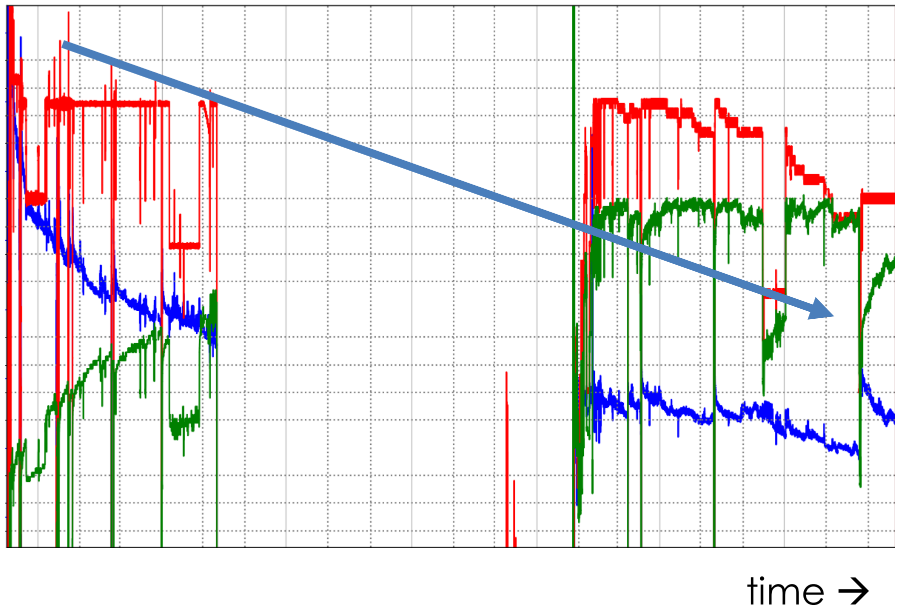
Methods to Identify

1. Injectivity decline

Field example 1



Field example 2



Methods to Identify

2. Solids

Difference between surface solids and subsurface solids

Solids found in filter

Solids found in well

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Methods to Identify

3. Visual inspection

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Field example 1

Table 2: Results bacteria sample 001.

Reads nr.	%	Organism	Remarks/isolation source
91381	60,87%	*Desulfotomaculum halophilum*	Sulphate reducing, anaerobic, halophilic, able to grow autotrophically.
23137	15,41%	*Desulfotomaculum geothermicum*	Sulphate reducing, anaerobic, able to grow autotrophically /Geothermal ground water
9403	6,26%	*Halanaerobium congolense*	Anaerobic, halophilic /petroleum crude oil
8918	5,94%	Peptostreptococcaceae bacterium Col 11	Anaerobic, often feremtatative /Kao-Mei Wetland
2582	1,72%	*Halanaerobium praevalens* DSM 2228	Salt-loving, anaerobic, some sulphate reducing /Great Salt Lake sediment
2014	1,34%	*Gelria glutamica*	Thermophilic, anaerobic, syntrophic /dry anaerobic digester
1668	1,11%	*Halanaerobium lacusrosei*	hypersaline lake
1468	0,98%	*Desulfonosporus* sp. AAN04	mud volcano
1396	0,93%	*Paenibacillus pocheonensis*	biogas Z7 sample
1252	0,83%	*Desulfuribacillus alkaliarsenatis*	leachate sediment
996	0,66%	*Marinilabilia nitratireducens*	
890	0,59%	*Desulfotomaculum* sp. BEN12	pit mud
488	0,33%	*Halanaerobium hydrogeniformans*	microbial biofuel cell inoculated with iron-reducing culture from sediment
471	0,31%	*Halanaerobium congolense*	produced water
416	0,28%	*Desulfotomaculum arcticum*	Sea
296	0,20%	*Desulfovibrio putealis*	
242	0,16%	*Garciella nitratireducens*	thermophilic chicken dung - cow slurry fermentation
236	0,16%	*Desulfotomaculum gibsoniae* DSM 7213	poplar biomass
225	0,15%	Peptostreptococcaceae bacterium Col 11	Guerrero Negro Hypersaline Mat 03; altitude 310m AMSL; sample depth 1m below water level, 2-3mm depth into the mat
208	0,14%	*Halanaerobium hydrogeniformans*	Lake Fazda sediment
207	0,14%	*Marinilabilia salmonicolor* JCM 21150	copper polluted sediment

