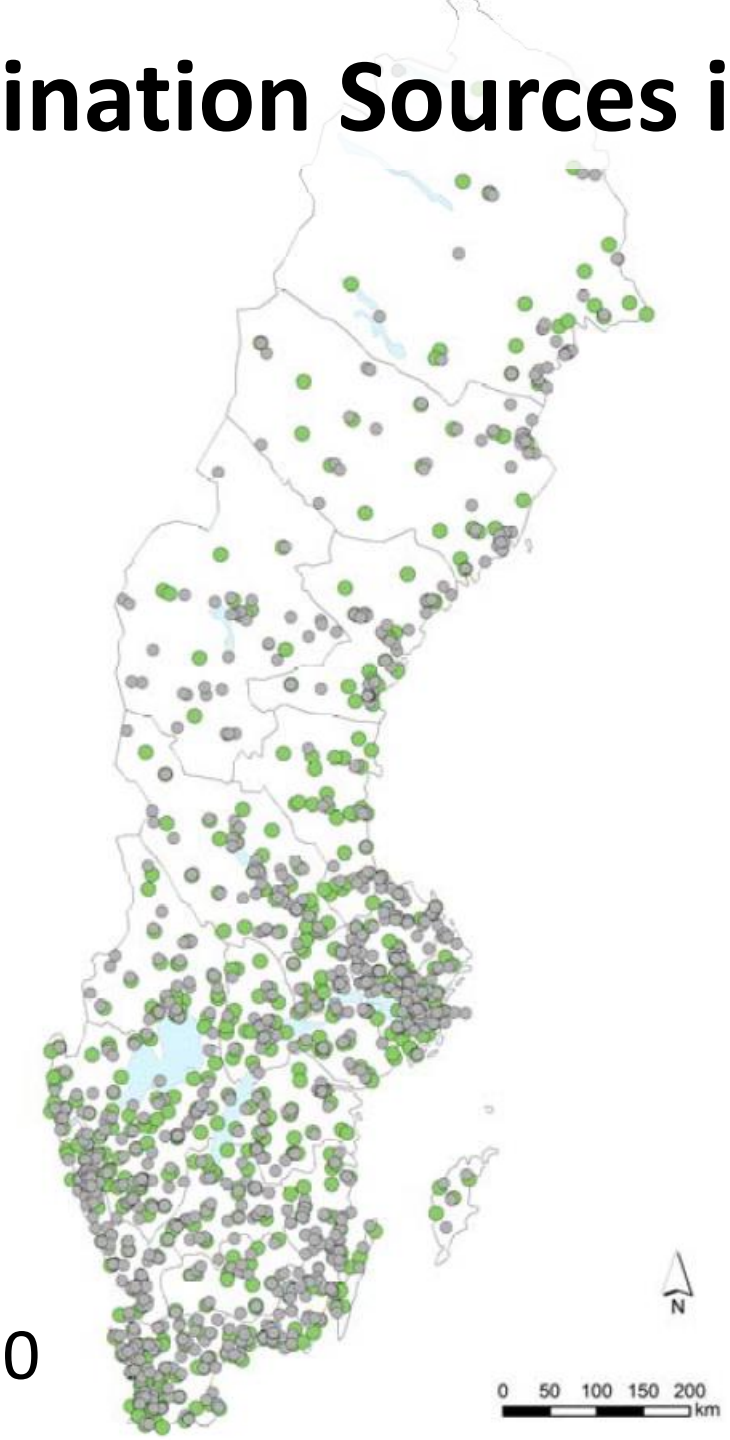
PFAS in the Environment – Should we be concert?

Lutz Ahrens

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

PFAS Contamination Sources in Sweden



Swedish EPA

>2000

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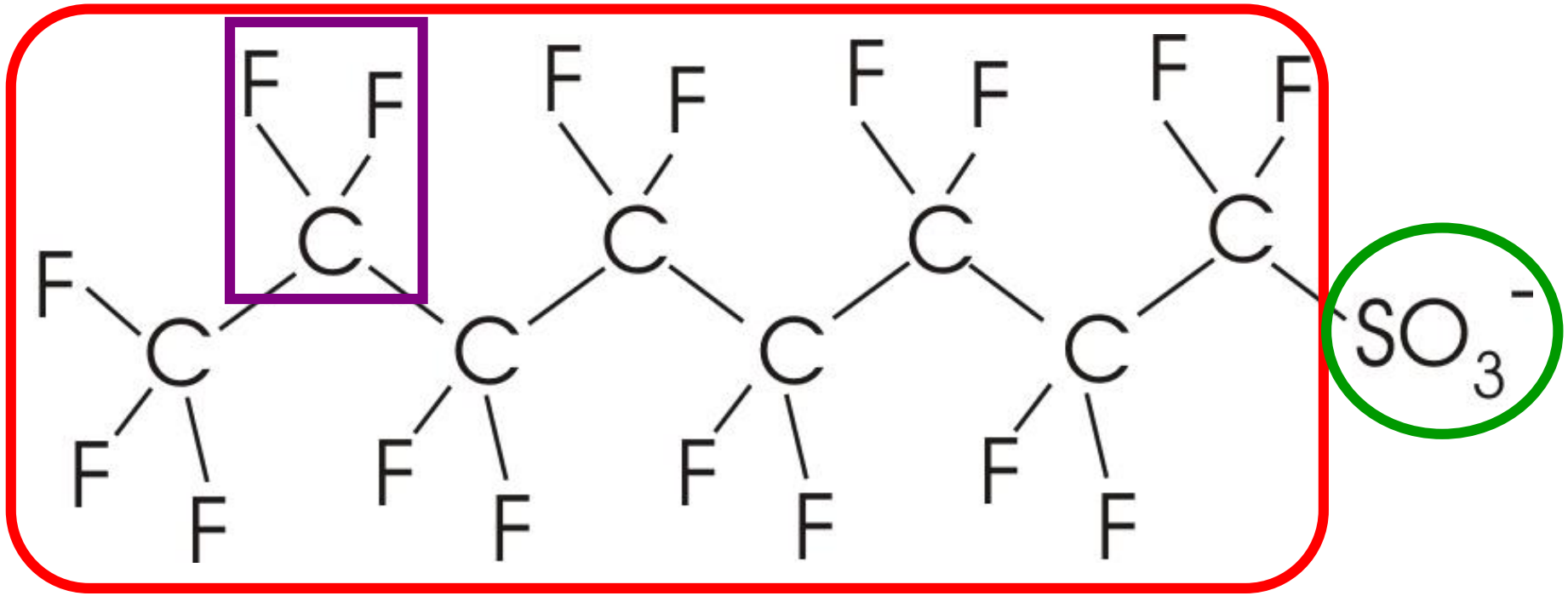
Characteristics of Per- and Polyfluoroalkyl Substances (PFASs)

