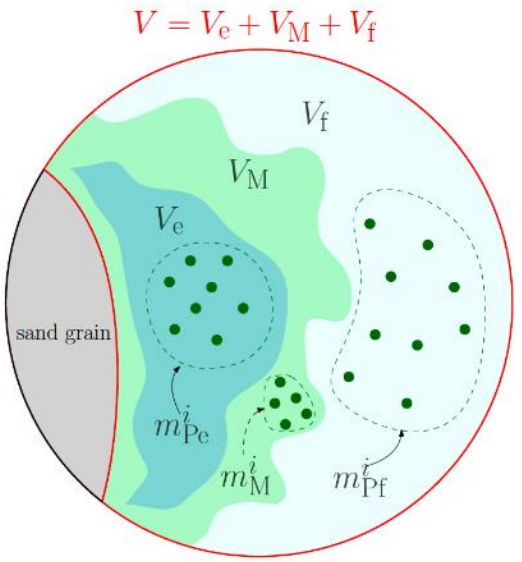
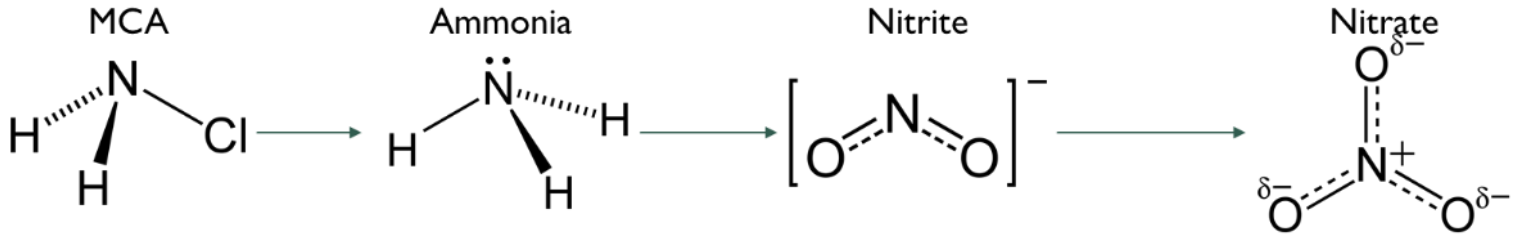
Engineering biofilms - understanding the links between human activities and microbial pathogens and communities

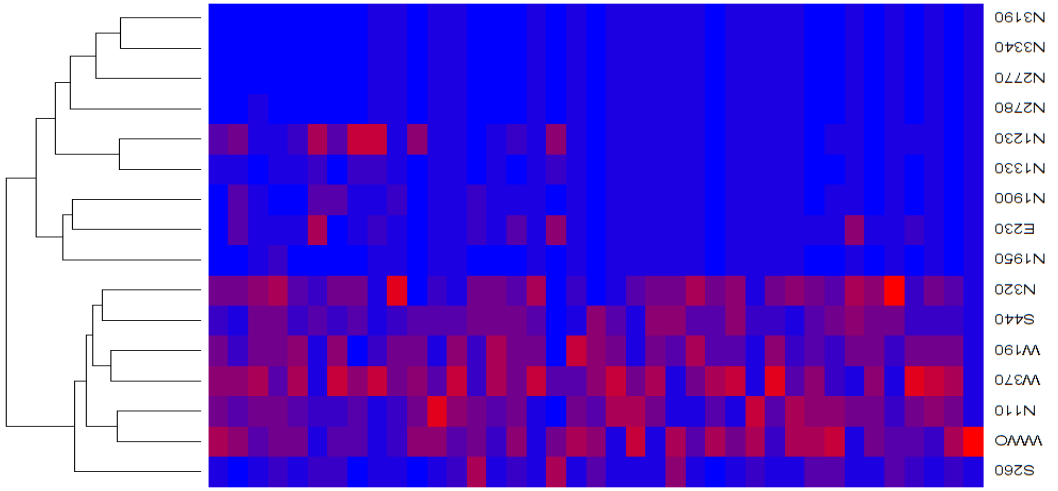


Associate Professor
Catherine J. Paul

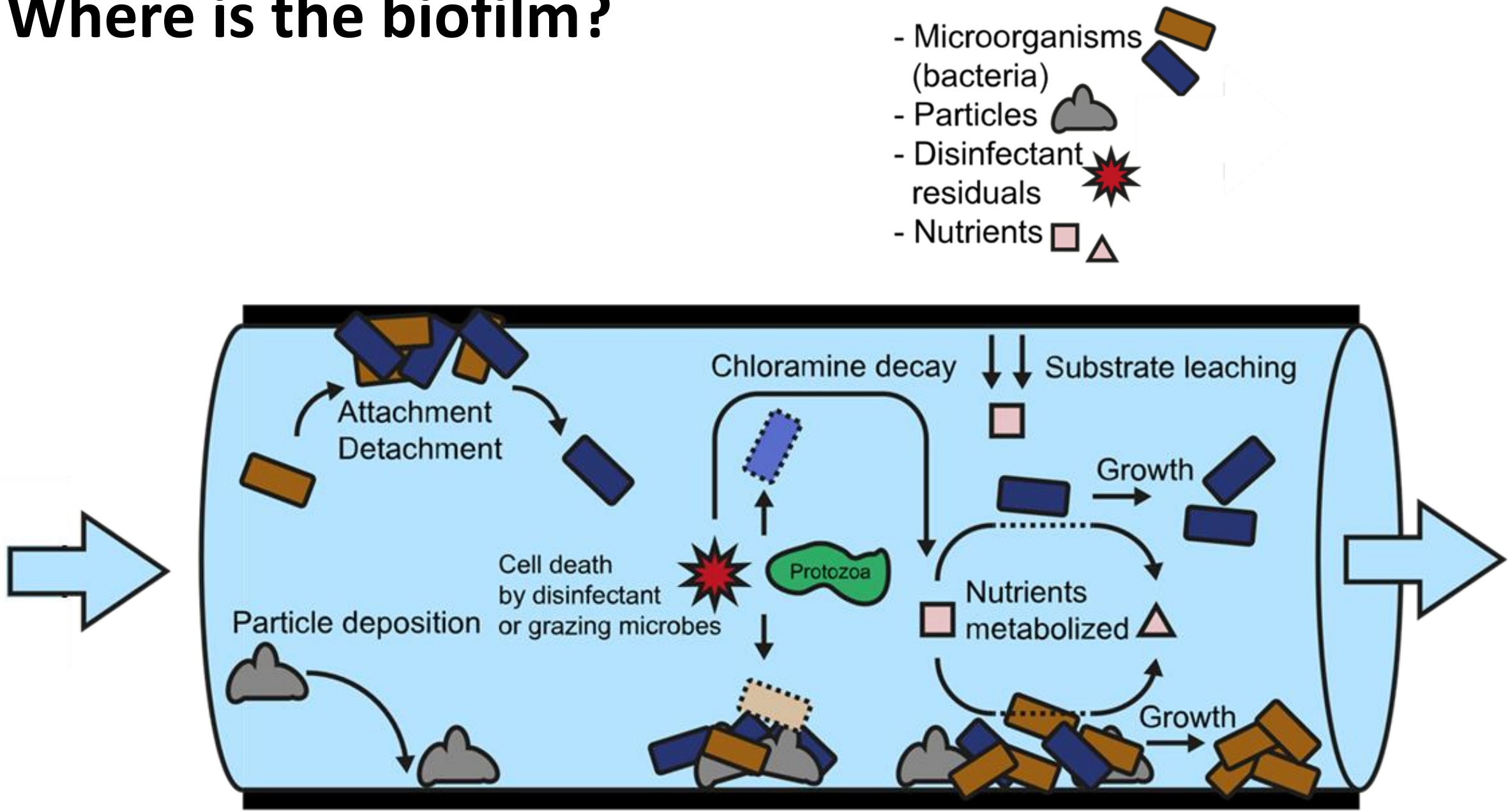
Division of Water Resources Engineering
Division of Applied Microbiology

Department of Building and Environmental Technology
Department of Chemistry
Faculty of Engineering
Lund University

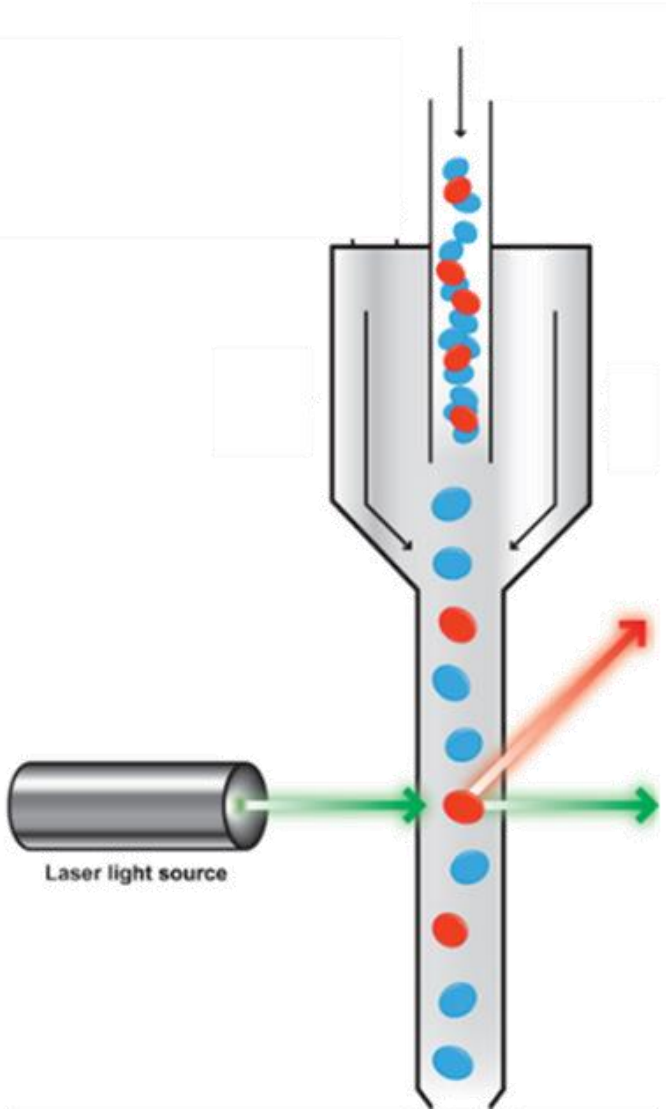


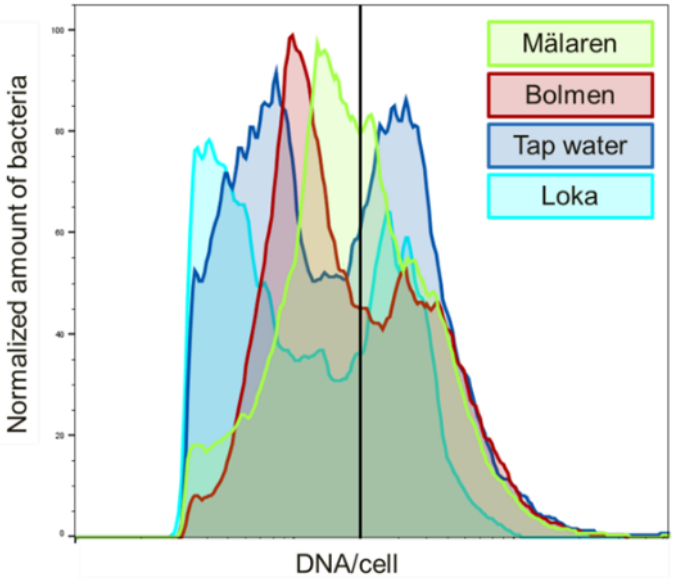


Where is the biofilm?



