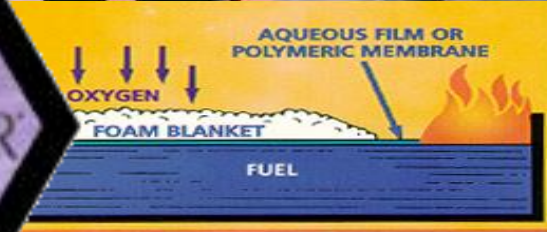
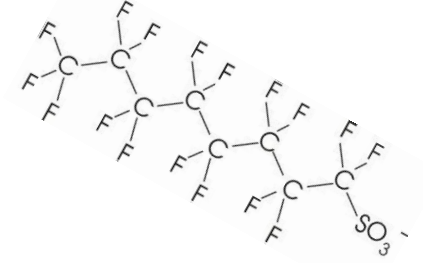
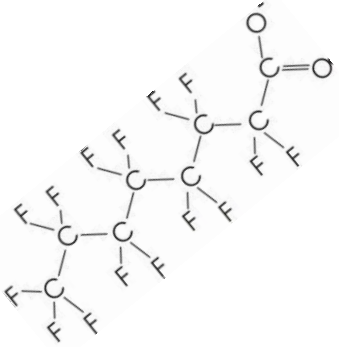