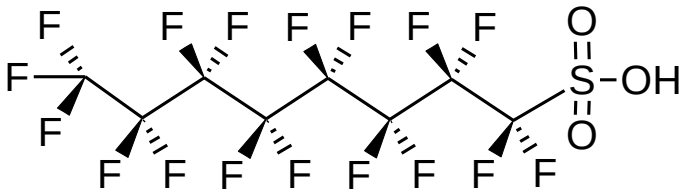


Perfluorooctane sulfonate (PFOS)

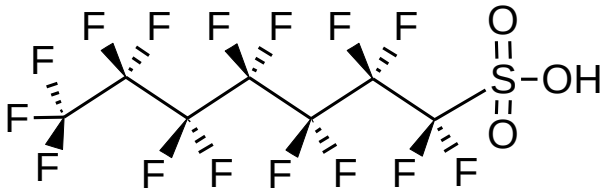
Characteristics of PFASs

Increasing sorption potential

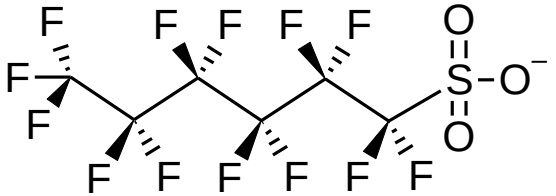
PFOS



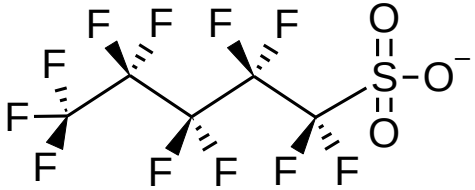
PFHpS



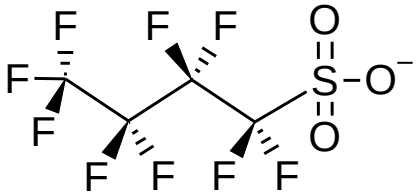
PFHxS



PFPeS

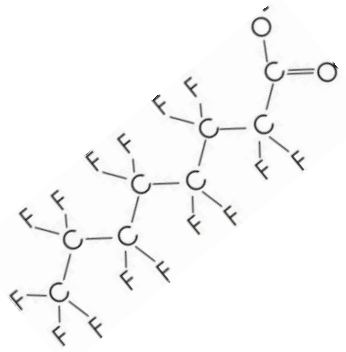


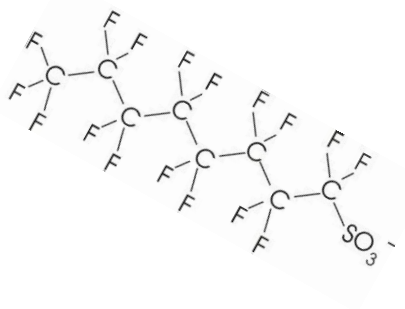
PFBS

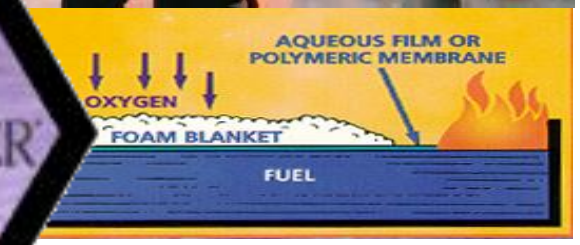


Increasing mobility

Per- and polyfluoroalkyl substances (PFASs)