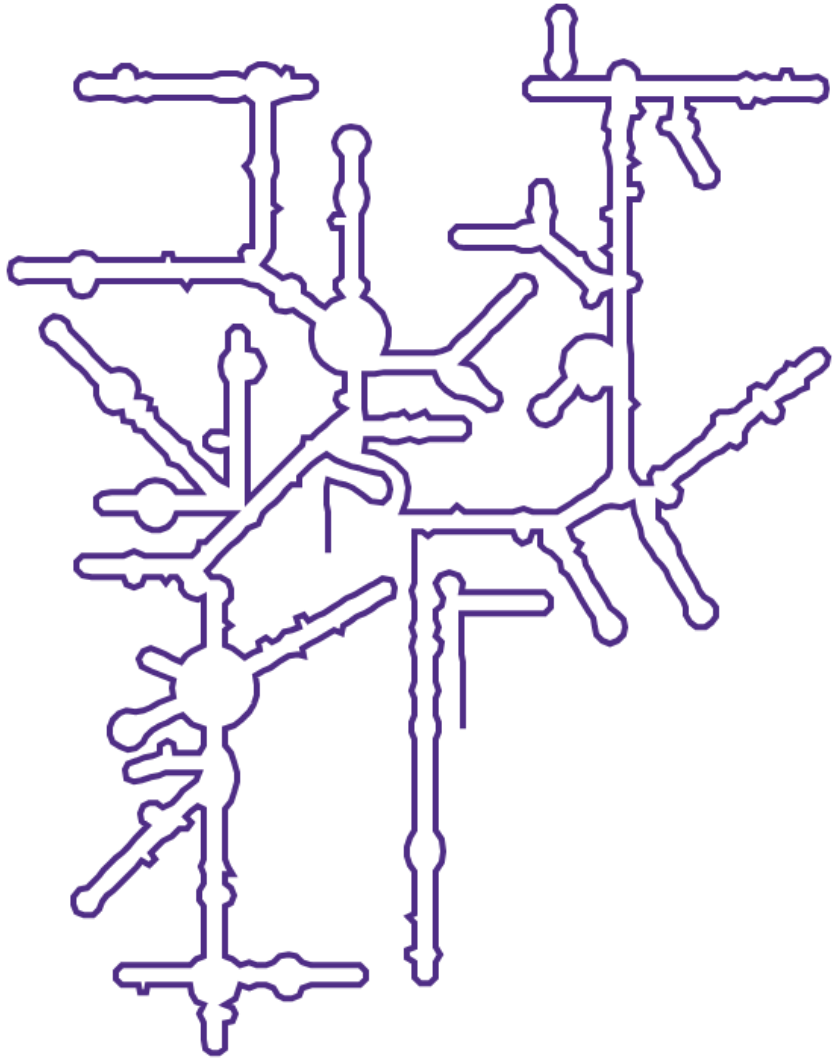
Our tools





- count the cells
- rough DNA profile

Our tools



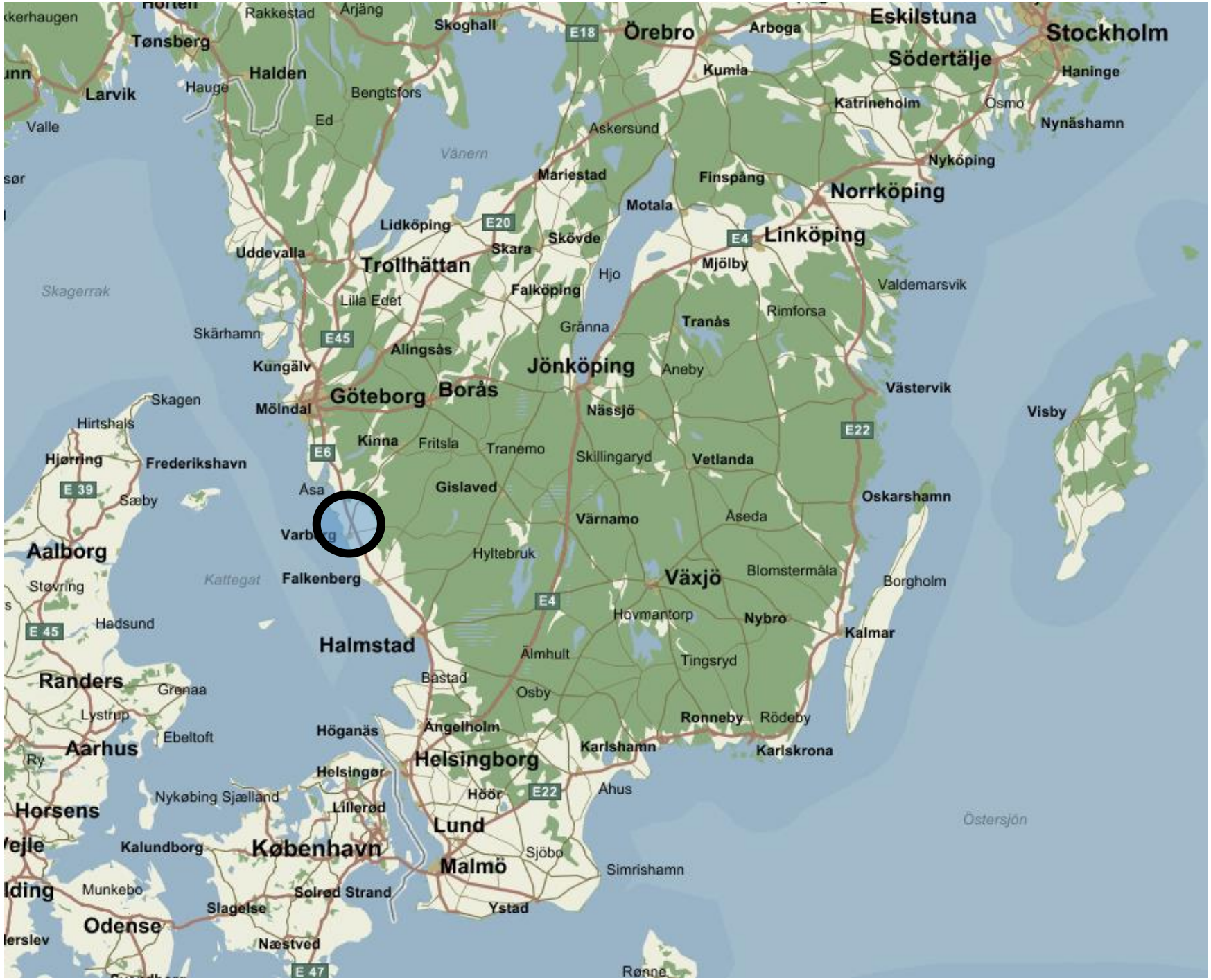
16S rRNA V3-V4
16S rRNA full length

Whole genomes (short and long reads)
Metagenomes

SciLifeLab

UPPMAX

NBIS

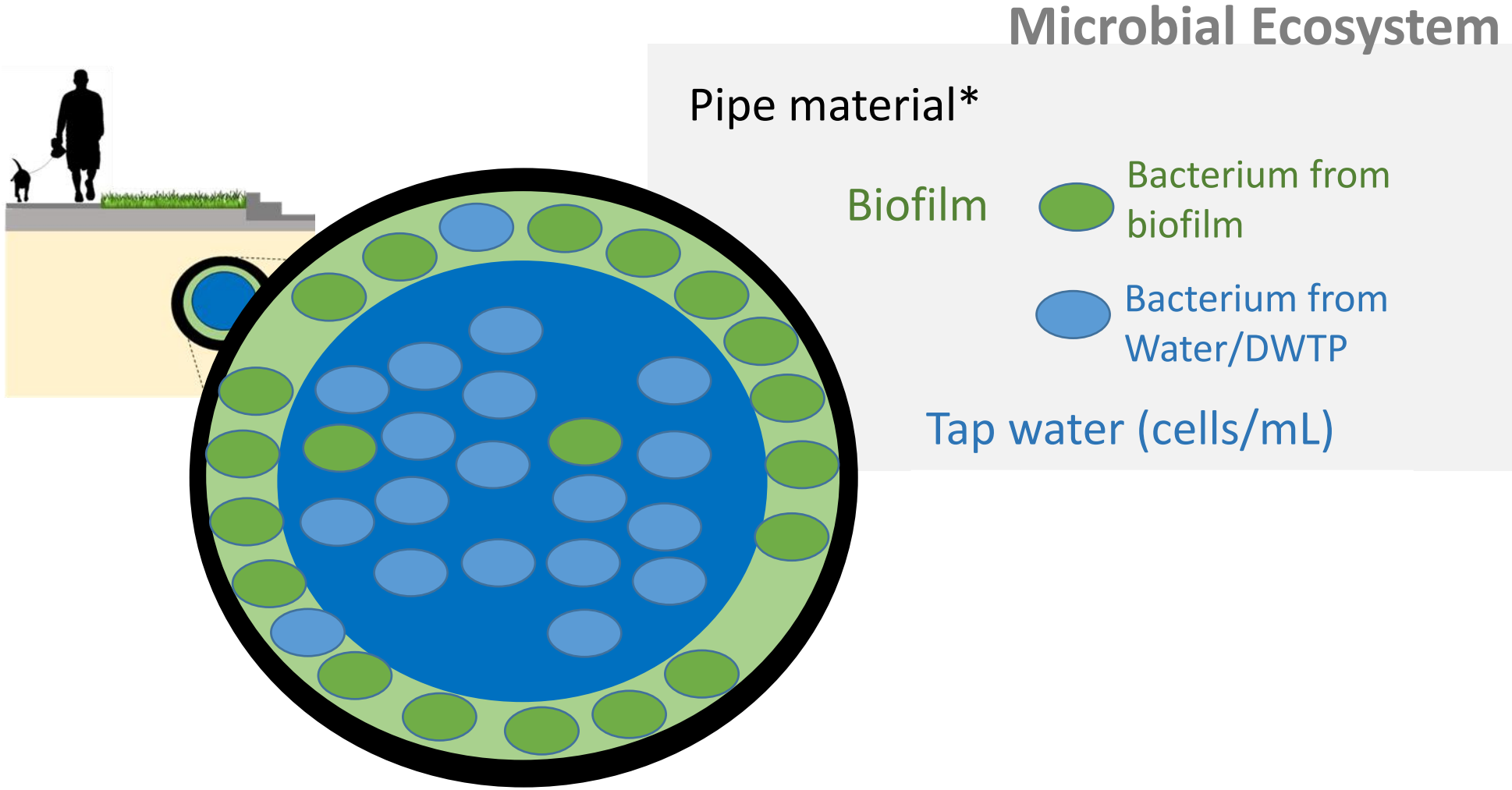

Rakkestad
Årjäng
Skoghall
E18
Örebro
Arboga
Eskilstuna
Stockholm
Tønsberg
Halden
Kumla
Södertälje
Haninge
Larvik
Hauge
Bengtsfors
Katrineholm
Osmo
Nynäshamn
Valle
Ed
Askersund
Vänern
Nyköping
Mariestad
Finspång
Norrköping
Motala
Lidköping
E20
Skövde
E4
Linköping
Uddevalla
Skara
Mjölby
Trollhättan
Hjo
Valdemarsvik
Skagerrak
Falköping
Lilla Edet
Rimforsa
Tranås
Gränna
Skärhamn
E45
Alingsås
Kungälv
Jönköping
Aneby
Västervik
Skagen
Göteborg
Borås
Mölndal
Nässjö
Visby
Hirtshals
E22
Kinna
Fritsla
Tranemo
E6
Skillingaryd
Vetlanda
Hjørring
Frederikshavn