# Innovative treatment solutions for PFAS

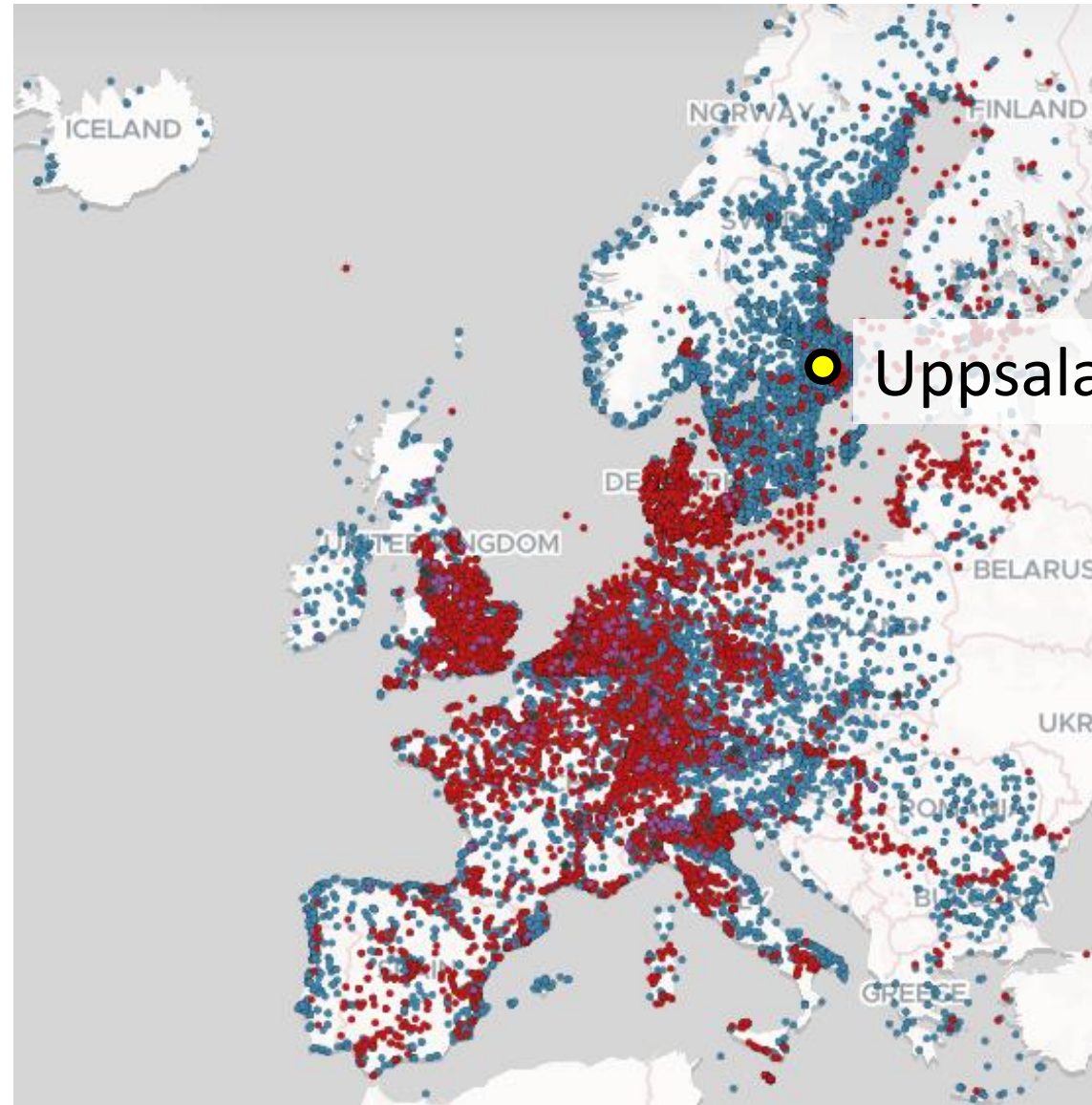
Lutz Ahrens

*Department of Aquatic Sciences and Assessment, SLU, Uppsala, Sweden*

# Per- and polyfluoroalkyl substances (PFASs)



# PFAS-Contaminated Sites in Europe



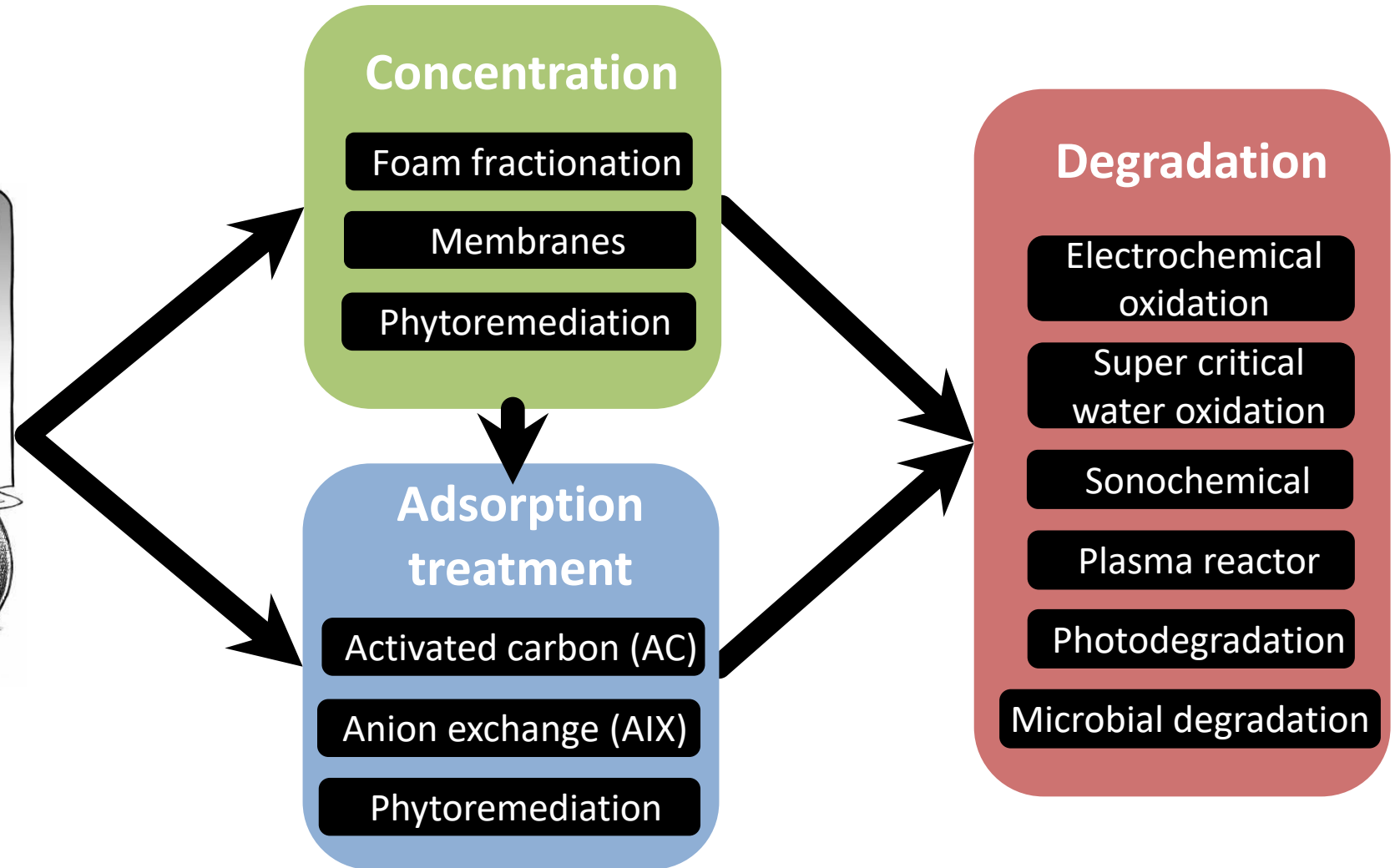
>17,000 sites

- Known contamination
- Presumptive contamination

# Development of PFAS Treatment Technologies



# PFAS Treatment Strategies for Water

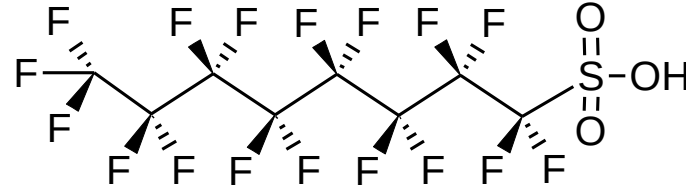


# Characteristics of PFASs

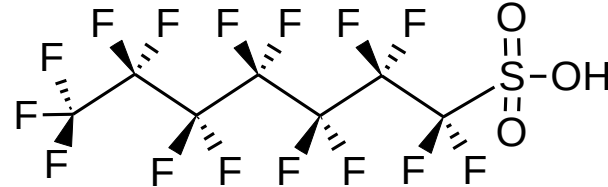
Increasing sorption potential



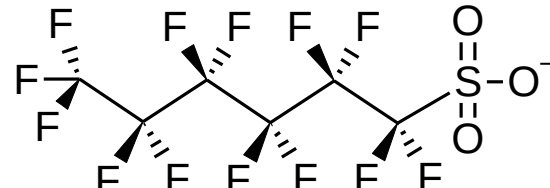
PFOS



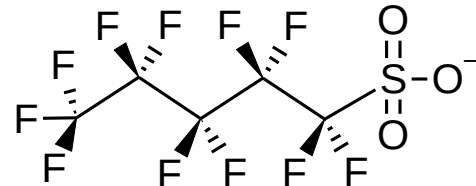
PFHpS



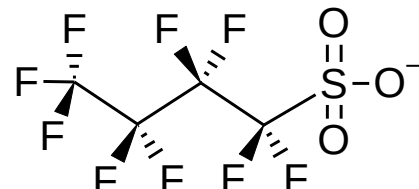
PFHxS



PFPeS



PFBS



Increasing mobility



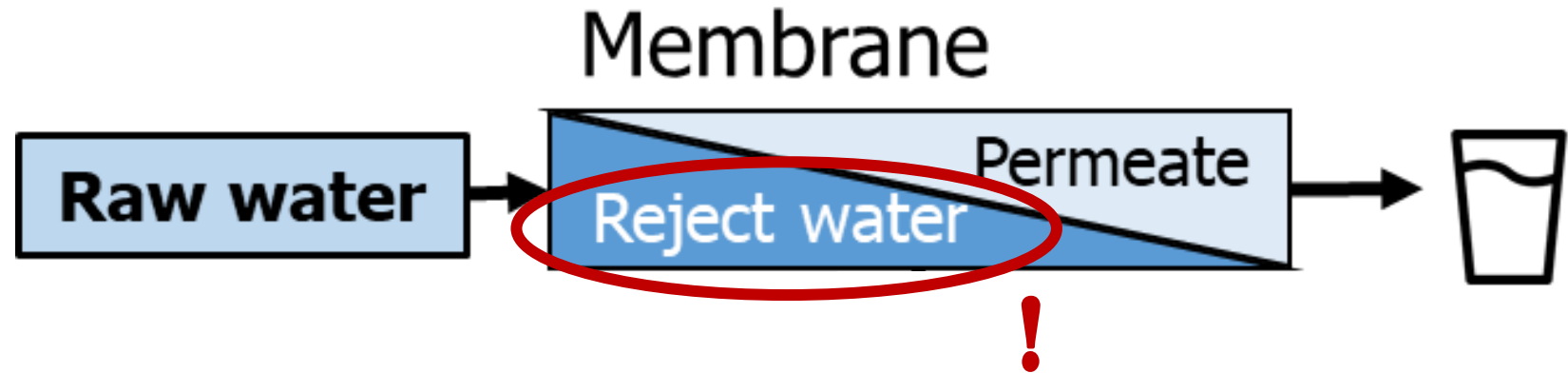
# PFAS Treatment Options - Concentration

Efficient removal of per- and polyfluoroalkyl substances (PFASs) in drinking water treatment: nanofiltration combined with active carbon or anion exchange†

Vera Franke,<sup>a</sup> Philip McCleaf,<sup>b</sup> Klara Lindegren<sup>†a</sup> and Lutz Ahrens<sup>a</sup>

## Concentration

Membranes  
• NF, RO

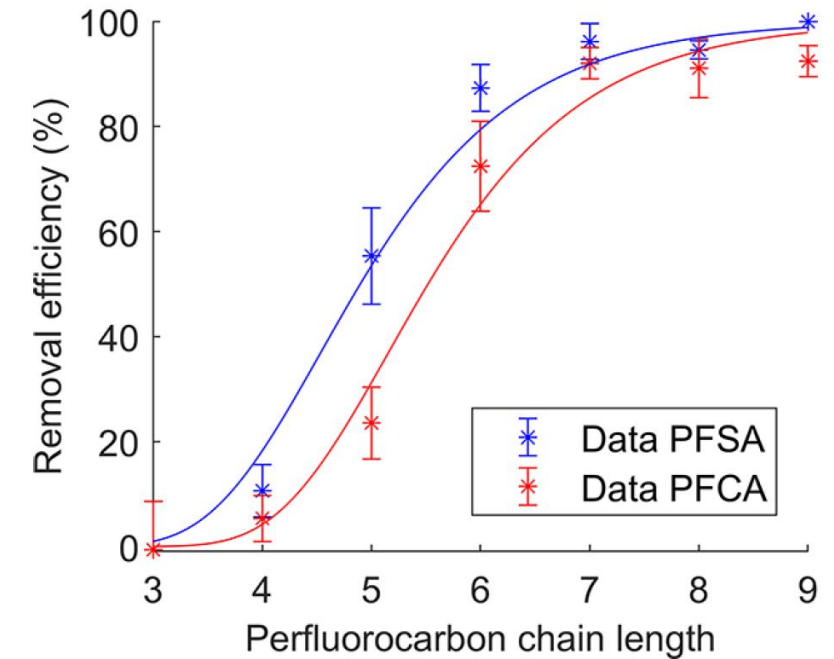
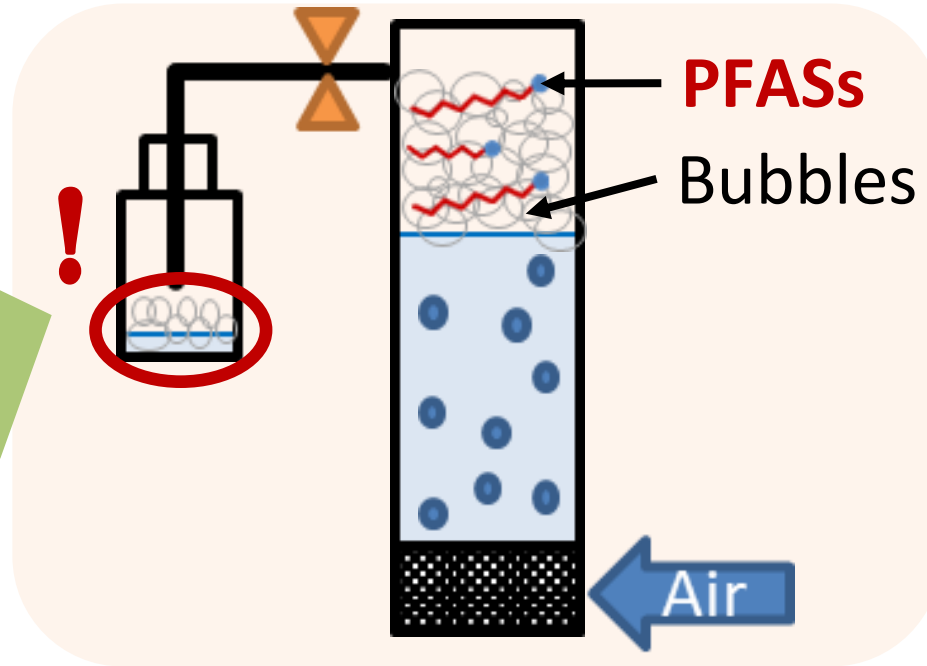


# PFAS Treatment Options - Concentration

## Concentration

Membranes  
• NF, RO

Foam  
fractionation



# ENVIRONMENTAL Science & Technology

[pubs.acs.org/est](https://pubs.acs.org/est)

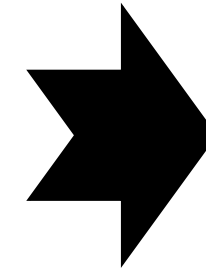
<sup>‡</sup>Tyréns AB, Västra Norrlandsgatan 10B, 903 27 Umeå, Sweden