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Field example 1

1% Biofouling

➢ Injectivity decline

78% SRP

➢ Reservoir souring, Scaling

~ 20 % MIC

➢ Well integrity issues

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Field example 2

Microbial Community	Relative Abundance (%)	Metabolic Basis	Common Source
Methanobacterium sp.	21%	Archeal, non-motile anaerobic, organic biomass digestors, methane producers	Aquatic Sediments, Soil, Sewage
Desulfotignum sp.	18%	Strictly anaerobic, gram negative bacterium, single polar flagellum. Sulphate reducing prokaryote (SRP) which has the potential to dominate in corrosive communities	Saline and hypersaline waters
Desulfofustis glycolicus	13%	Strictly anaerobic, gram negative club-shaped bacterium, Sulphate reducing prokaryote (SRP), utilises glycolic acid as a key substrate (electron donor and carbon source)	Marine sediments
Desulphovibrio sp.	12%	Anaerobic, motile sulphate reducing prokaryote, inherently linked to MIC processes, abundant in both high-organic material environments as well as in extremely oligotrophic habitat	Marine and freshwater systems
Marinobacter Hydrocarbonoclassicus	11%	Adapt to highly diverse environmental conditions, gram negative rod shaped, motile proteobacteria, hydrocarbon clastic so linked to hydrocarbon degradation	Marine Waters

Ref: SGS

Field example 2

21% Biofouling

31% SRP

12% MIC

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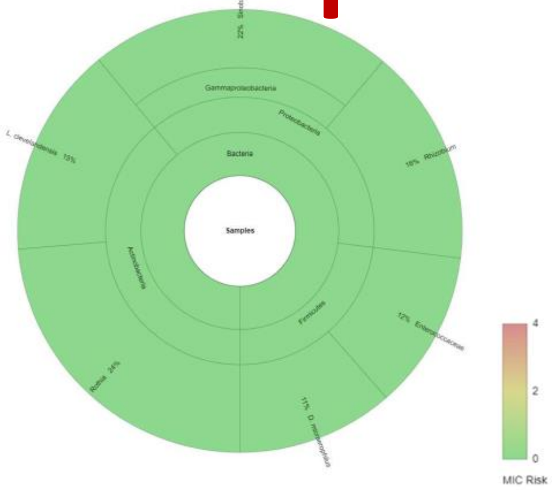
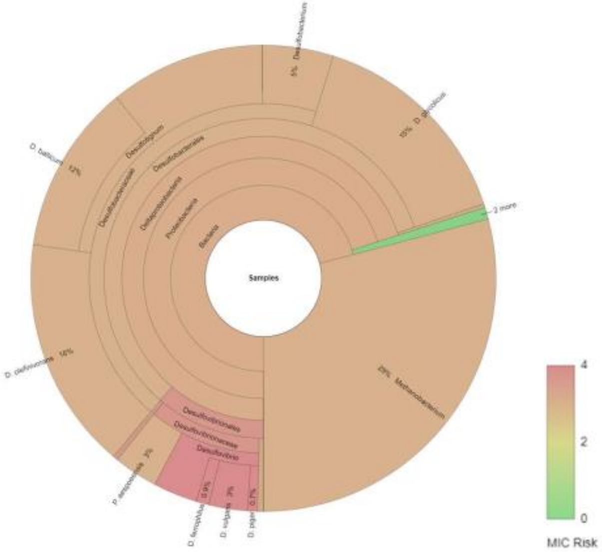
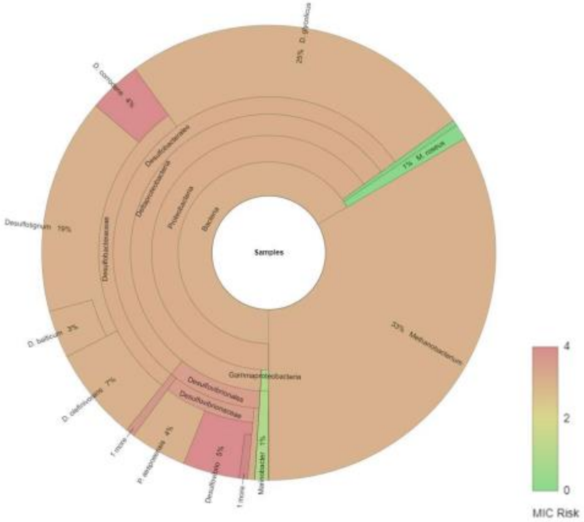