Oskarshamn
E 39
Sæby
Åseda
Gislaved
Värnamo
Varberg
Hyltebruk
Aalborg
Växjö
Blomstermåla
Kattegat
Falkenberg
Borgholm
Støvring
E4
Hovmantorp
Nybro
Kalmar
E 45
Hadsund
Halmstad
Älmhult
Tingsryd
Randers
Grenaa
Båstad
Osby
Lystrup
Ronneby
Rödeby
Höganäs
Ängelholm
Ebeltoft
Karlshamn
Karlskrona
Aarhus
Helsingborg
Ry
Helsingør
Höör
E22
Åhus
Nykøbing Sjælland
Horsens
Lillerød
Lund
Kalundborg
København
Sjöbo
Malmö
Simrishamn
Munkebo
Solrød Strand
Ystad
Slagelse
Odense
Næstved
E 47
Rønne
Östersjön

Humans impact microbiomes by changing processes in drinking water production.

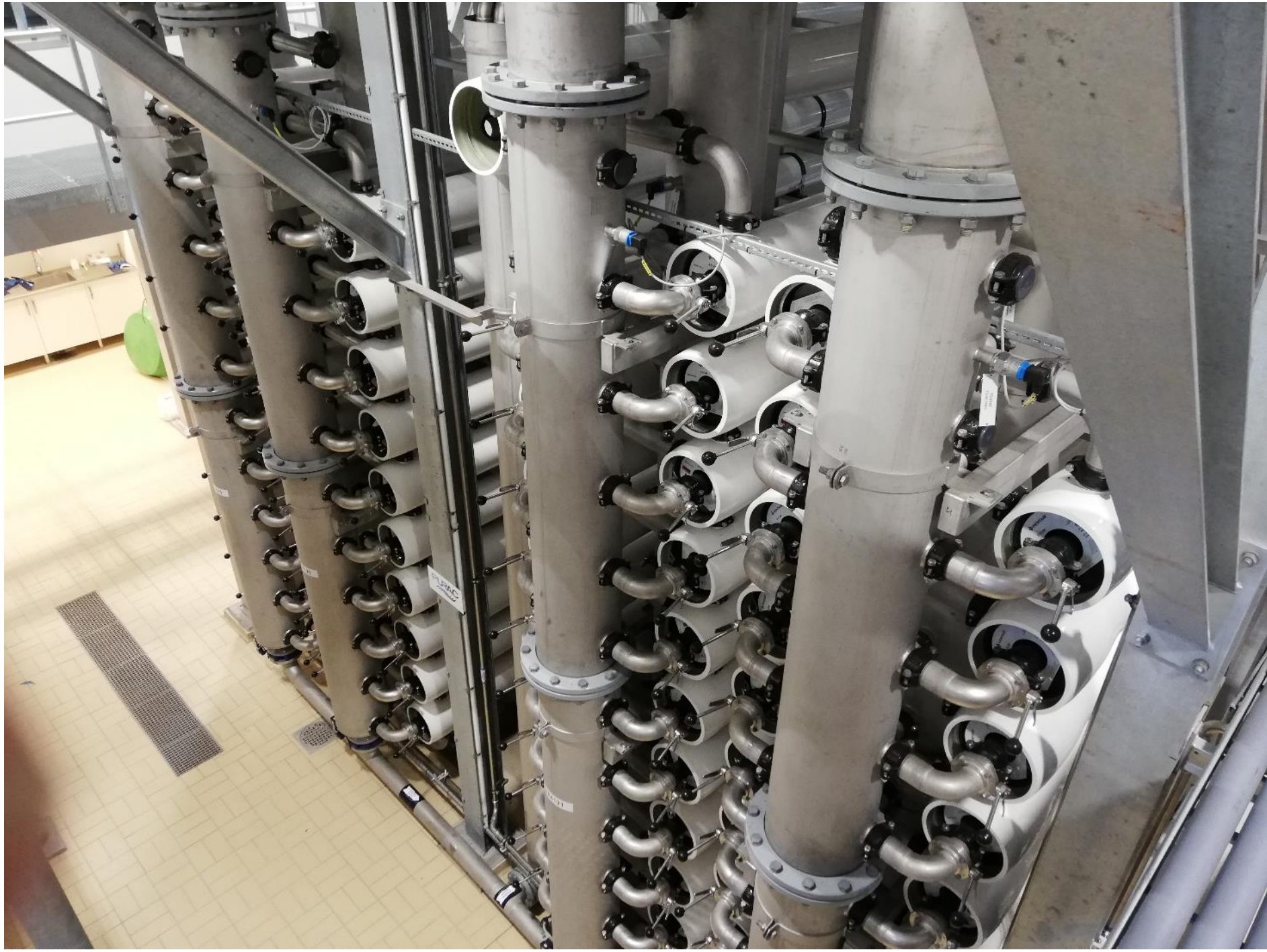
How many biofilm bacteria are there in drinking water?

How can our knowledge of biofilm make water safer?

This biofilm is constantly interacting with the water

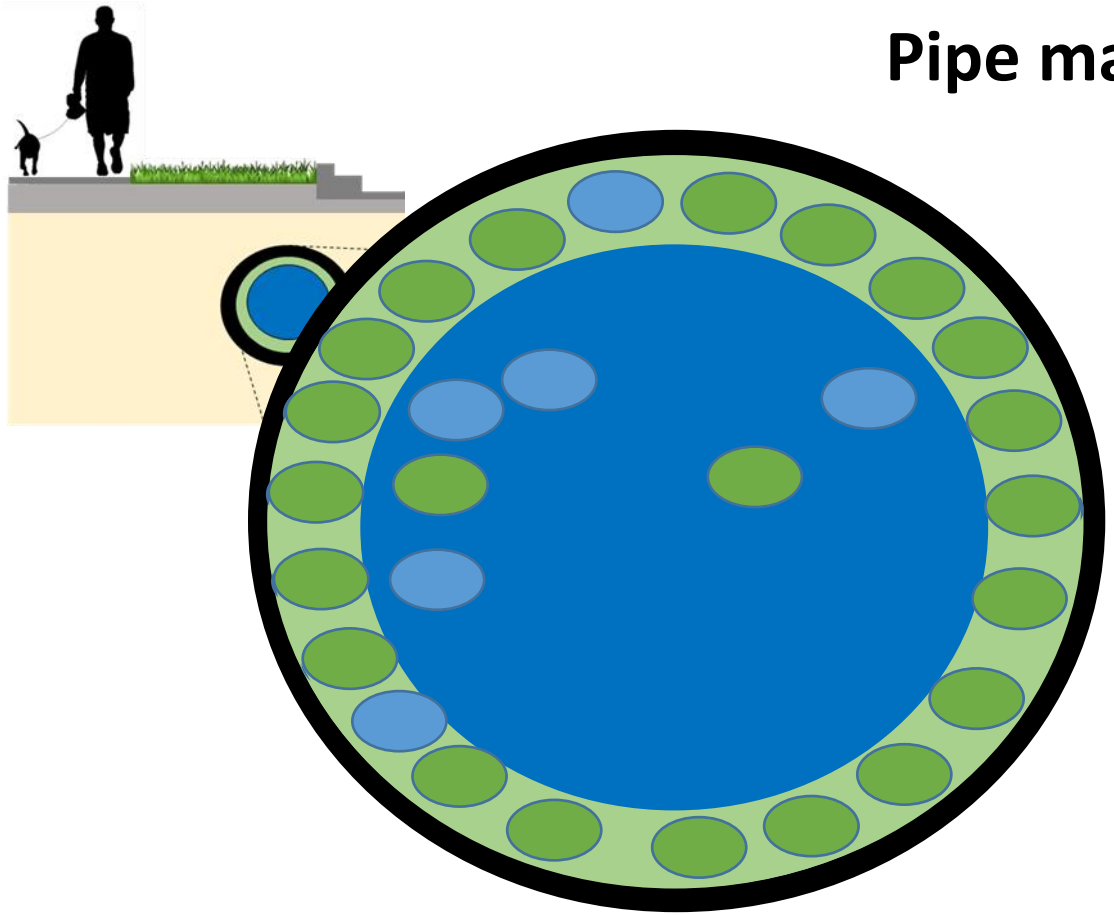


*not to scale



IDEA:

Installation of UF in Varberg



Pipe material*

Biofilm

Bacterium from biofilm

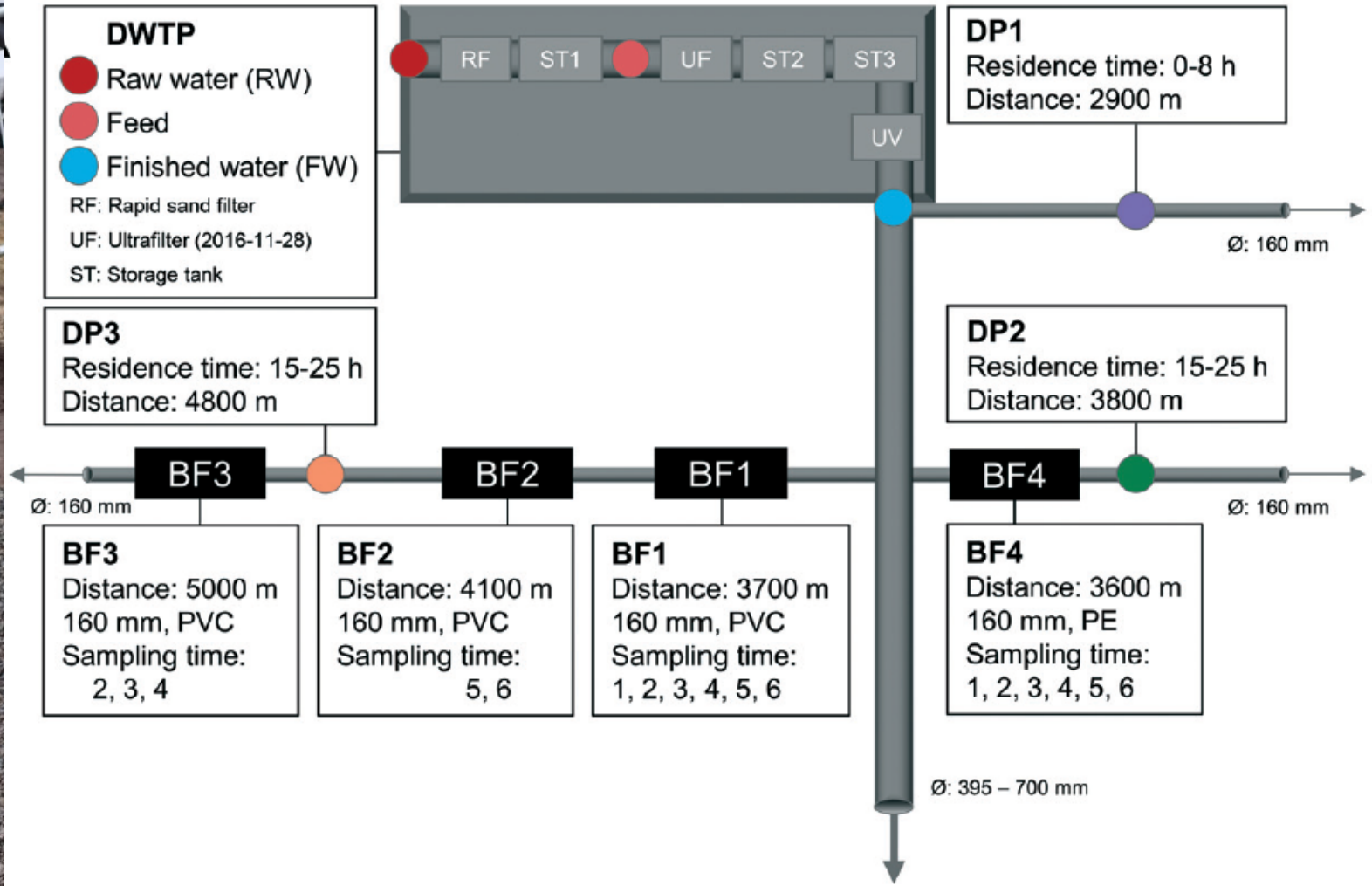
Bacterium from Water/DWTP

Tap water (cells/mL)

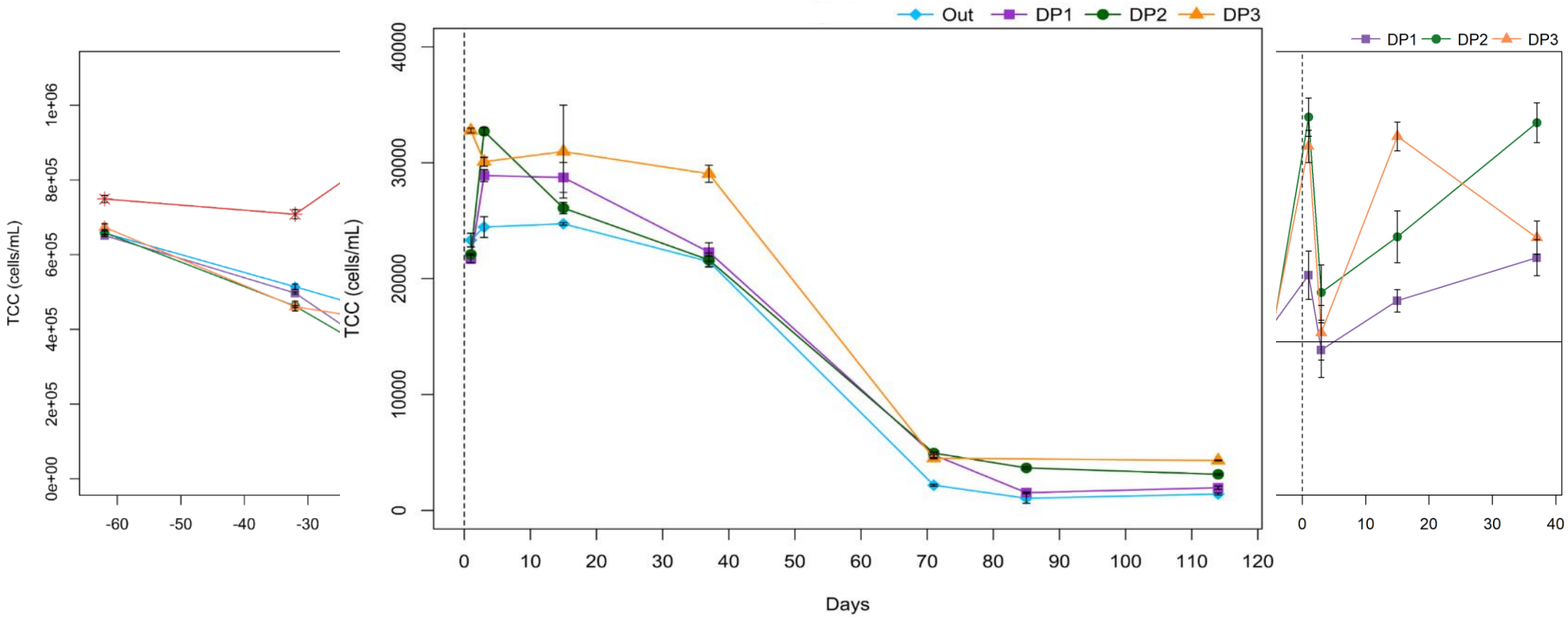
Varberg: 750 000

*still not to scale

Chan, S., Pullerits, K., Keucken, A., Persson, K.M., Paul, C.J. and Rådström, P., 2019. Bacterial release from pipe biofilm in a full-scale drinking water distribution system. npj Biofilms and Microbiomes, 5(1), p.9.



How many bacteria are leaving the biofilm?