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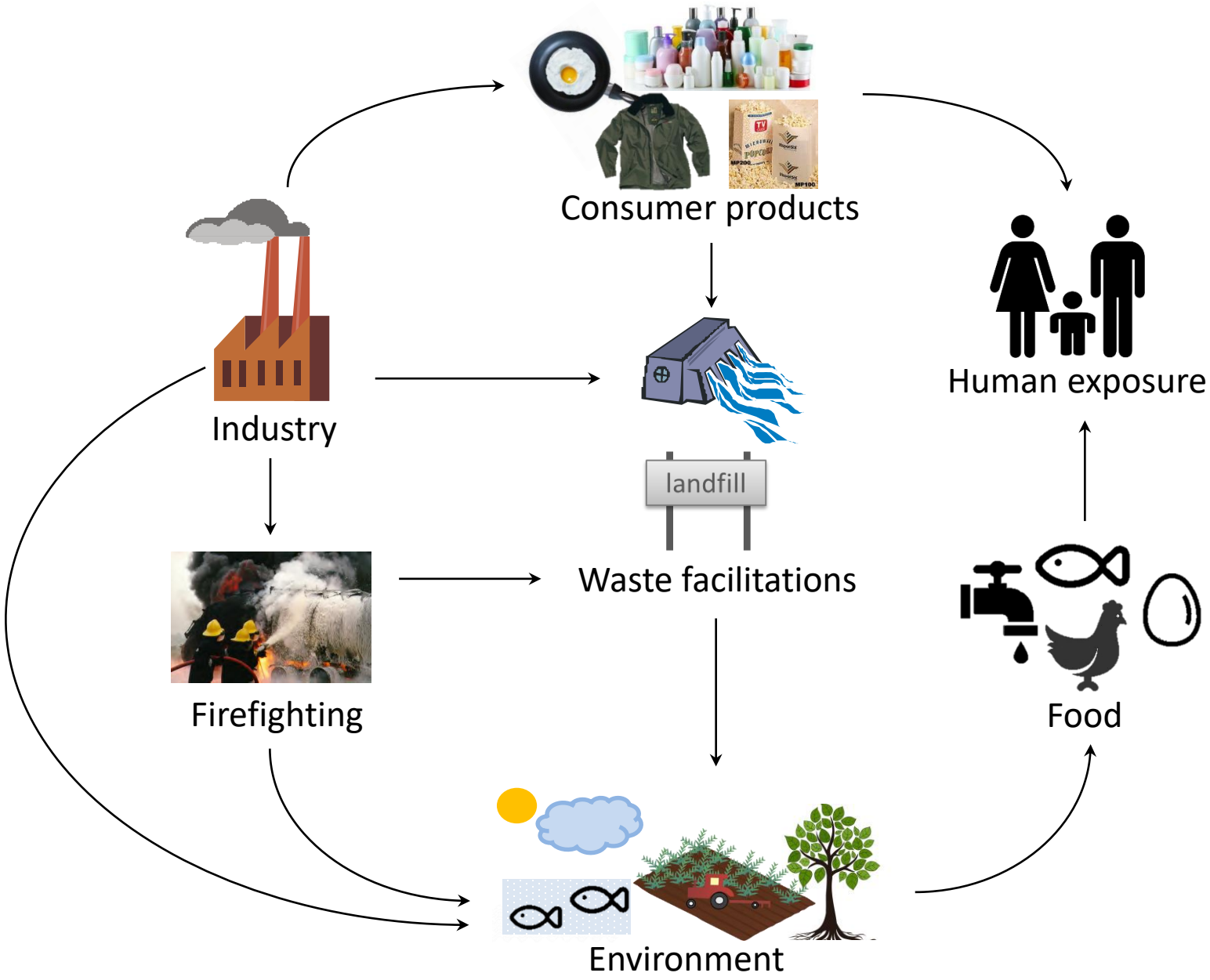
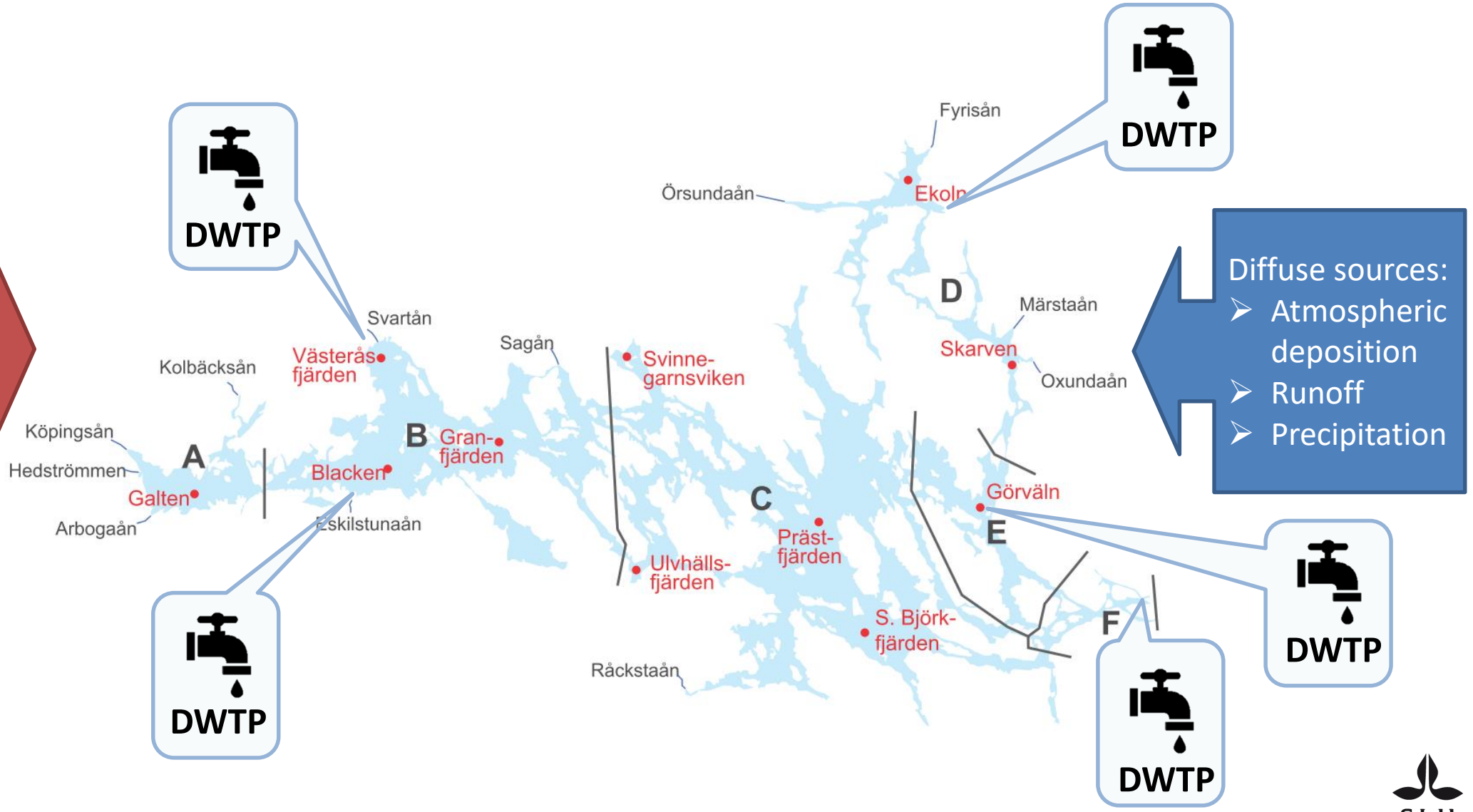
Circulation of PFASs in the Environment



Sources of PFAS to the Aquatic Environment

Point sources:
- Industrial/ manufacturing facilities
- Fire training facilities
- Wastewater treatment plants
- Landfills