# Plants Burden of total PFASs

| Plant tissue | Burden (%) |        |
|--------------|------------|--------|
|              | Birch      | Spruce |
| Foliage      | 8 - 63     | 20     |
| Twigs        | 20         | 4 - 26 |
| Stem         | 14 - 88    | 53     |
| Roots        | 1 - 4      | 23     |

Biomass



→ Incineration  
(>1000 °C)

Taylor P et al., 2014,  
*Chemos.* 110, 17-22

→ Calcium  
catalysed  
defluorination  
(~350°C)

Wang et al., 2015,  
*ES&T*, 49, 5672-5680



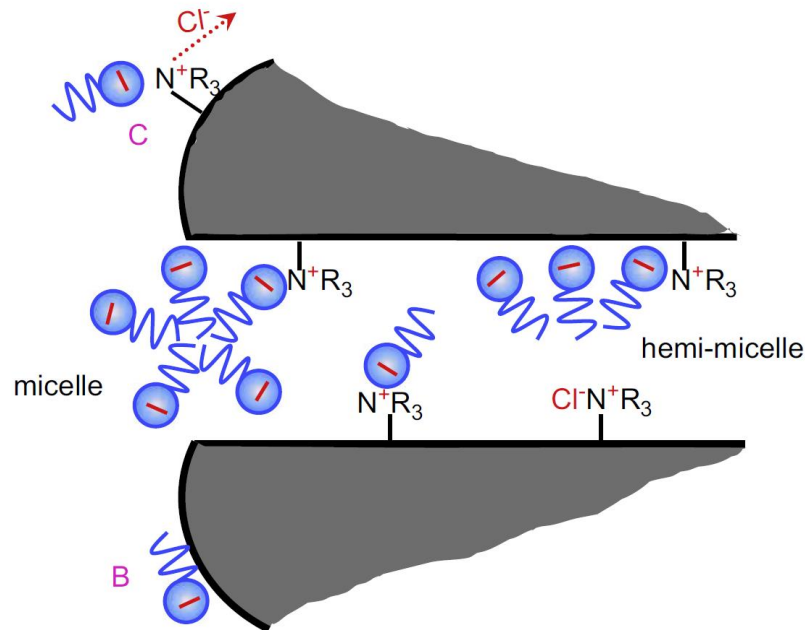
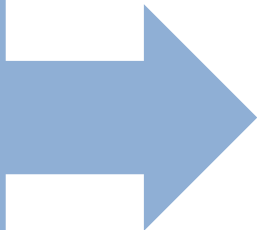
# Adsorption Treatment

Stabilization/  
solification

Activated  
carbon (AC)  
GAC  
PAC

Anion exchange  
(AIX)

Other sorbents



Removal efficiency of multiple poly- and perfluoroalkyl substances (PFASs) in drinking water using granular activated carbon (GAC) and anion exchange (AE) column tests

Philip McCleaf<sup>a,\*</sup>, Sophie Englund<sup>b</sup>, Anna Östlund<sup>b</sup>, Klara Lindegren<sup>b</sup>, Karin Wiberg<sup>b</sup>, Lutz Ahrens<sup>b</sup>

<sup>a</sup> Uppsala Water and Waste AB, P.O. Box 1444, SE-751 44, Uppsala, Sweden

<sup>b</sup> Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences (SLU), P. O. Box 7050, SE-750 07 Uppsala, Sweden



McCleaf, Englund, Östlund, Lindegren, Wiberg, Ahrens, 2017, *Water Res*, 120, 77-87

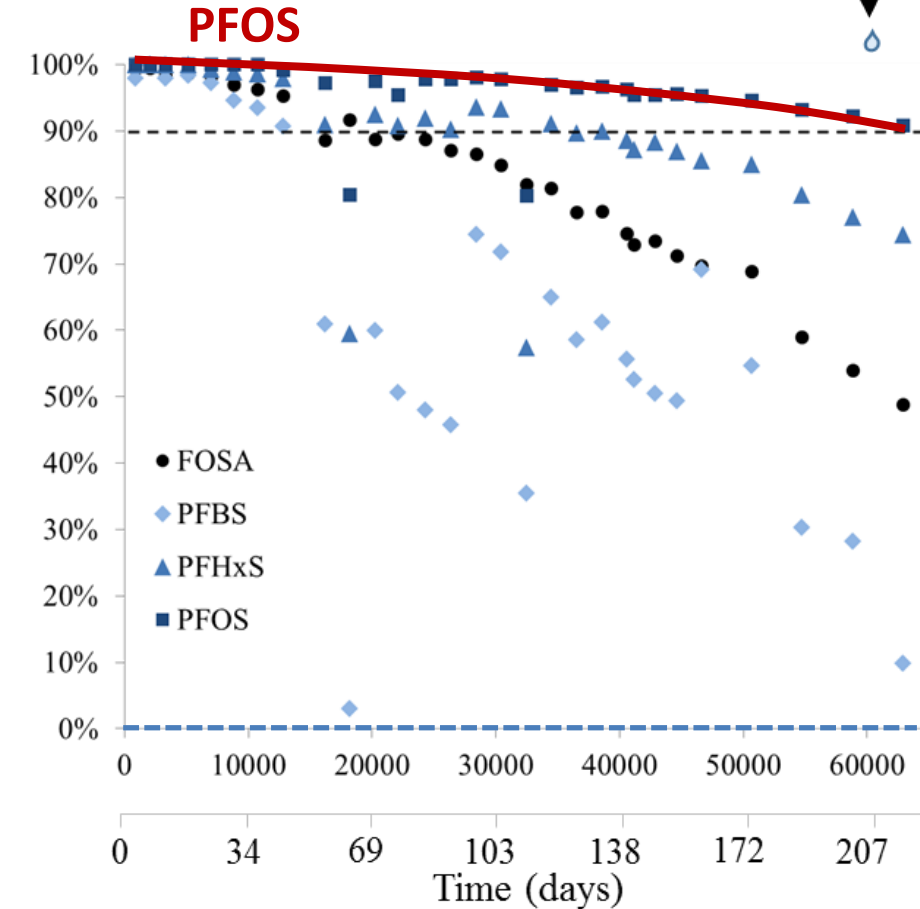
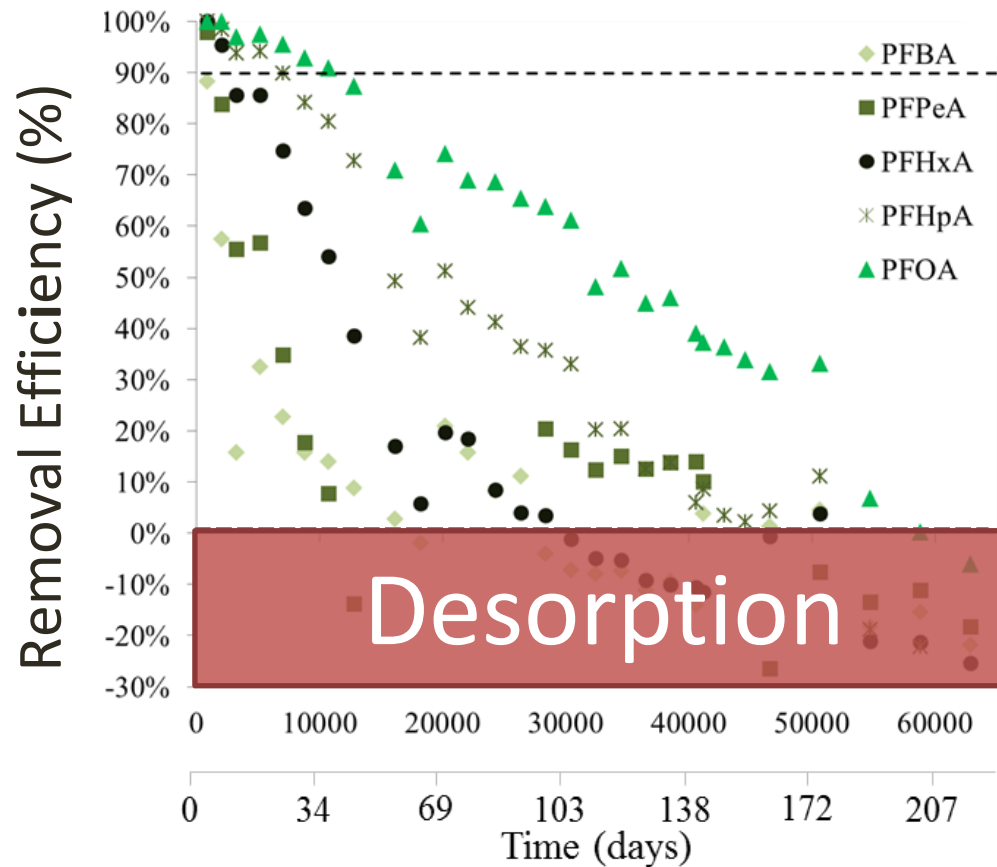
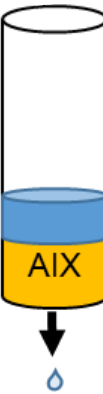
Belkouteb N, Franke V, McCleaf P, Köhler S, Ahrens L. 2020. *Water Res*, 182, 115913