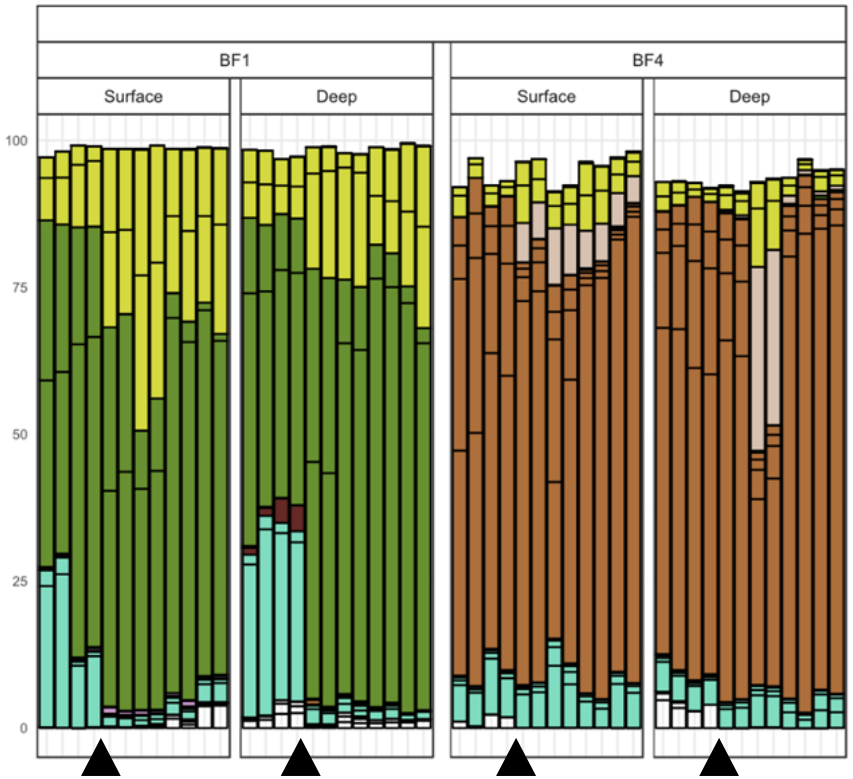


From the DWTP
From the biofilm

Before UF: around 750 000 cells/mL
Before UF: 0.5%

After UF: around 2000 cells/mL%
After UF: 58%

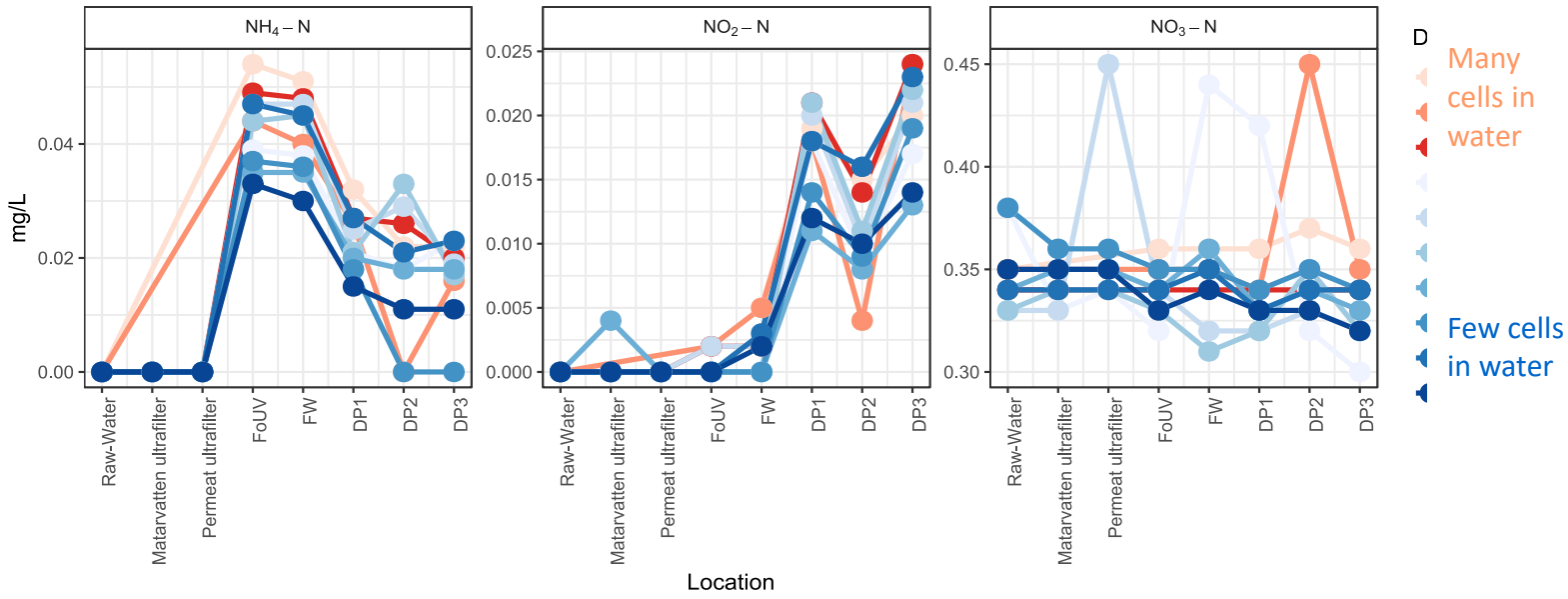
BF 1 BF3,4



UF start

Nitrosomonadaceae ***Nitrospira*** ***Hyphomicrobium***

$NH_2Cl \rightarrow NO_2^- + 2H^+$ $NO_2^- \rightarrow NO_3^-$ $NO_2^- \leftarrow NO_3^-$



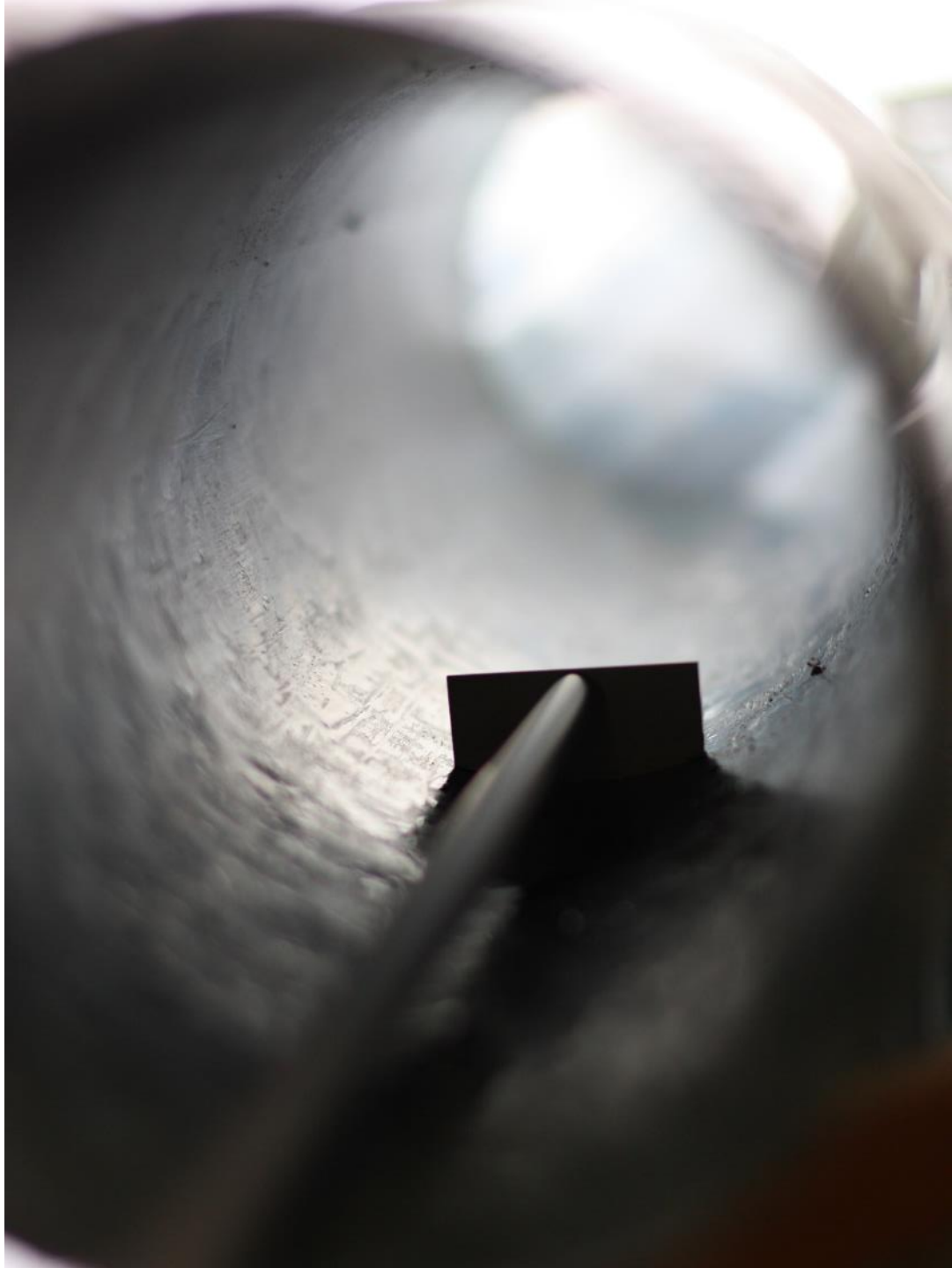
Pullerits, K., Chan, S., Ahlinder, J., Keucken, A., Rådström, P. and Paul, C.J., 2020. Impact of coagulation–ultrafiltration on long-term pipe biofilm dynamics in a full-scale chloraminated drinking water distribution system. *Environmental Science: Water Research & Technology*, *6*(11), pp.3044-3056.

We have learned:

The biofilm influences the drinking water to a greater extent when ultrafiltration is present.

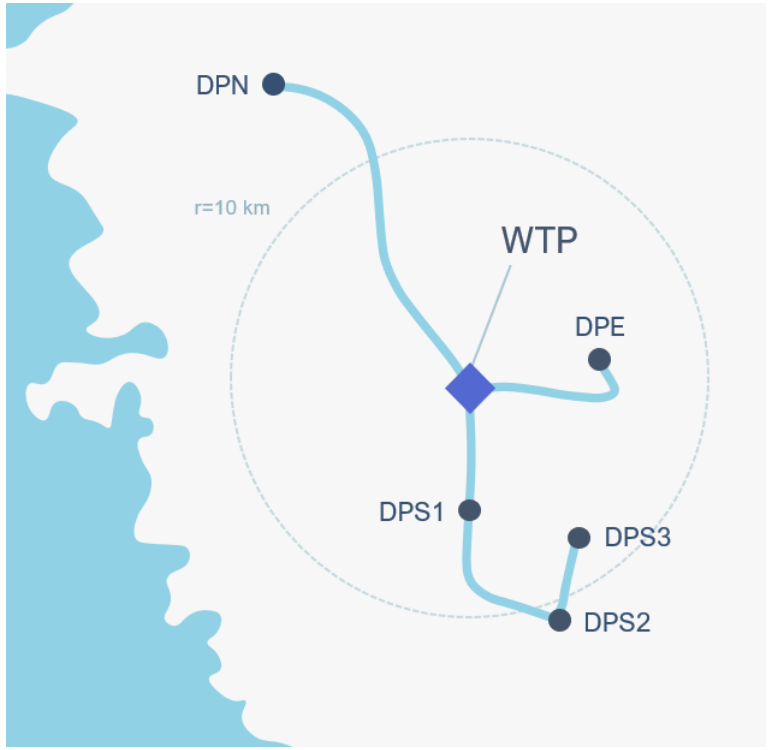
The biofilm didn’t change when ultrafiltration was installed.