Diffuse sources:
- Atmospheric deposition
- Runoff
- Precipitation

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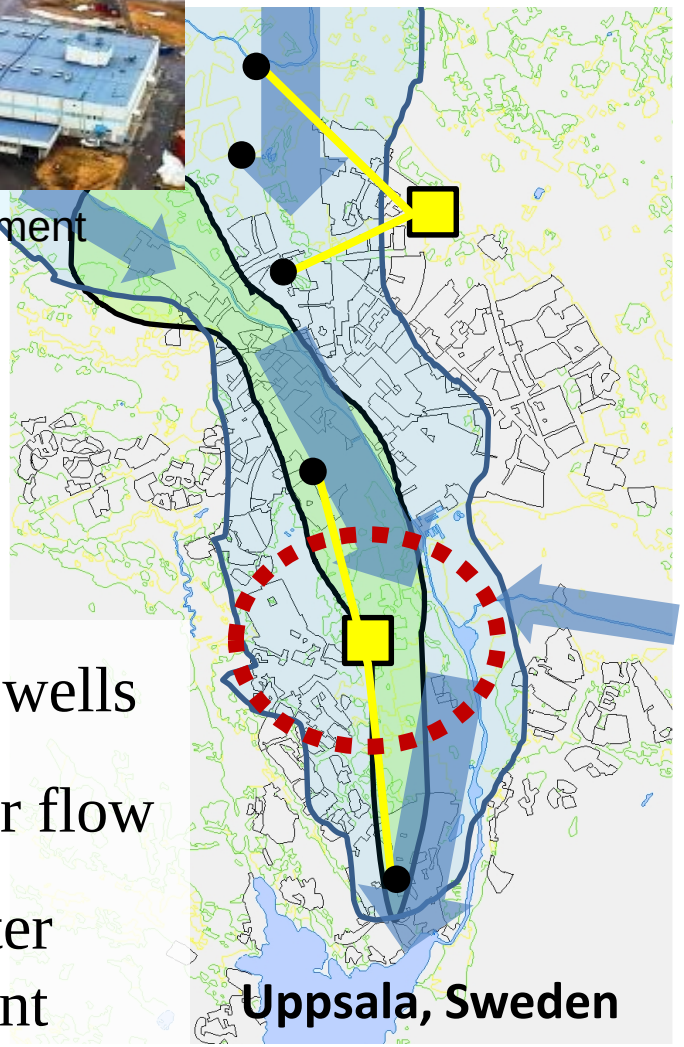
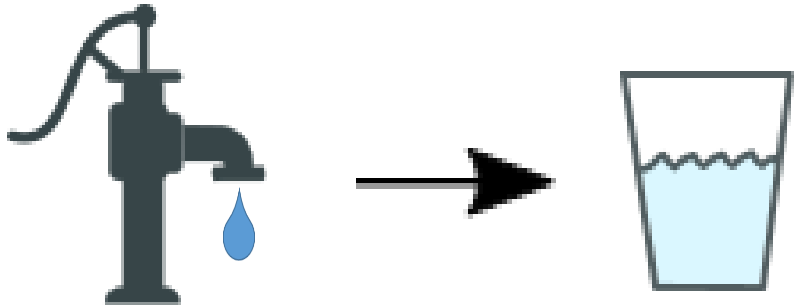
PFASs in Drinking Water

Swedish Defense Department



- Drinking water wells
- Groundwater flow
- Drinking water treatment plant



$PFAS_{in} \approx PFAS_{out}$

Sörengård M, Bergström S, McCleaf P, Wiberg K and Ahrens L, 2022. *Environ. Pollut.*, 311**,** 119981.

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Guideline Values for PFASs in Drinking Water

2013

National Food Agency

$\sum PFAS_7 \leq 90$ ng L^{-1}

$\sum_7$PFASs
PFPeA - C_4
PFHxA - C_5
PFHpA -C_6
PFOA - C_7
PFBS - C_4
PFHxS - C_6
PFOS - C_8

2016

National Food Agency

$\sum PFAS_{11} \leq 90$ ng L^{-1}

$\sum_{11}$PFASs
PFBA - C_3
PFPeA - C_4
PFHxA - C_5
PFHpA -C_6
PFOA - C_7
PFNA - C_8
PFDA - C_9
PFBS - C_4
PFHxS - C_6
PFOS - C_8
6:2 FTSA

2020

$\sum PFAS_{20} \leq 100$ ng L^{-1}

Total PFASs ≤ 500 ng L^{-1}

$\sum_{20}$PFASs
C_4–C_{13} PFSAs
C_4–C_{13} PFCAs
Total PFASs

2023

National Food Agency

Sampling required

$\sum PFAS_{21} \leq 100$ ng L^{-1}

Total PFASs ≤ 500 ng L^{-1}

$\sum PFAS_4 \leq 4$ ng L^{-1}

$\sum_{21}$PFASs
C_4–C_{13} PFSAs
C_4–C_{13} PFCAs
6:2 FTSA
Total PFASs
$\sum_4$PFASs
PFOA - C_7
PFNA - C_8
PFHxS - C_6
PFOS - C_8

2026

National Food Agency

Treatment required

$\sum PFAS_4 \leq 4$ ng L^{-1}

?

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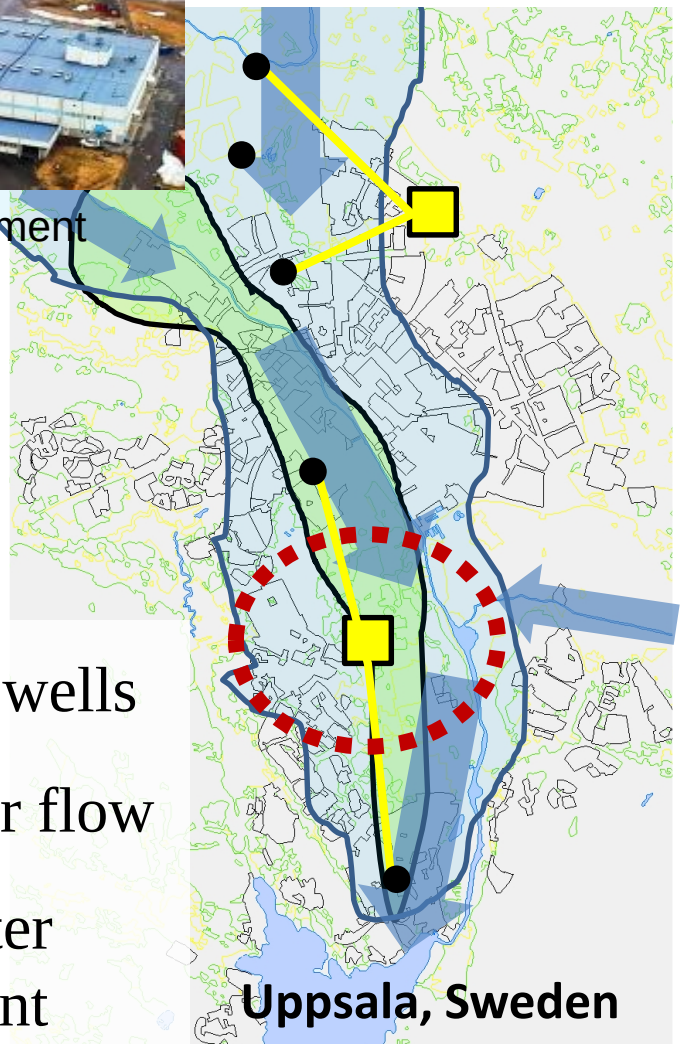
PFASs in Drinking Water

Swedish Defense Department



- Drinking water wells
- Groundwater flow
- Drinking water treatment plant

Raw water

- 100-200 ng/L for $\sum_{21}$PFAS
- ~80 ng/L for $\sum_{4}$PFAS

Drinking water limits

- $\sum PFAS_{21} \leq 100$ ng/L
- $\sum PFAS_{4} \leq 4$ ng/L

Sörengård M, Bergström S, McCleaf P, Wiberg K and Ahrens L, 2022. *Environ. Pollut.*, 311**,** 119981.