Yu, Zhang, Deng, Huang, Yu, 2009. *Water Res*, 43,1150-1158

# PFAS Treatment Options - Adsorption Treatment

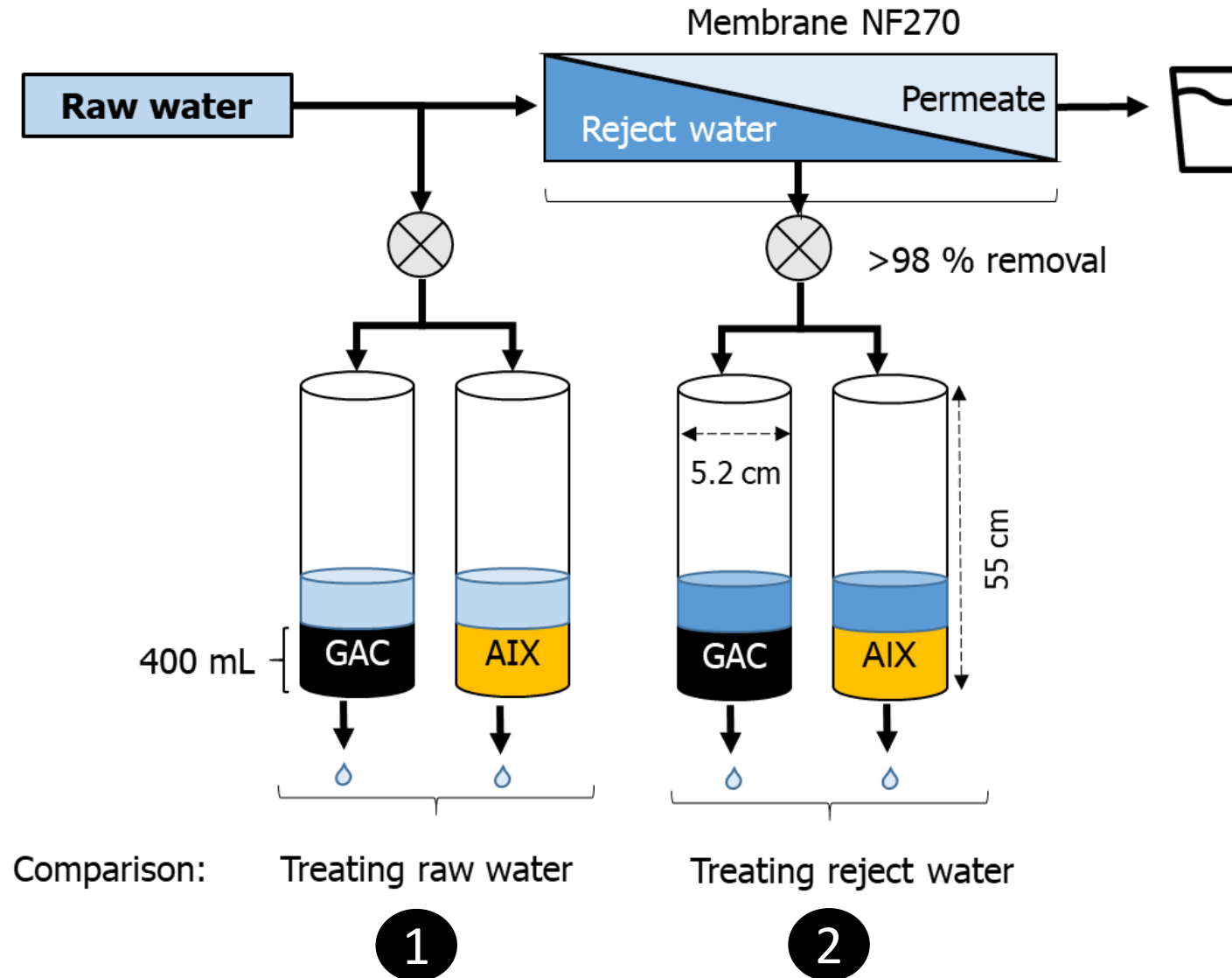
Adsorption  
treatment

Anion exchange  
(AIX)

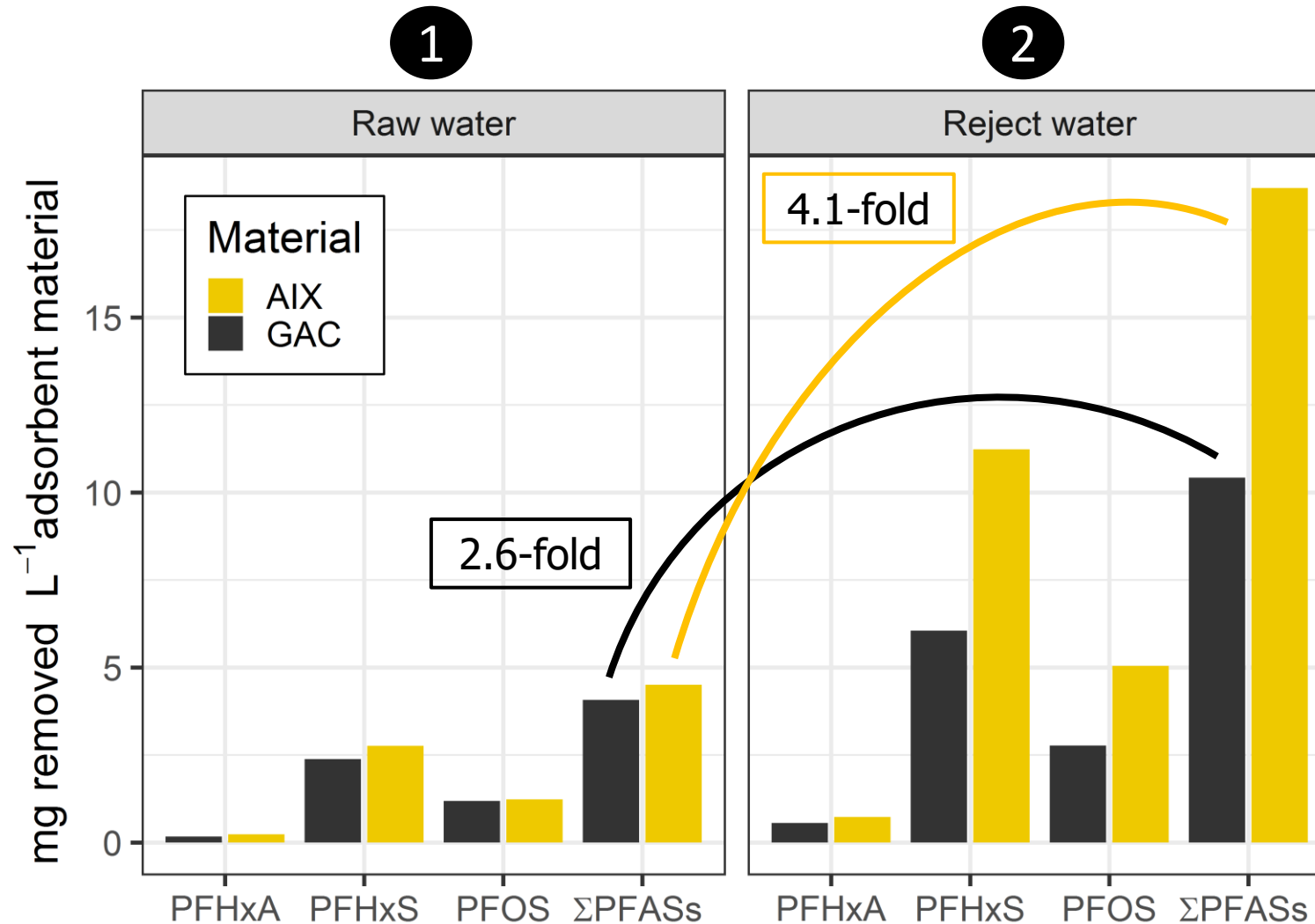


McCleaf, Englund, Östlund, Lindegren, Wiberg, Ahrens, 2017, *Water Res*, 120, 77-87  
Belkouteb N, Franke V, McCleaf P, Köhler S, Ahrens L. 2020. *Water Res*, 182, 115913