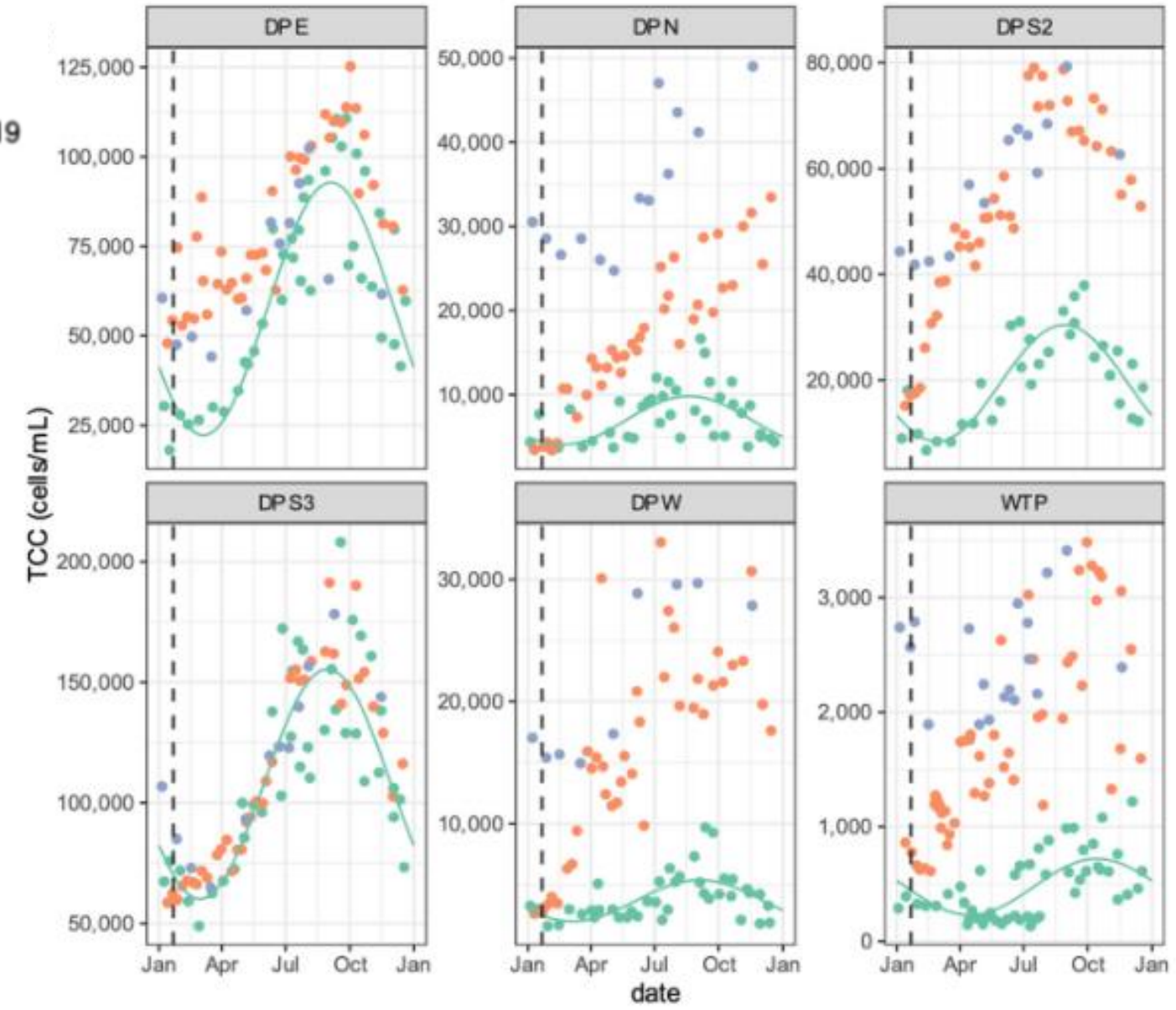
….because the biofilm is an nitrogen-based ecosystem.



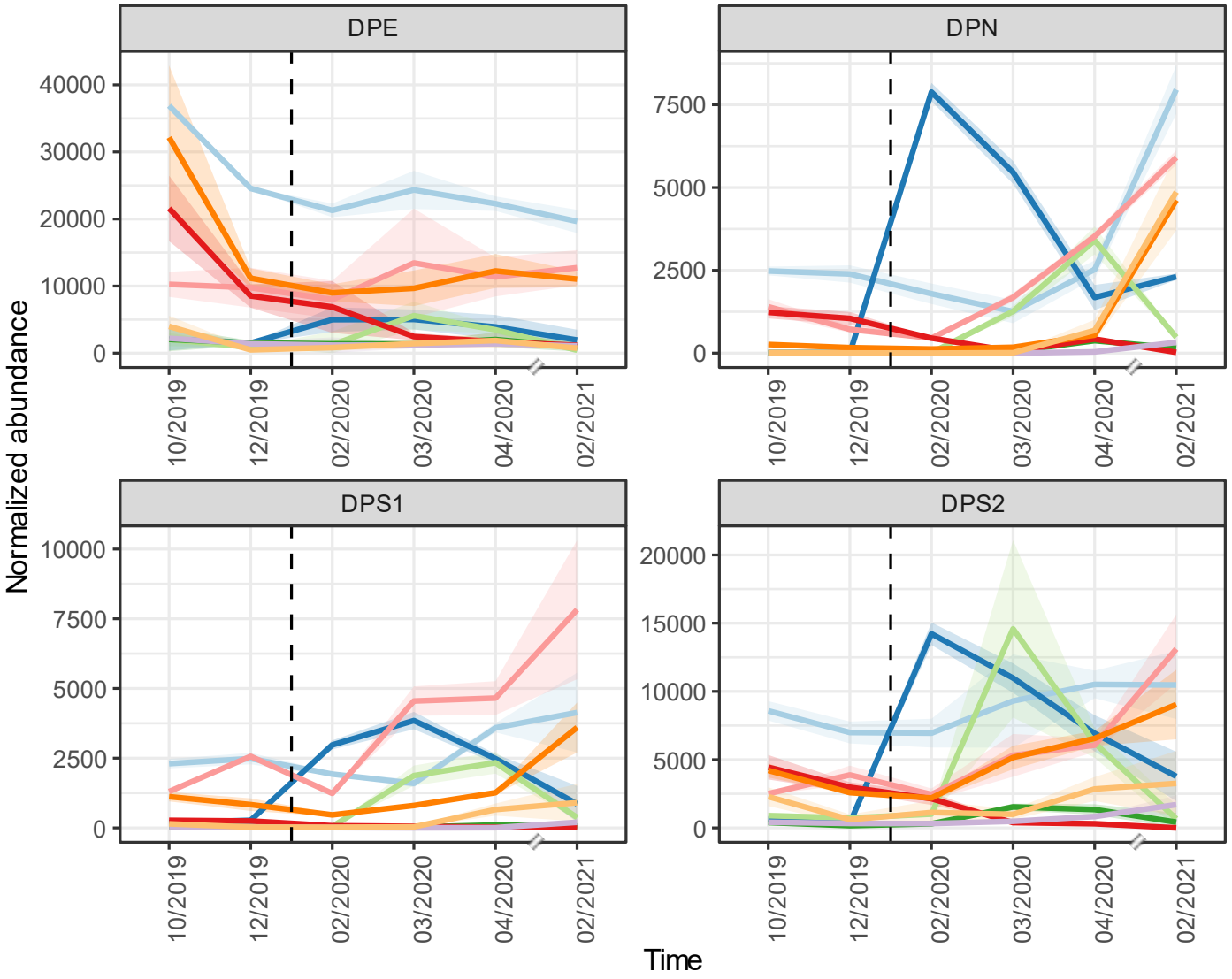
In a monochloraminated system….

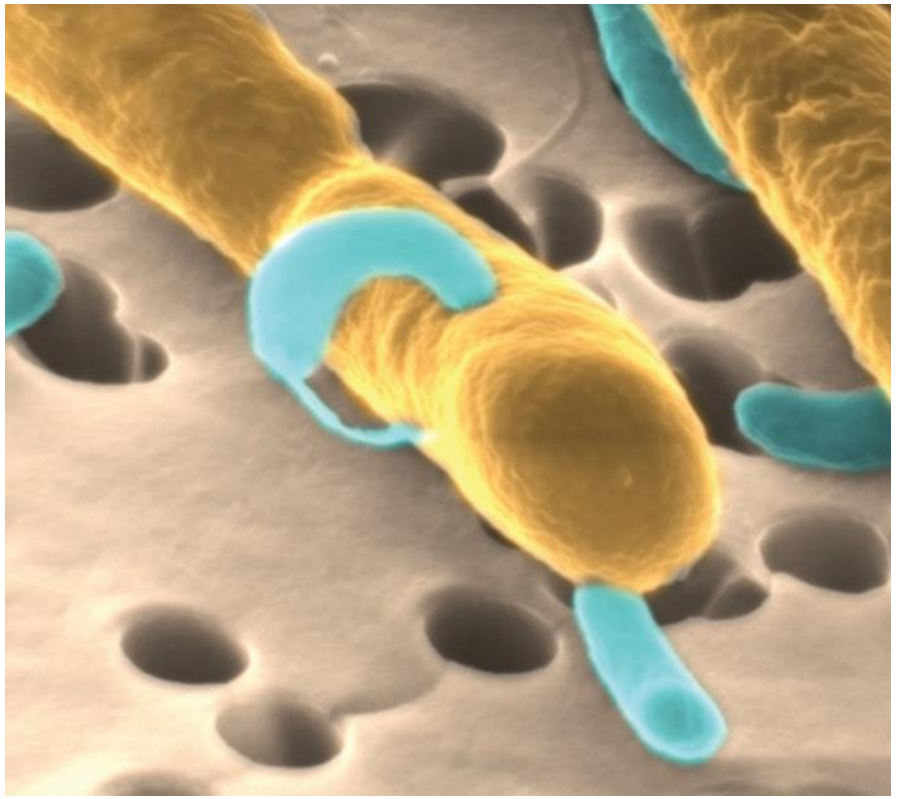
are we just feeding the biofilm?