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PFASs in Drinking Water

Swedish Defense Department

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What can we do?

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Sörengård M, Bergström S, McCleaf P, Wiberg K and Ahrens L, 2022. *Environ. Pollut.*, 311, 119981.

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PFAS Treatment Strategies for Water

Concentration

- Foam fractionation
- Membranes
- Phytoremediation

Adsorption treatment

- Activated carbon (AC)
- Anion exchange (AIX)
- Phytoremediation

Degradation

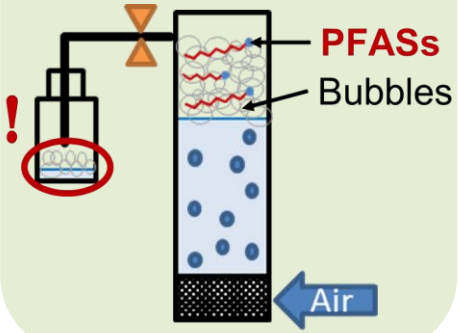
- Electrochemical oxidation
- Super critical water oxidation
- Sonochemical
- Plasma reactor
- Photodegradation
- Microbial degradation

McCleaf P, Kjellgren Y, Ahrens L. 2021. AWWA, e1238
Franke V, McCleaf P, Lindegren K, Ahrens L. 2019. *ESWRT*, 5, 1836–1843
Gobelius L, Lewis J., Ahrens L. 2017, *ES&T*, 51, 12602-12610

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
Smith, Wiberg, McCleaf, Ahrens. 2022. ES&T Water, 2, 841-851

PFAS Treatment Options for Water

Foam fractionation



Concentration

- Foam fractionation
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- Phytoremediation

Adsorption treatment

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- Anion exchange (AIX)
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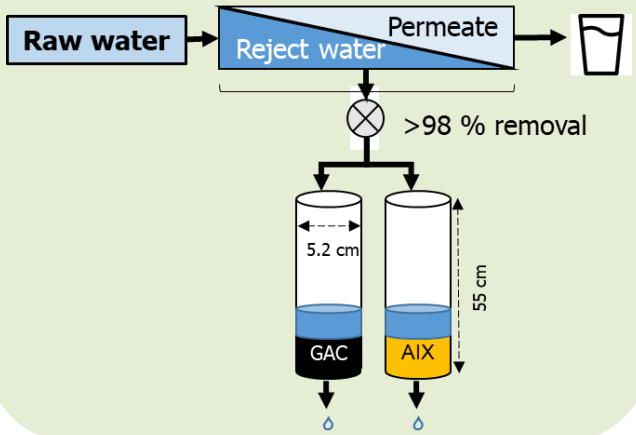
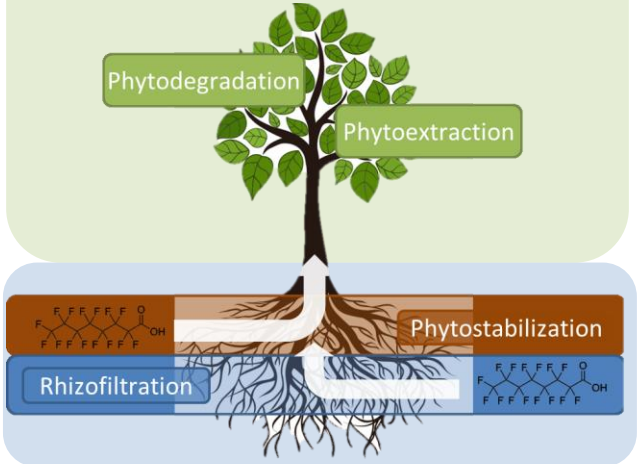
Degradation