# Combination of nanofiltration + adsorption



# Combination of nanofiltration + adsorption



# PFAS Treatment Options - Degradation

## Degradation

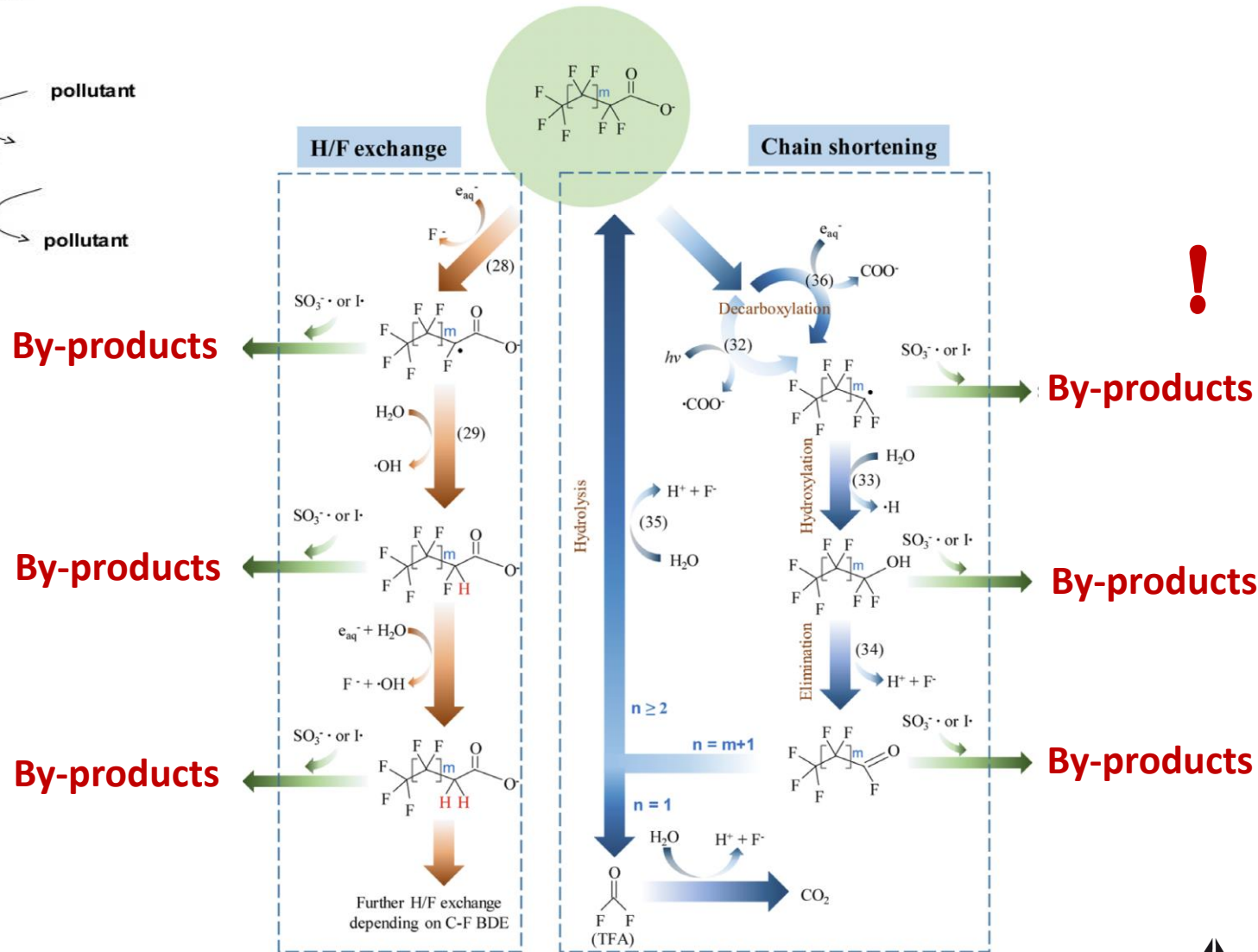
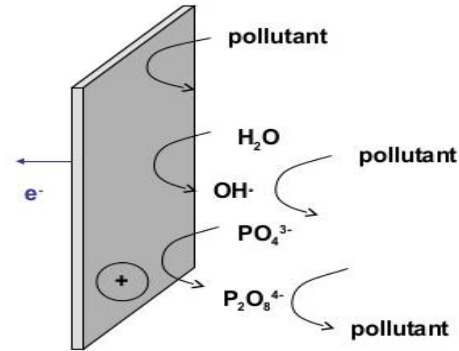
Electrochemical oxidation

Super critical water oxidation

Sonochemical

Plasma reactor

Microbial degradation



# PFAS Treatment Options - Degradation

## Degradation

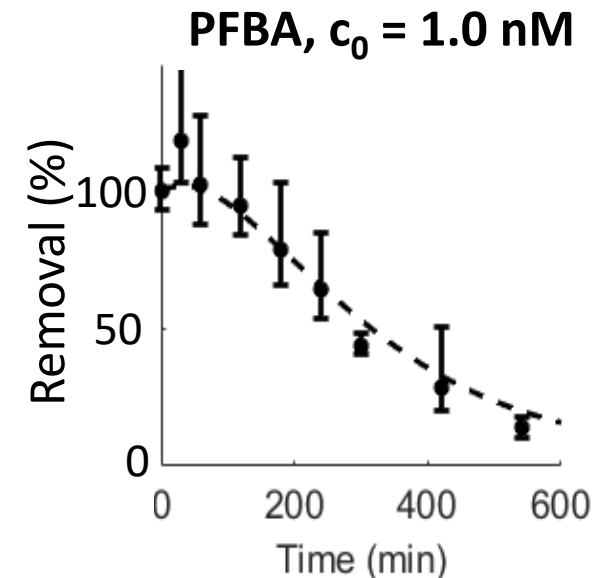
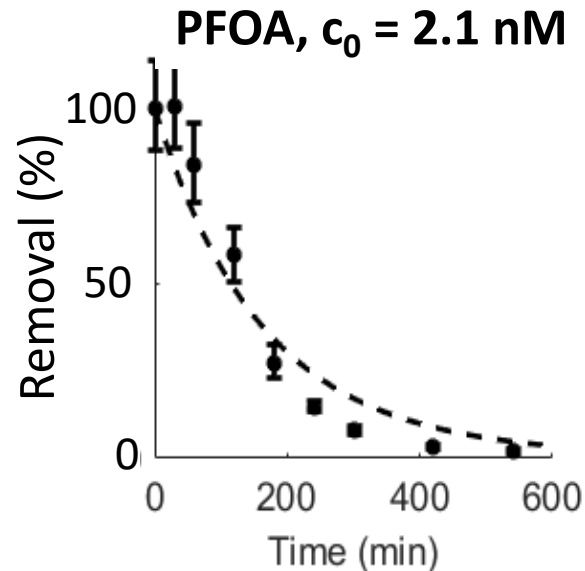
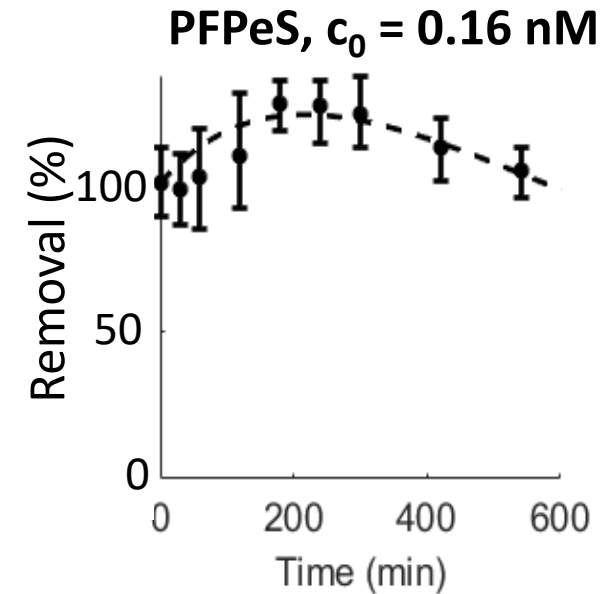
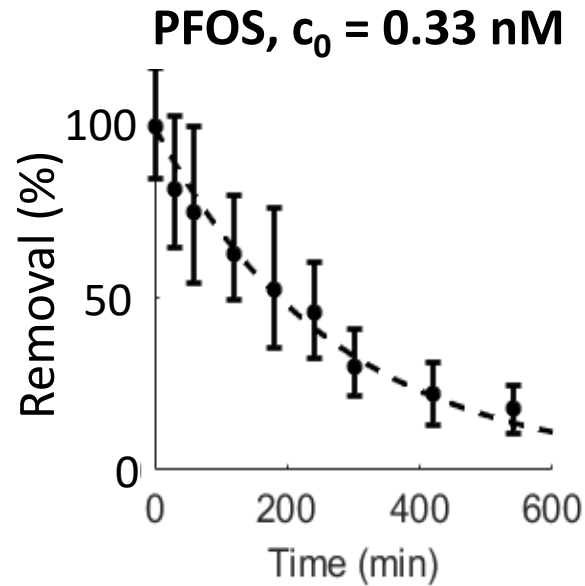
Electrochemical  
oxidation