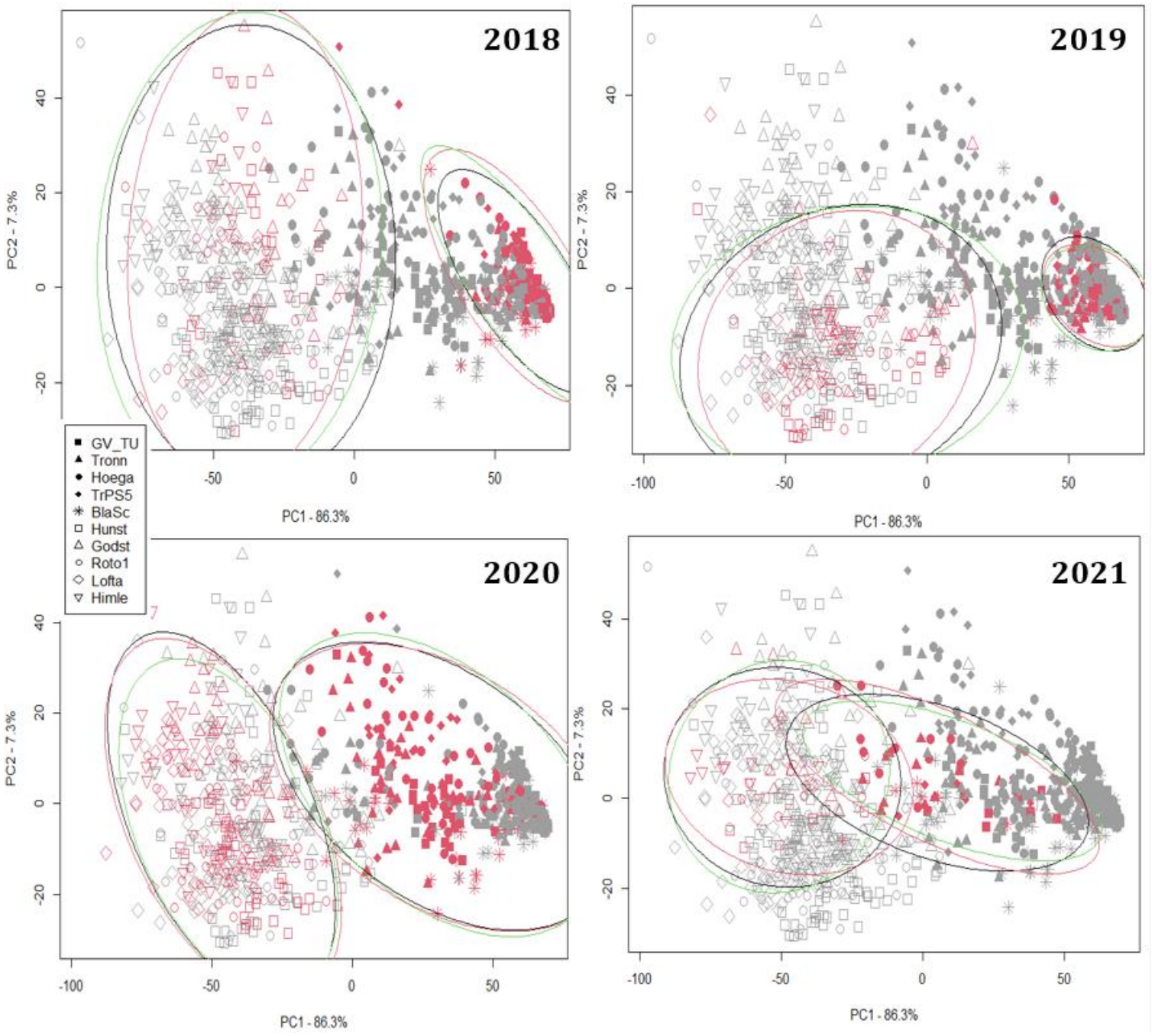




Rosenqvist, T., Danielsson, M., Schleich, C., Ahlinder, J., Brindefalk, B., Pullerits, K., ... & Paul, C. J. (2023). Succession of bacterial biofilm communities following removal of chloramine from a full-scale drinking water distribution system. *npj Clean Water*, *6*(1), 41.


DPE
DPN
DPS1
DPS2
Normalized abundance
Time
40000
30000
20000
10000
0
7500
5000
2500
15000
10/2019
12/2019
02/2020
03/2020
04/2020
02/2021



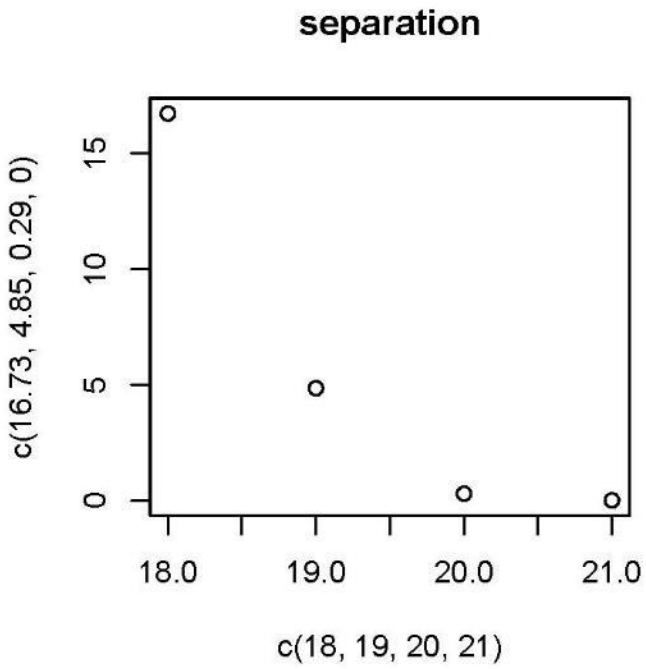


10 locations
Weekly flow cytometry

Solid shapes are close to the DWTP

Empty shapes are further away

Red is that year's data



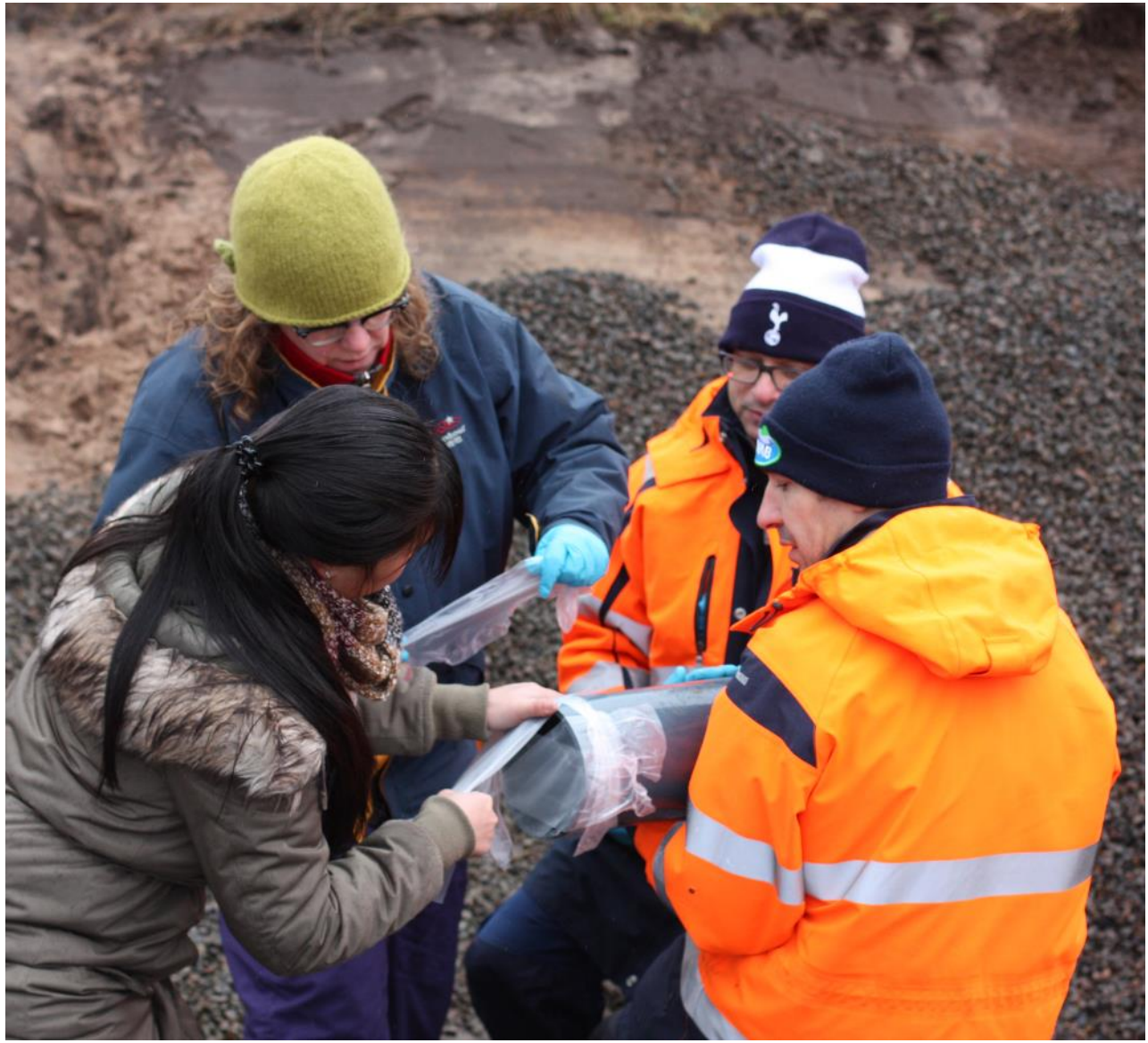
We have learned:

We are feeding the biofilm.

No indications of compromised safety.

Rare taxa from the biofilm can appear in abundance if the conditions are right.