- Electrochemical oxidation

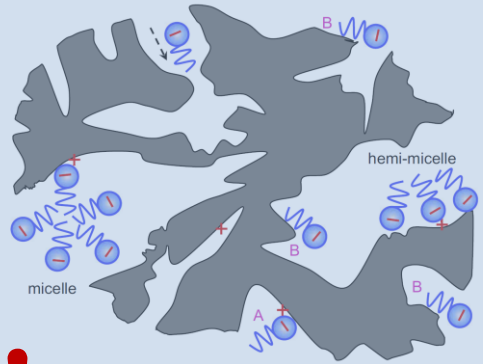
NF membrane



Phytoremediation

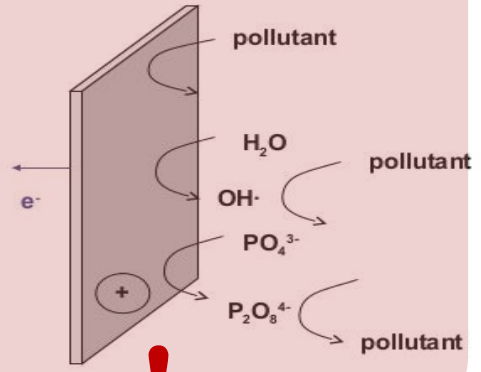


GAC



! Short chain PFASs

Electrochemical oxidation



! By-products

McCleaf P, Kjellgren Y, Ahrens L. 2021. AWWA, e1238
Franke V, McCleaf P, Lindegren K, Ahrens L. 2019. *ESWRT*, 5, 1836–1843
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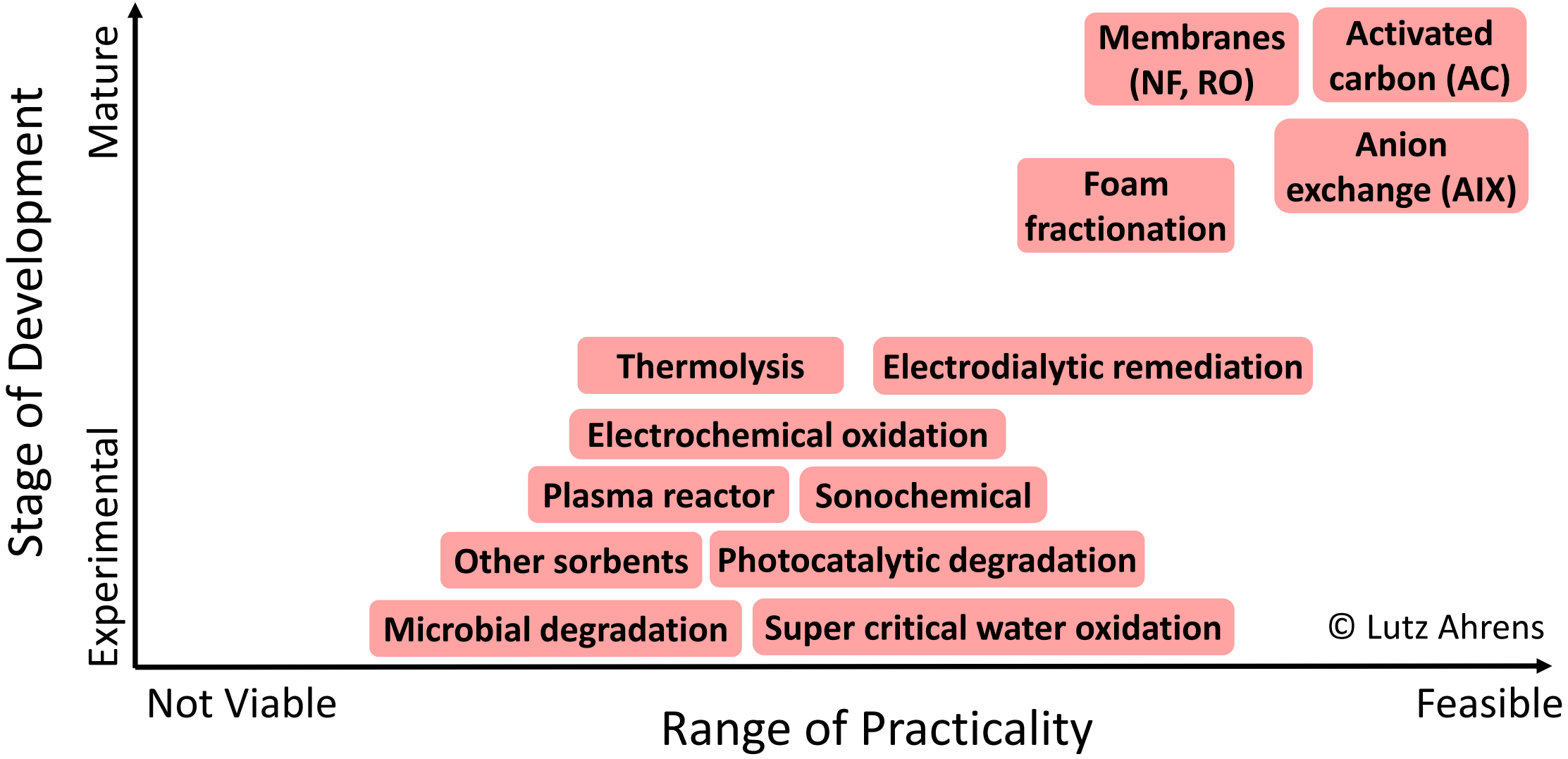
PFAS Treatment Options for Water



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PFASs in Drinking Water

Swedish Defense Department

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What can we do?

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Drinking water limits
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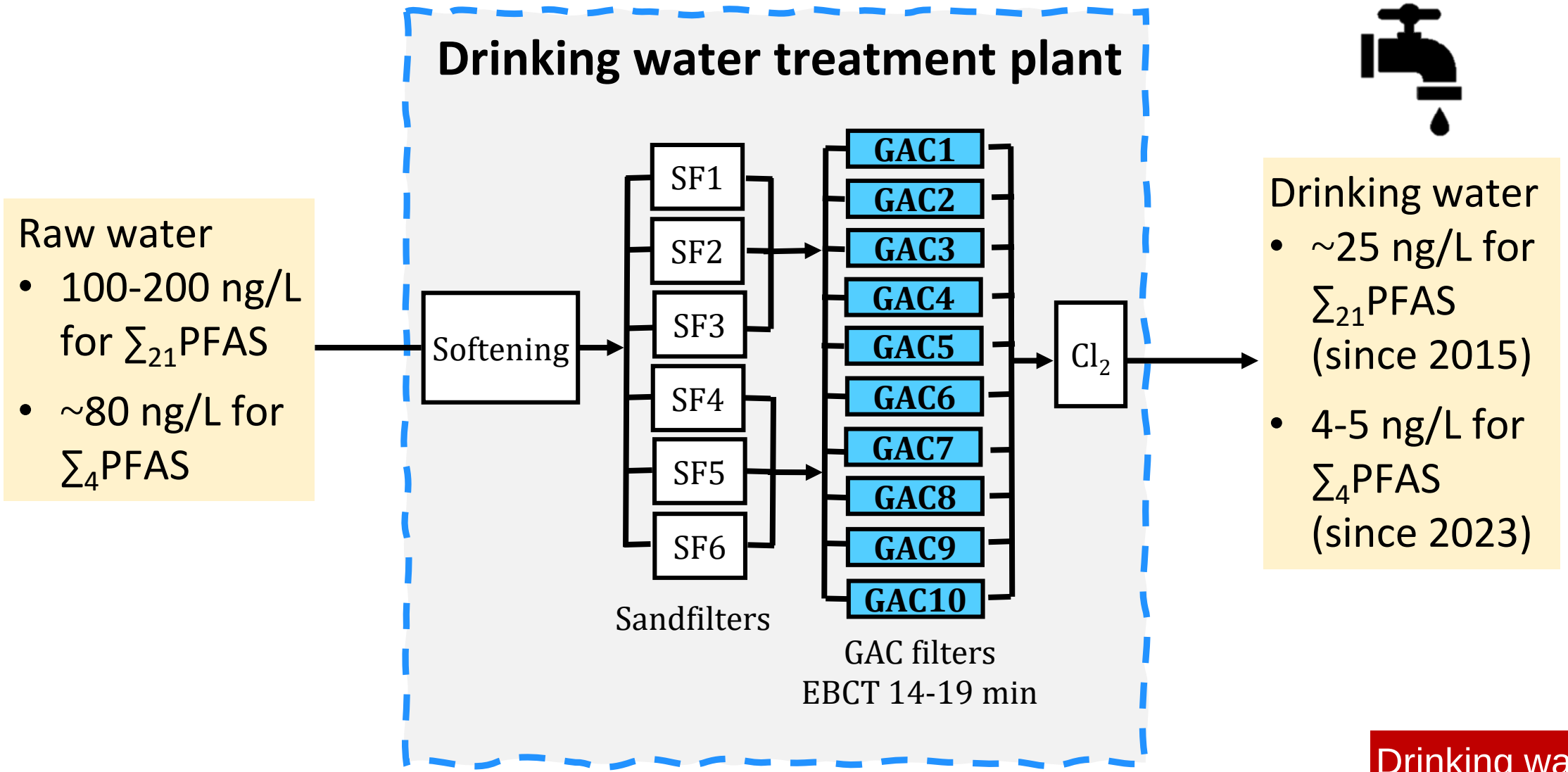
PFAS Treatment Options – Uppsala's Drinking Water Plant