Super critical  
water oxidation

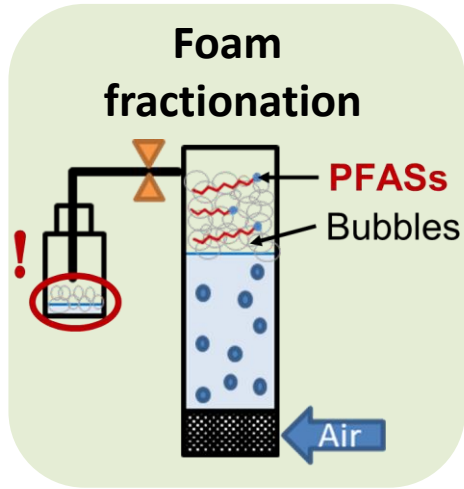
Sonochemical

Plasma reactor

Microbial  
degradation



# PFAS Treatment Options for Water



## Concentration

Foam fractionation

Membranes

Phytoremediation

## Adsorption treatment

Activated carbon (AC)

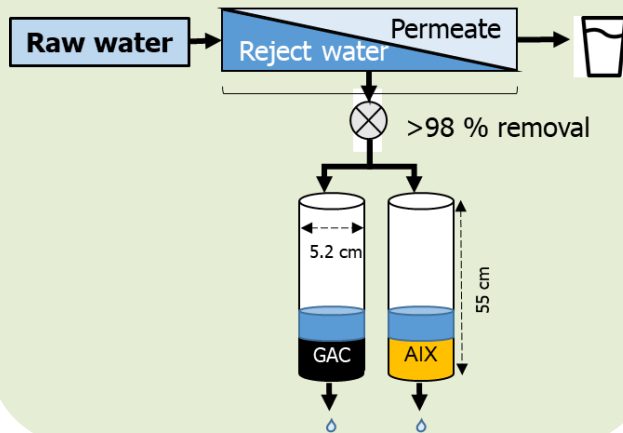
Anion exchange (AIX)