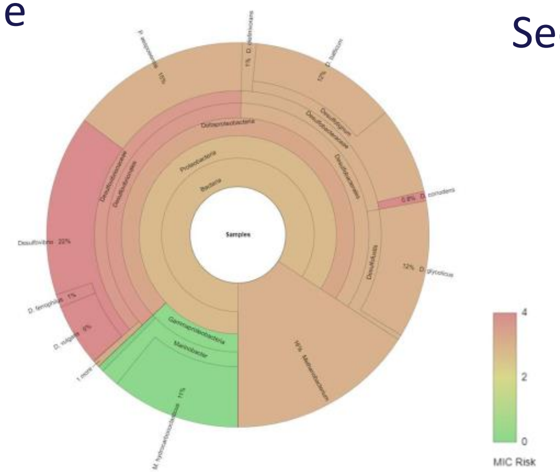
Water sample



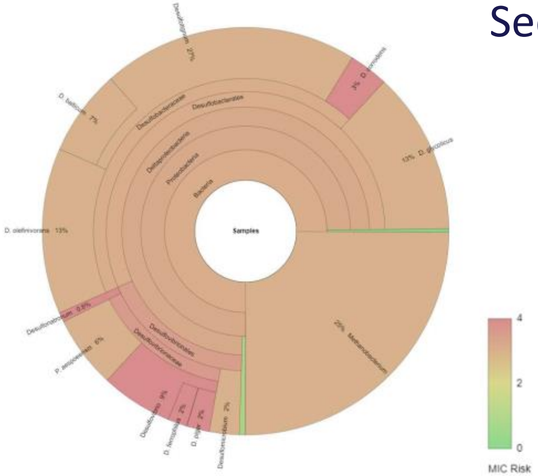
Sediment top filter



Sediment bottom filter



Swab filter housing top



Swab filter housing bottom

	Good control
	Preventive action
	Corrective action

Industry standard interpretation guide

Field learnings

- High diversity in main species
- No direct relation between different reservoirs
- Huge difference in species within one geothermal system

Sample location	Level of contamination
Flowing water	
Stagnant water	
Sediment top filter	
Sediment bottom filter	
Swab top filter	
Swab bottom filter	

Contamination sources

Sources of contamination:

- Human interaction
    - Introducing contaminated tools into the well
    - Reinjection of produced water
- Reservoir itself

Catalysts:

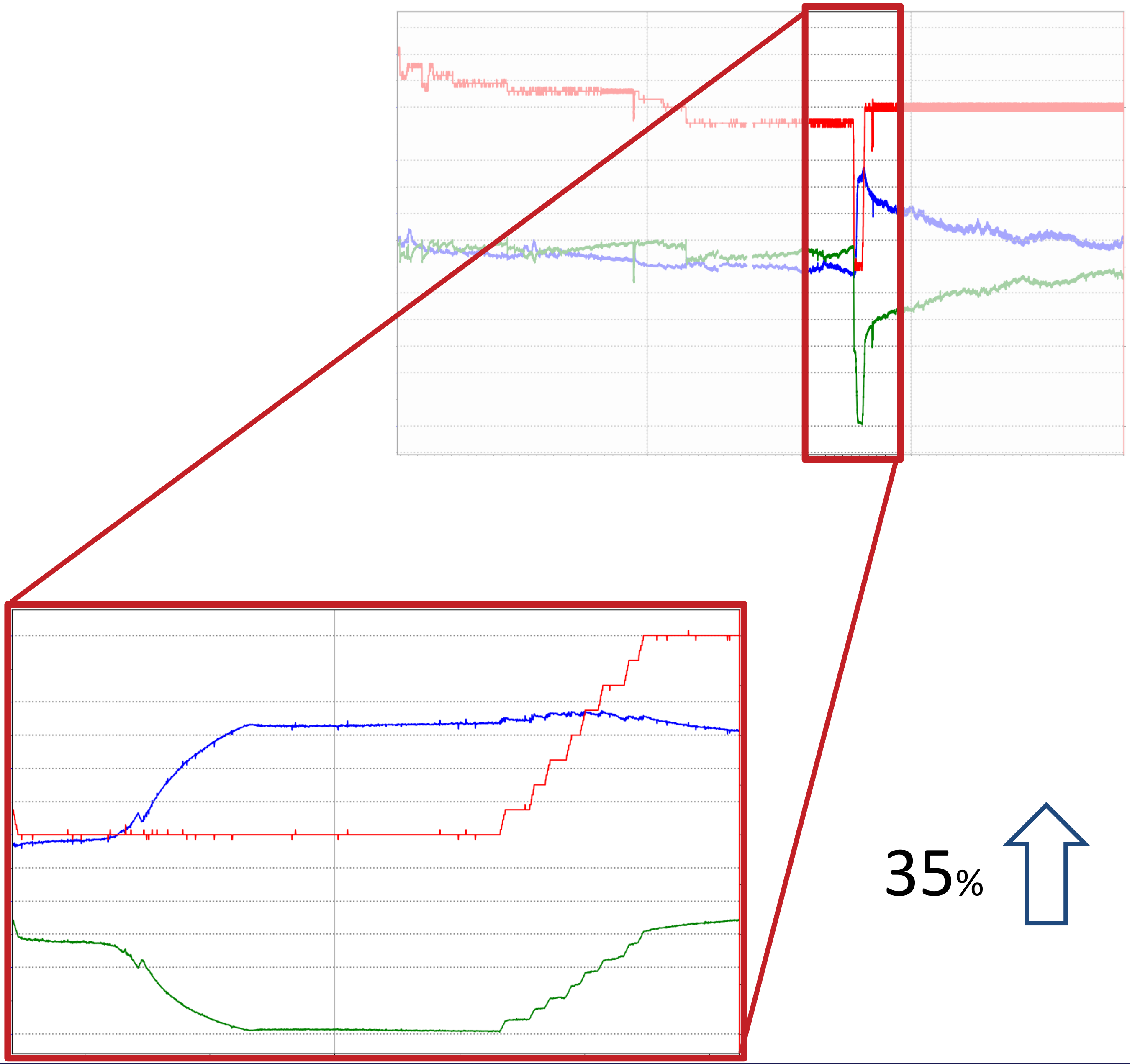
- Temperature
- Chemicals:
    - Corrosion inhibitors
    - Oxygen scavengers
    - and even biocides....