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

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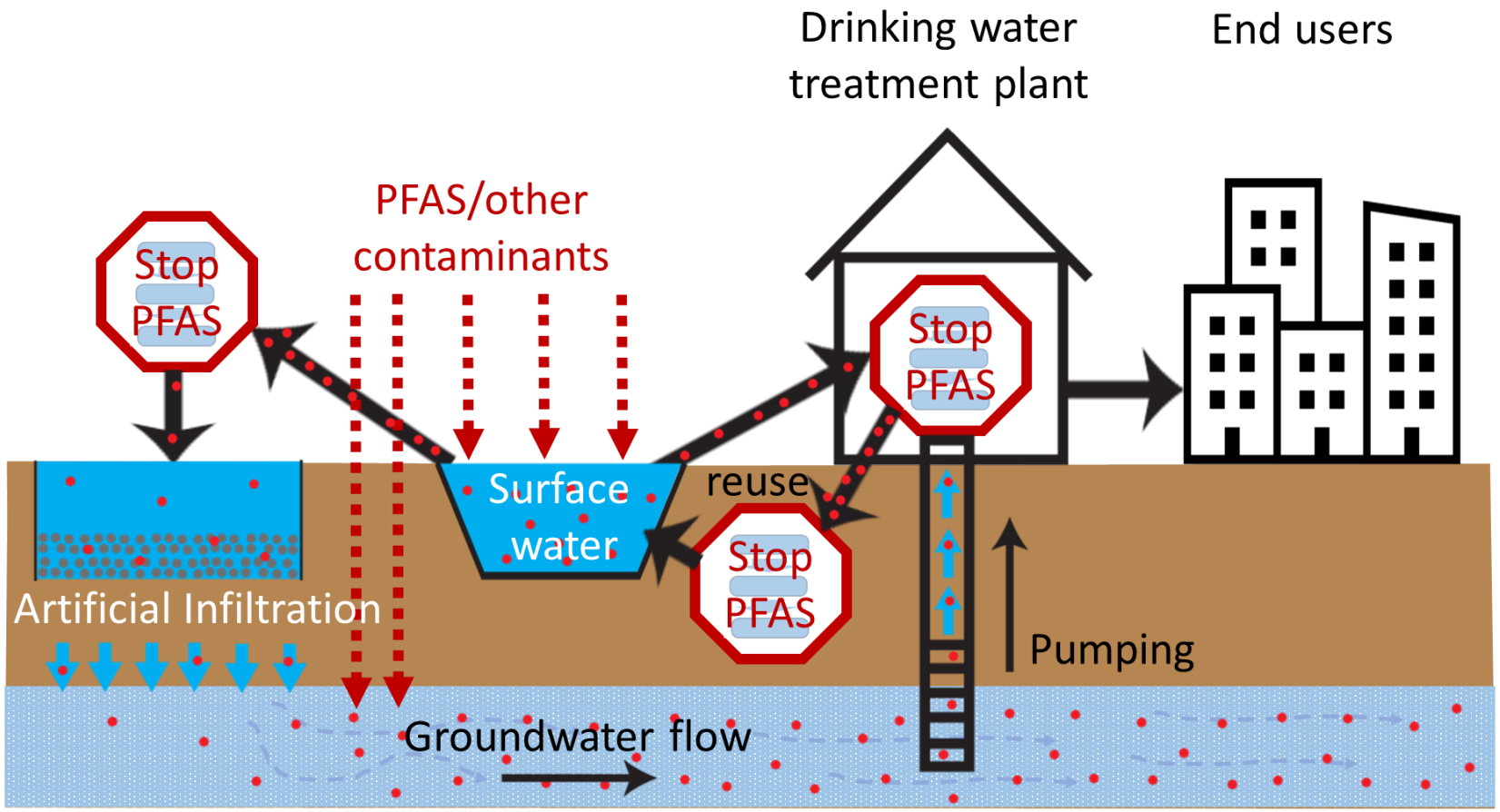
Sustainable innovative drinking water treatment solutions for large-scale water supply and reuse (SIDWater)



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NORRVATTEN
SYDVATTEN
STOCKHOLM VATTEN OCH AVFALL
LUNDS UNIVERSITET
UNIVERSITAS GOTHOBURGENSIS
UPPSALA UNIVERSITET
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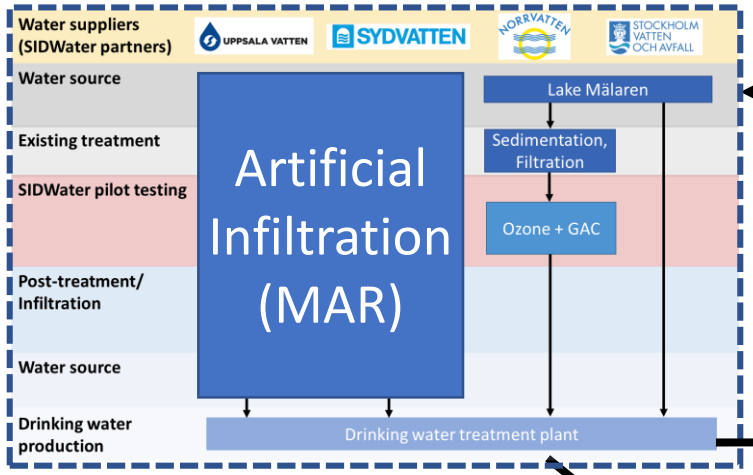
SID Water