Phytoremediation

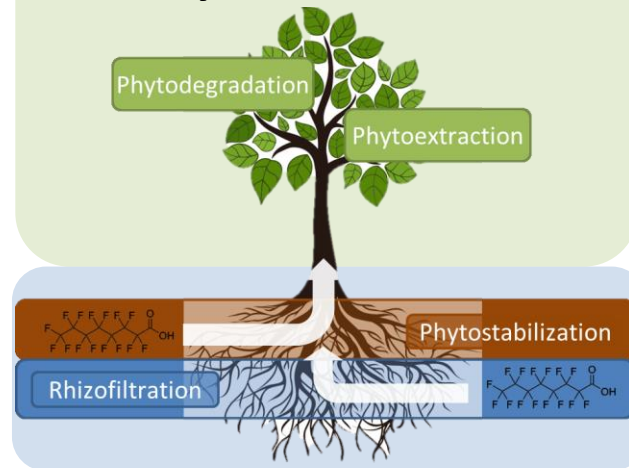
## Degradation

Electrochemical oxidation

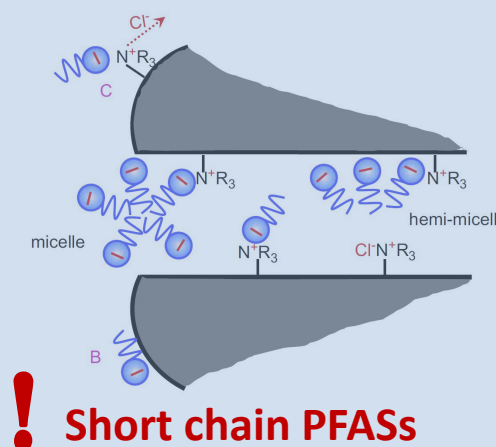
## NF membrane



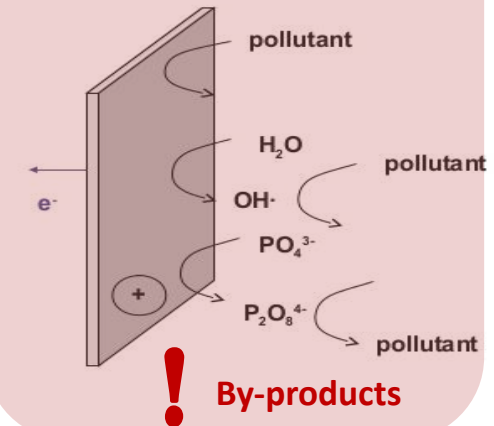
## Phytoremediation



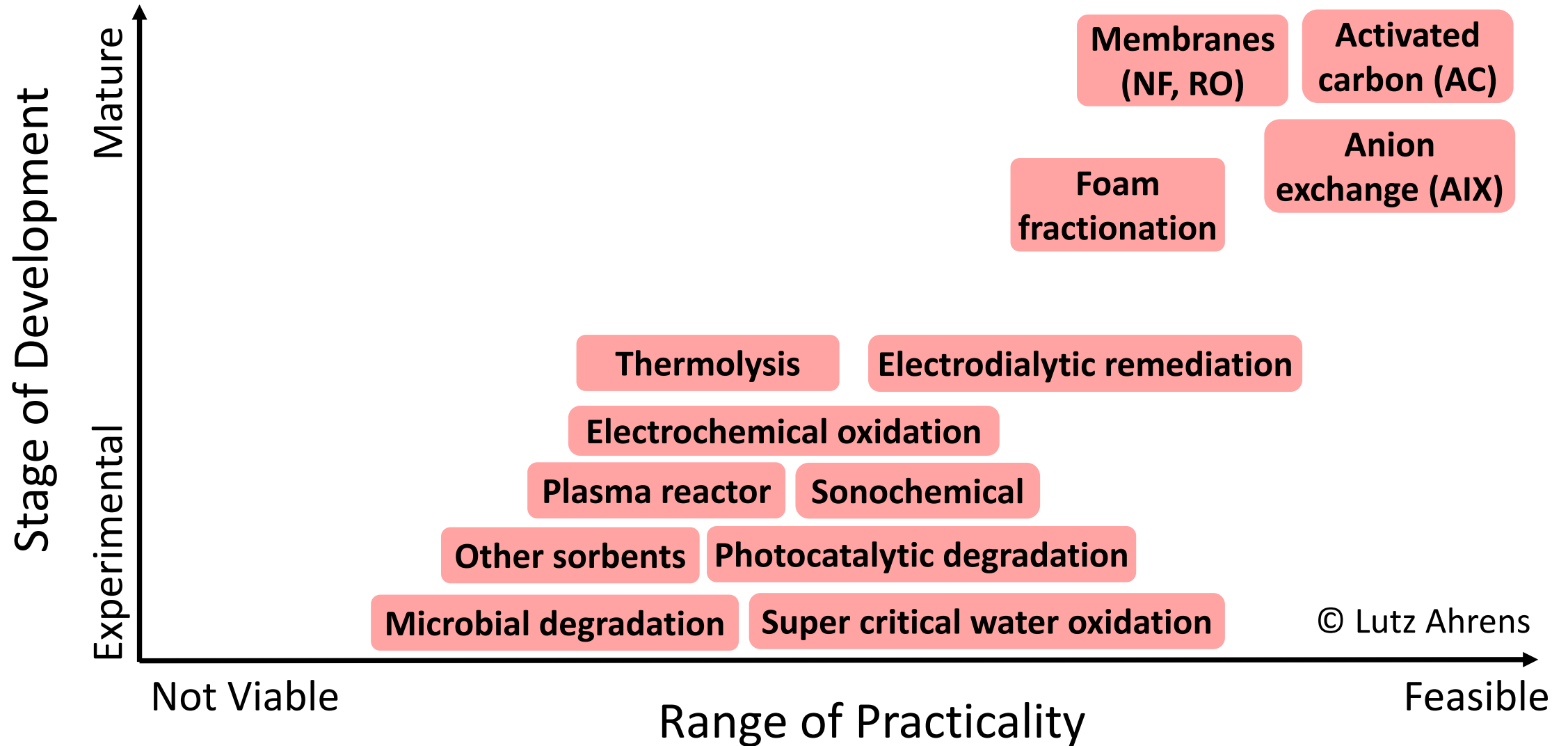
## AIX



## Electrochemical oxidation



# PFAS Treatment Options for Water



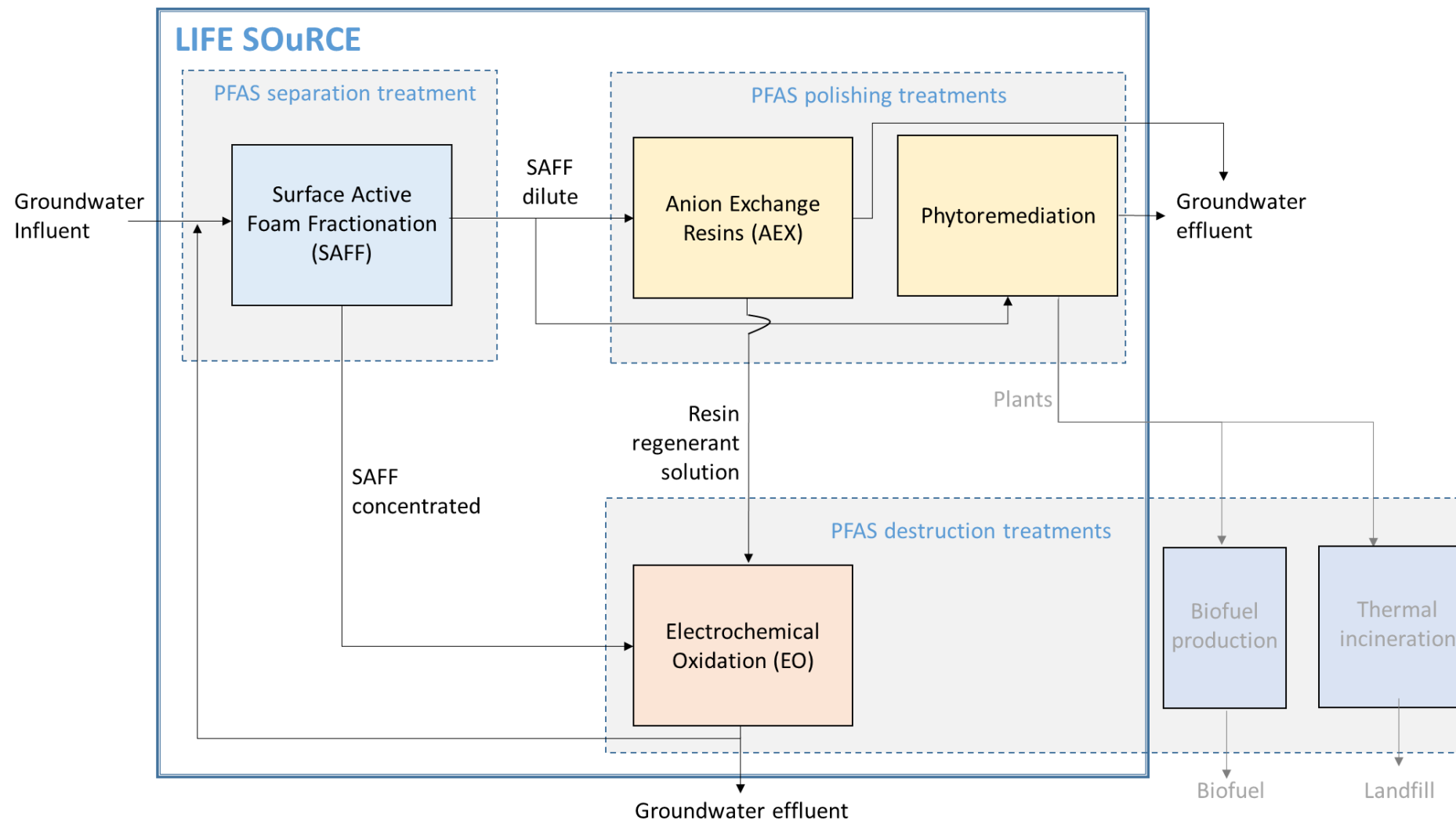
© Lutz Ahrens

# Example 1

## LIFE SOuRCE – PFAS Treatment of Groundwater (2021-2025)

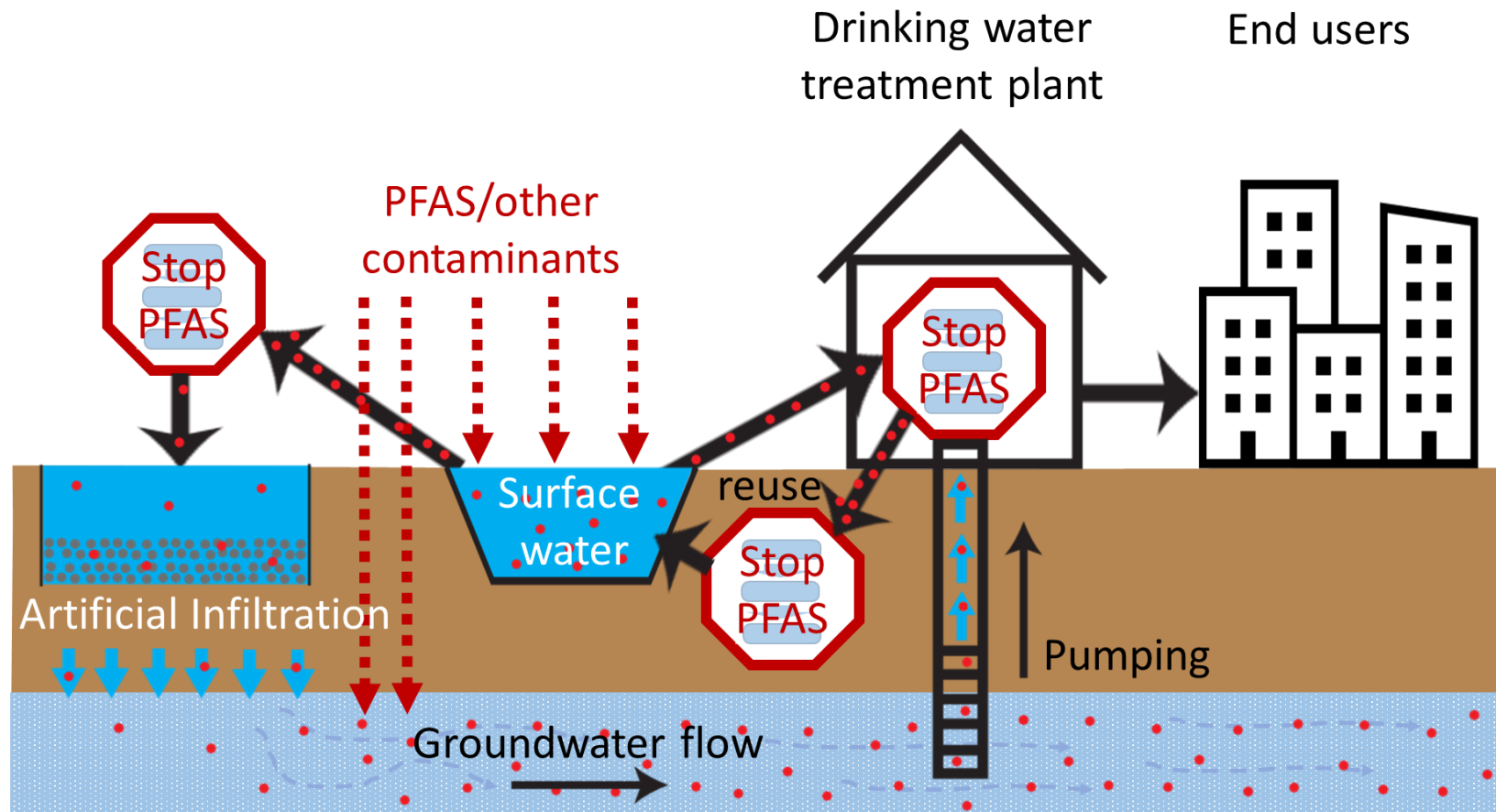


Treatment train  
for removal of  
PFASs in  
groundwater



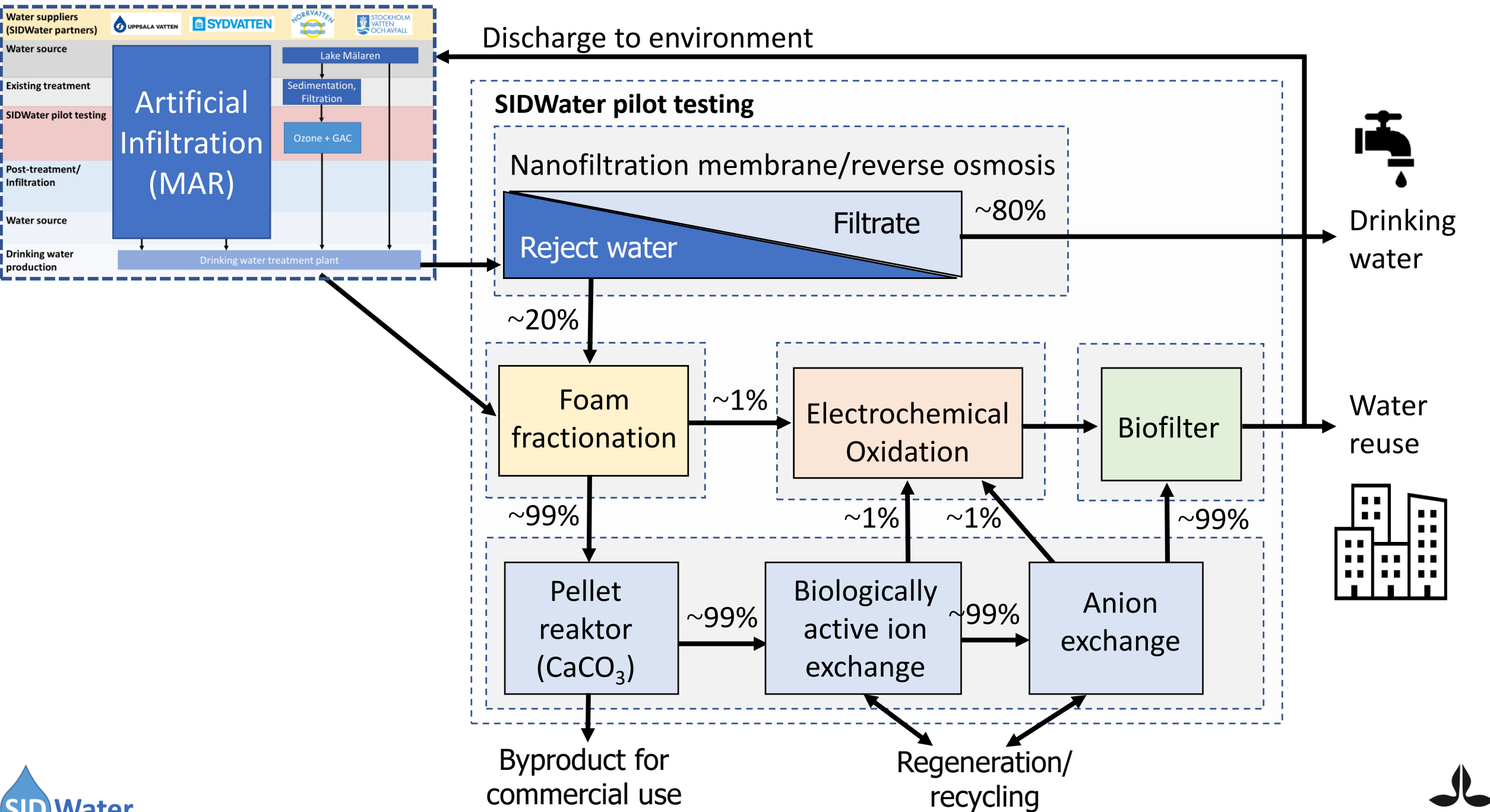
## Example 2

# Sustainable innovative drinking water treatment solutions for large-scale water supply and reuse (SIDWater)

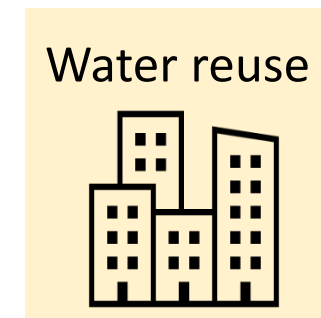