Universities and utilities can help each other



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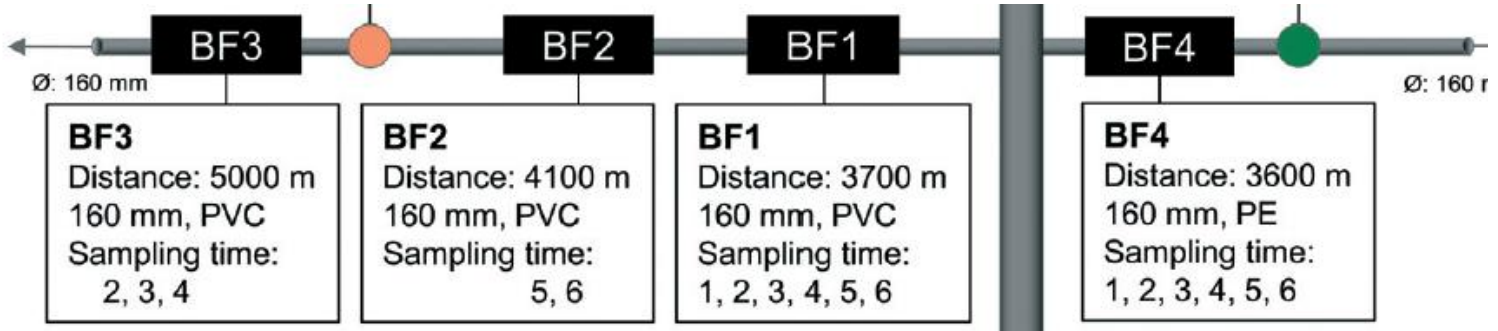
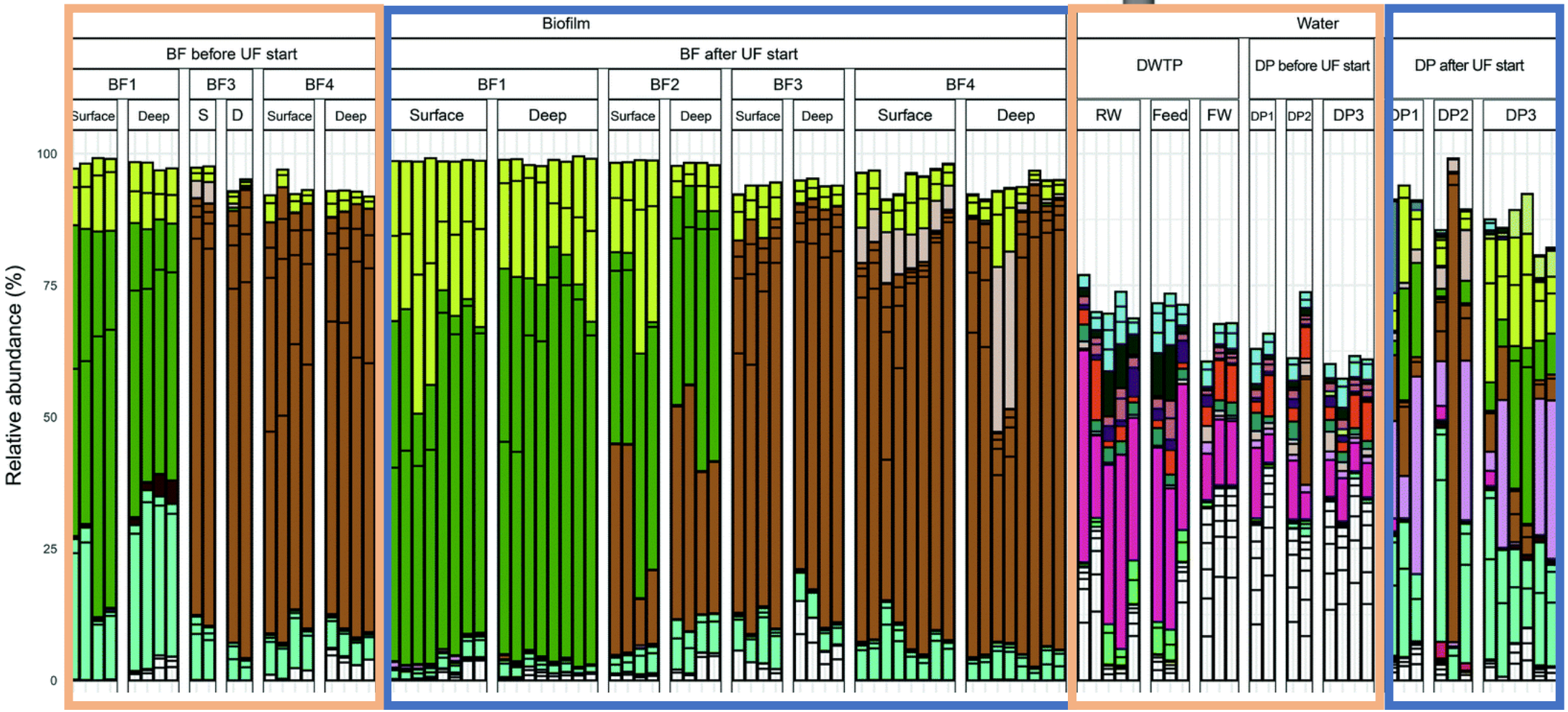
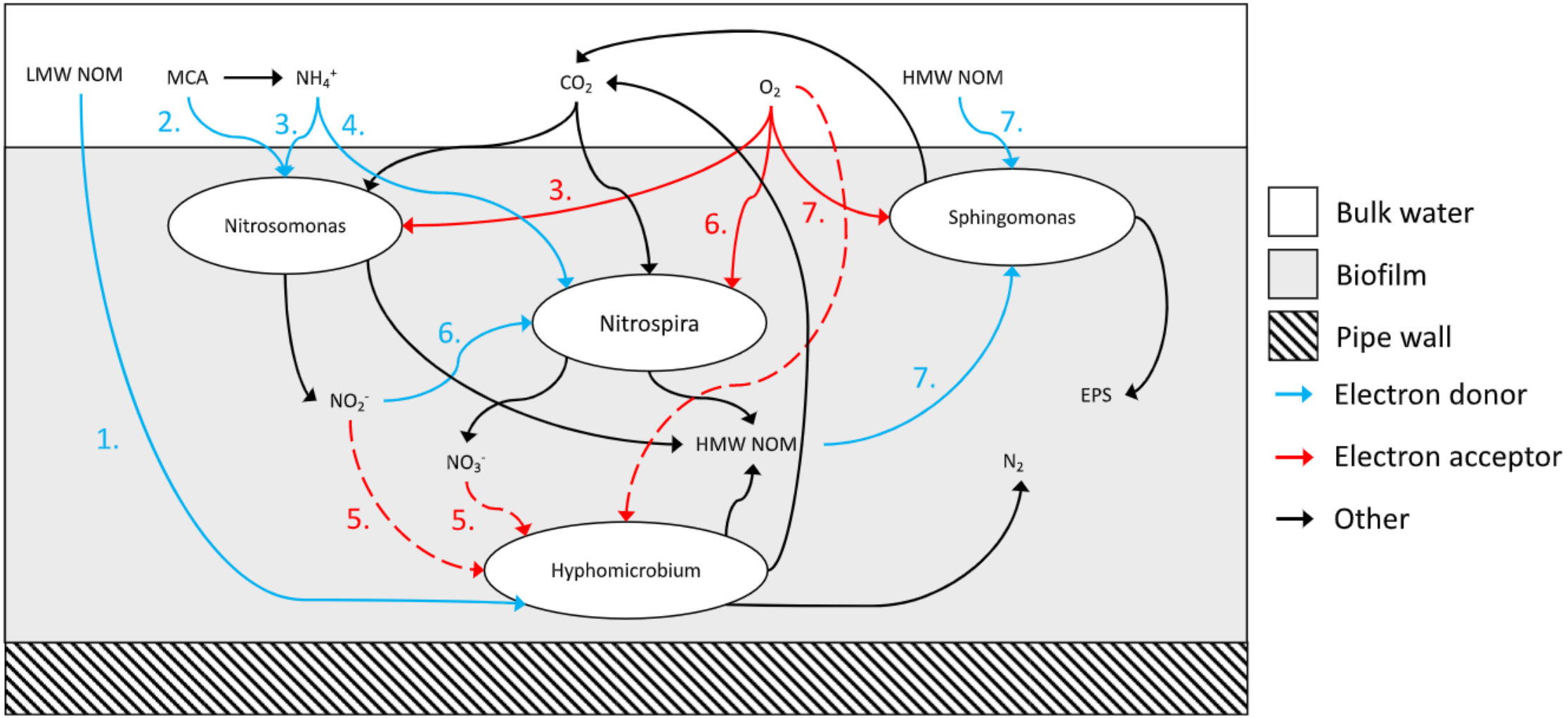
Questions or comments

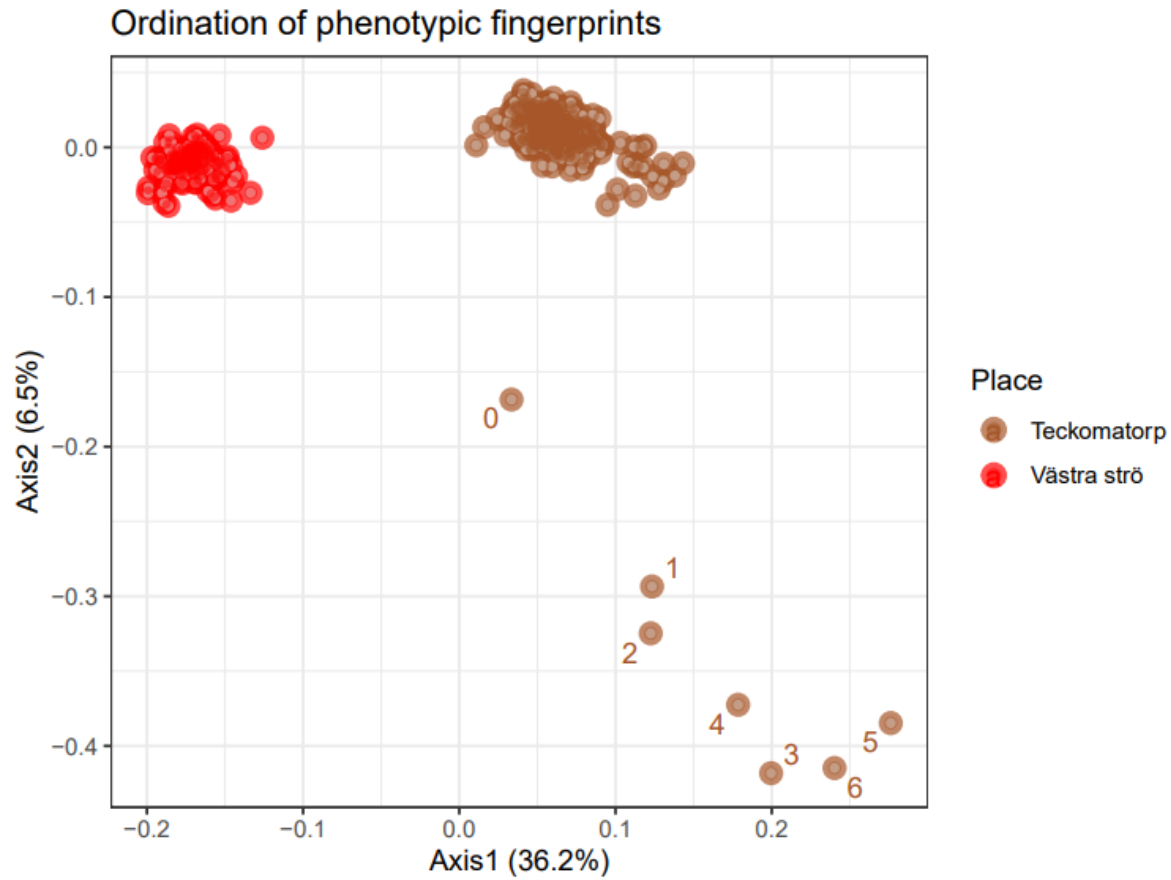
Before UF

After UF






LMW NOM
MCA
NH_4^+
CO_2
O_2
HMW NOM
2.
3.
4.
7.
Nitrosomonas
3.
6.
7.
Sphingomonas
Nitrospira
6.
NO_2^-
7.
EPS
1.
NO_3^-
HMW NOM
N_2
5.
5.
Hyphomicrobium
Bulk water
Biofilm
Pipe wall
Electron donor
Electron acceptor
Other


Ordination of phenotypic fingerprints
Axis2 (6.5%)
Axis1 (36.2%)
0.0
−0.1
−0.2
−0.3
−0.4
−0.2
−0.1
0.0
0.1
0.2
0
1
2
3
4
5
6
Place
Teckomatorp
Västra strö