Treatment options

1) Identification of microbes present

2) Treatment plan
   - Kill tests
   - Sampling interval & location
   - Growth rate

3) Biocidal treatment
   - Type of biocide
   - As far upstream as possible



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Early signs

Changes in system response

- Injectivity
- Filter change-out rate
- NORM
- Water analysis

Key factors:

- Iron corrosion product
- Presence of
  - Ironoxide
  - Sulfide
  - Silicon dioxide/Calcium oxide

Advise

Optimise data and sampling analysis protocol including:

- Water analysis should include
  - Sulphate/sulphide
  - Iron
  - Volatile Fatty Acids (VFA's)
  - Total Suspended Solids (TSS)
  - Silt density index (SDI)

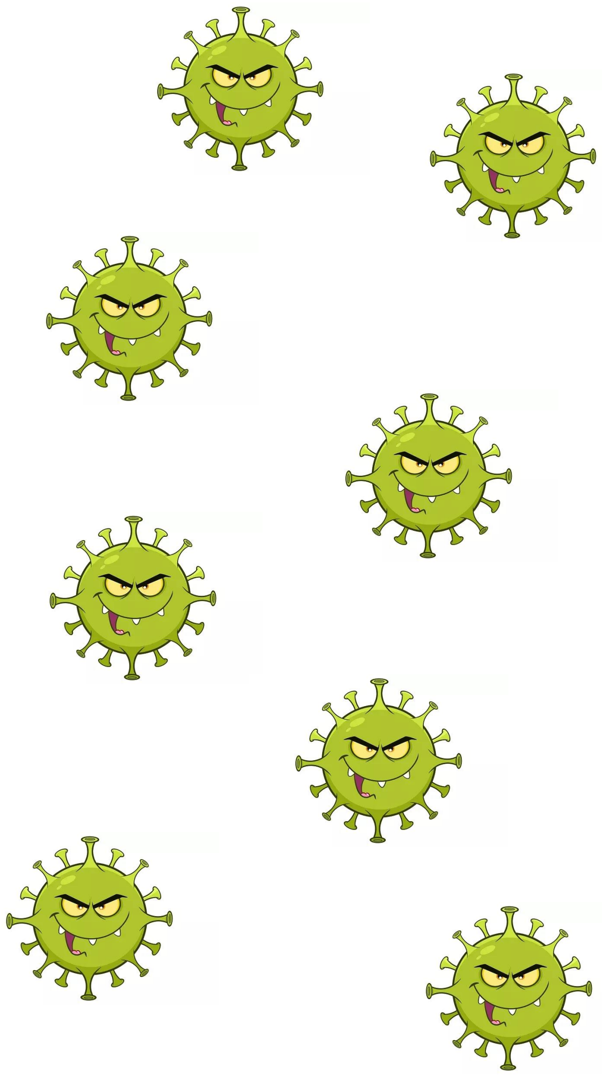
- ATP testing on water and bottom filters

- Trending analysis on injection data

- Gas sample analysis
  - Hydrogen (H_2)
  - Hydrogen Sulphide (H_2S)

Conclusion

- Prevention is better than treatment
- 2/3 systems are under control
- Available treatment options good when the following is in place:
  - Representative microbiological analysis
  - Treatment protocol
  - Frequent production analysis



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