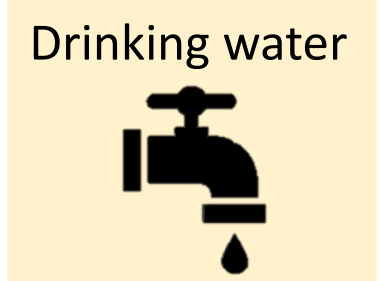
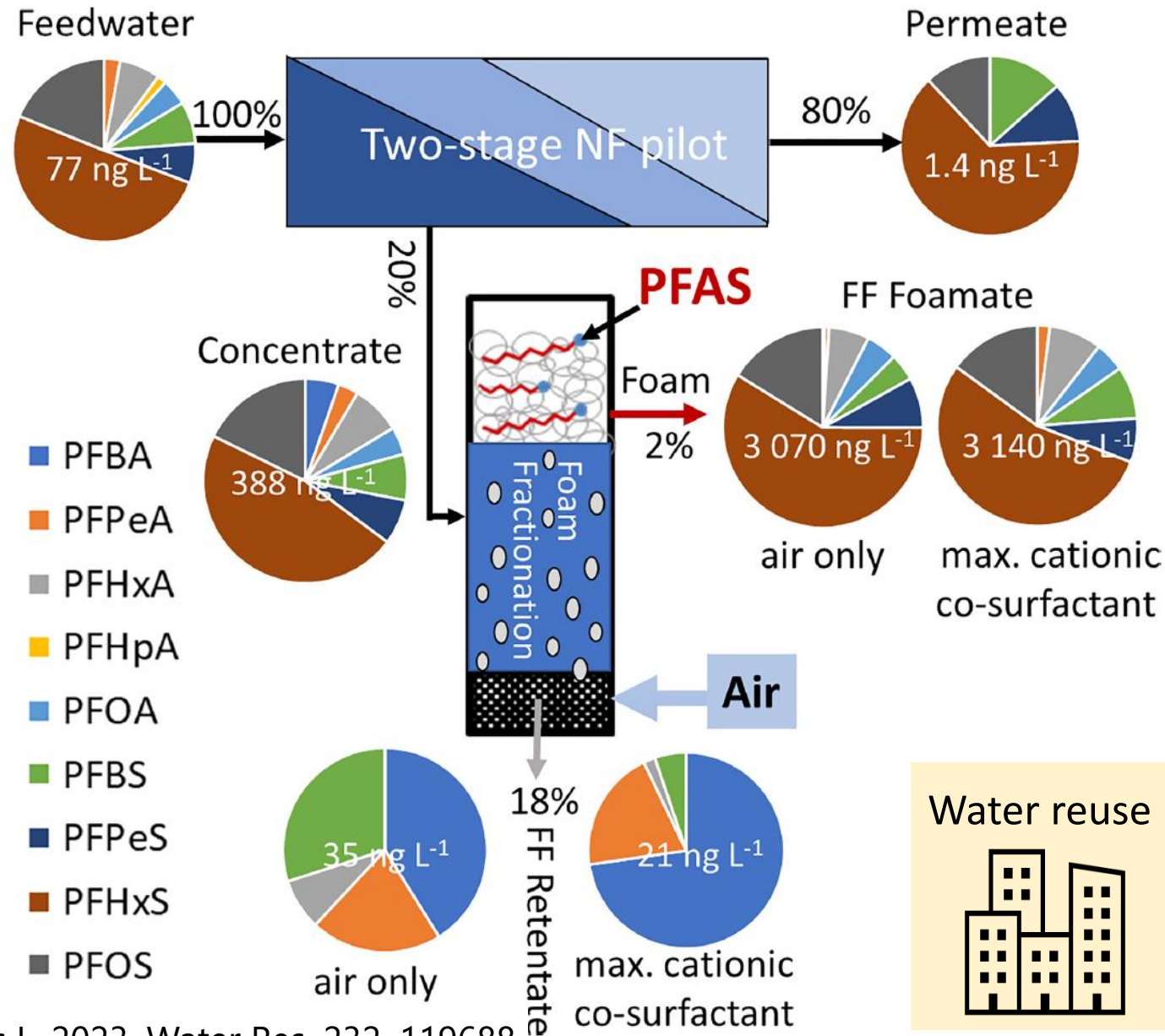


UPPSALA  
UNIVERSITET



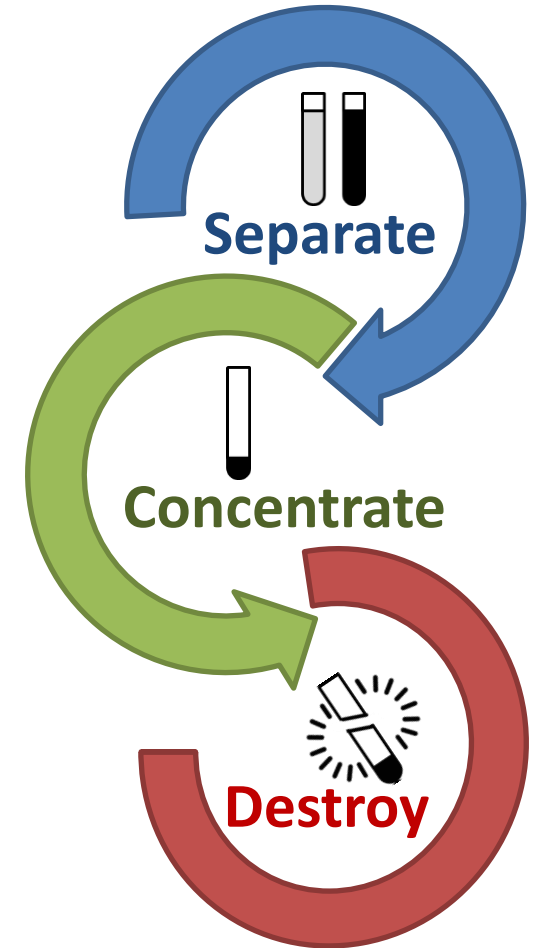


# Combination of Nanofiltration + Foam Fractionation



# Take Home Message

- ❖ Each treatment technique has their **advantage** and **disadvantage**, so **combination of different treatment techniques is often the best solution**



# Thank you!



The LIFE SOuRCE project (LIFE20 ENV/ES/000880) has received funding from the LIFE Programme of the European Union



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 860665.



Contact: [lutz.ahrens@slu.se](mailto:lutz.ahrens@slu.se)