FORMAS



Discharge to environment

SIDWater pilot testing

Reverse osmosis/nanofiltration membrane

Reject water

Filtrate

>80%

Drinking water

<20%

Foam fractionation

~1%

Electrochemical Oxidation

Biofilter

Water reuse

~99%

~1%

~1%

~99%

Pellet reaktor ($CaCO_3$)

~99%

Biologically active ion exchange

~99%

Anion exchange

Byproduct for commercial use

Regeneration/ recycling

SIDWater

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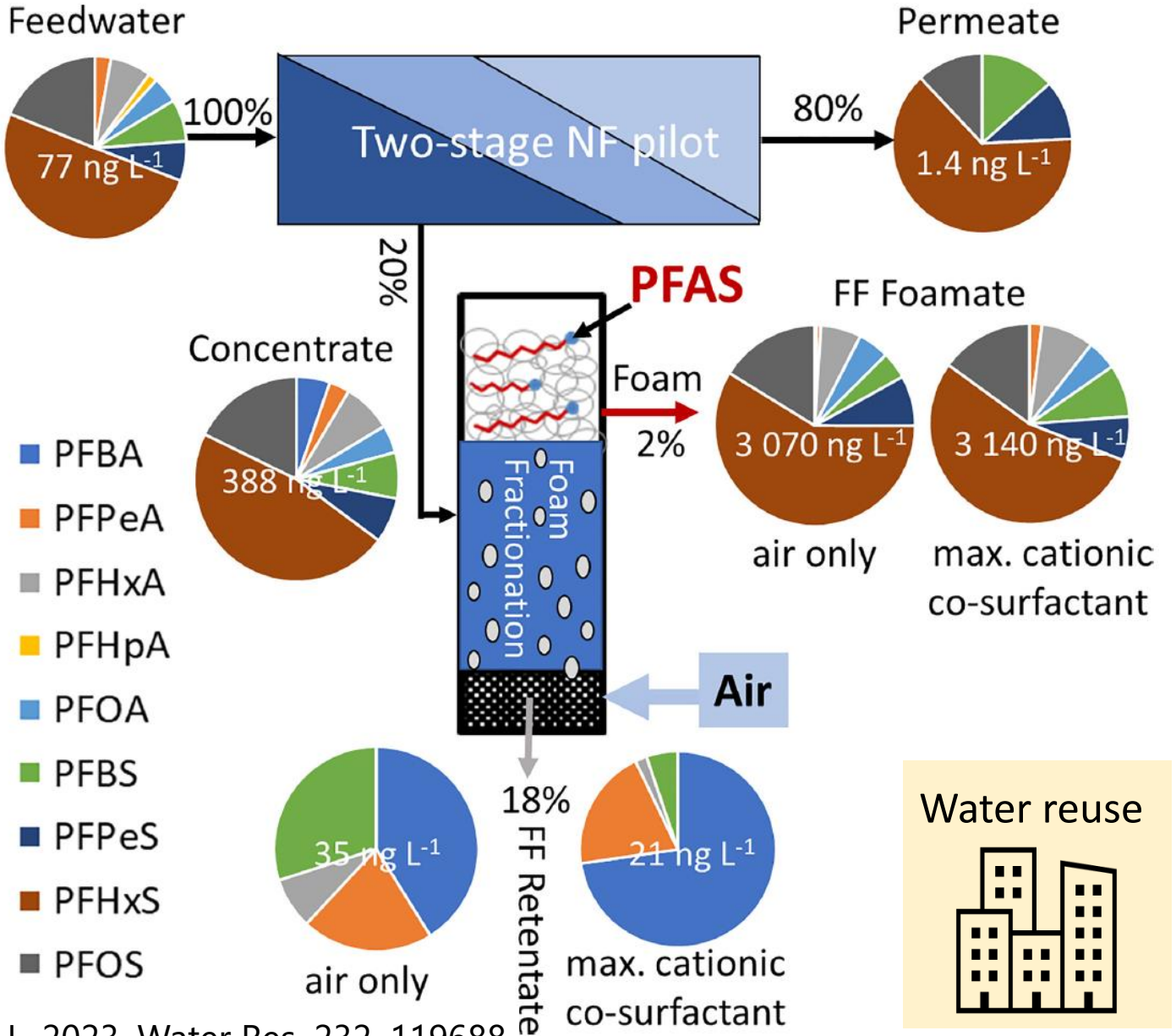
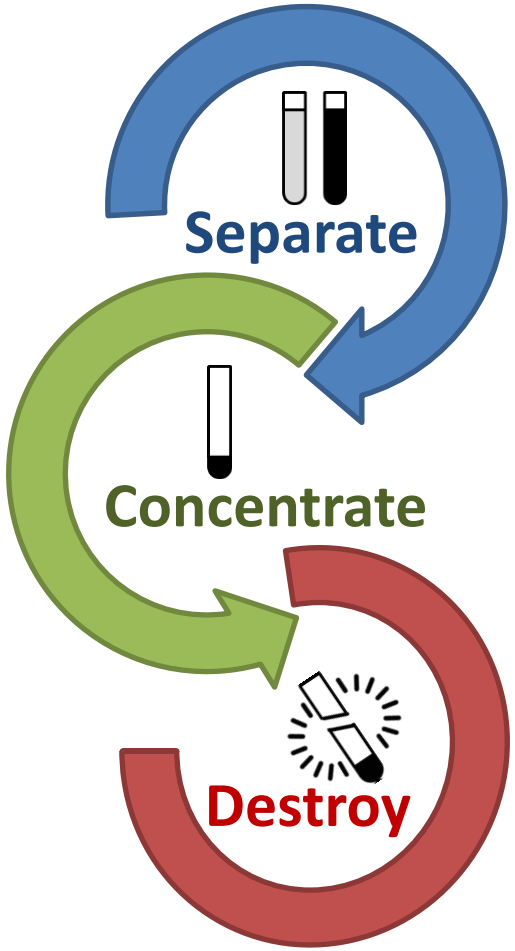
Combination of Nanofiltration + Foam Fractionation



McCleaf P, Stefansson W, Ahrens L. 2023. Water Res, 232, 119688

Take Home Message

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



Thank you!

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Contact: lutz.ahrens@slu.se