

On site treatment solutions for PFAS contaminated groundwater *halftime seminar*

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Background

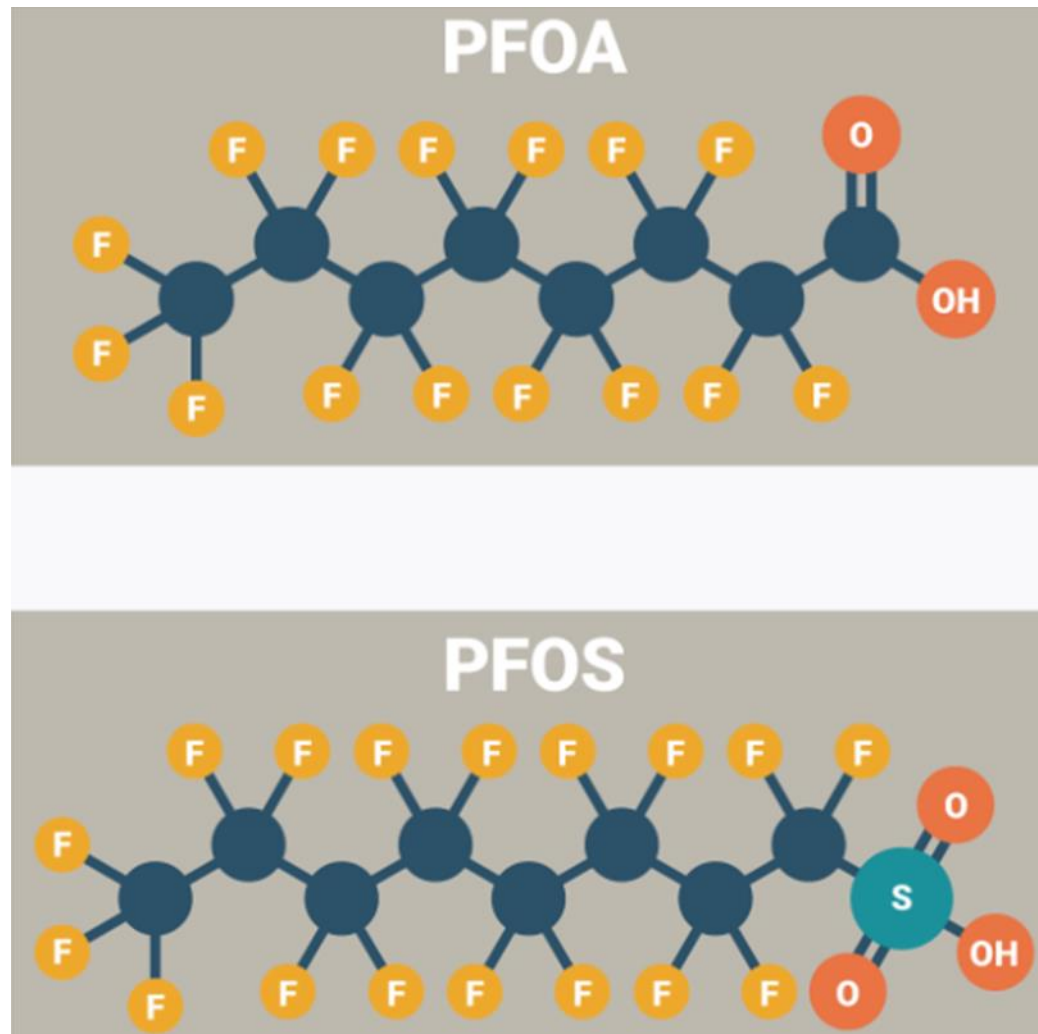
PFAS

- Per and polyfluorated alkyl substances
- Mobile
- Persistent
- Coupled to a wide range of adverse health effects



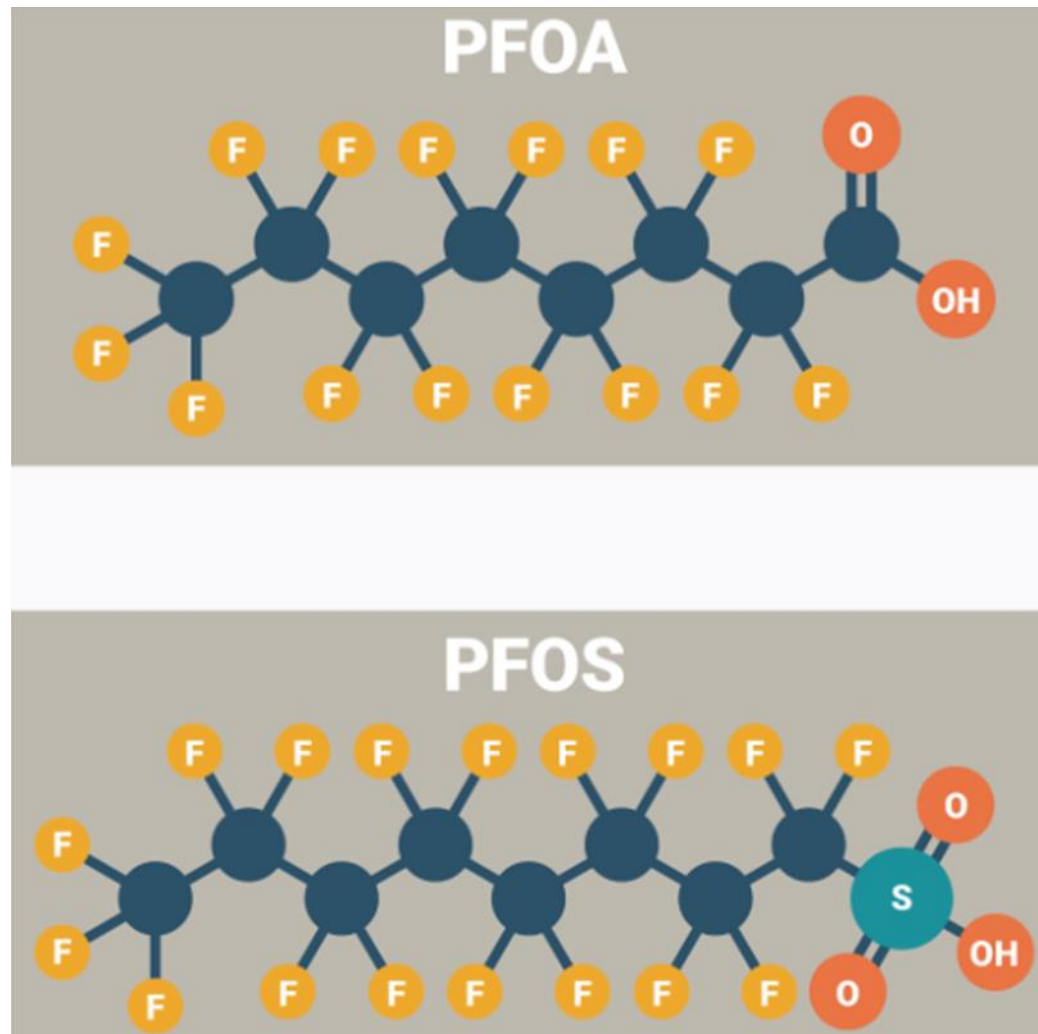
PFAS

- Thousands of PFAS with widely varying properties
- This presentation will focus on
 - Perfluorinated carboxylic acids (PFCAs)
 - Perfluorinated sulfonic acids (PFSAs)

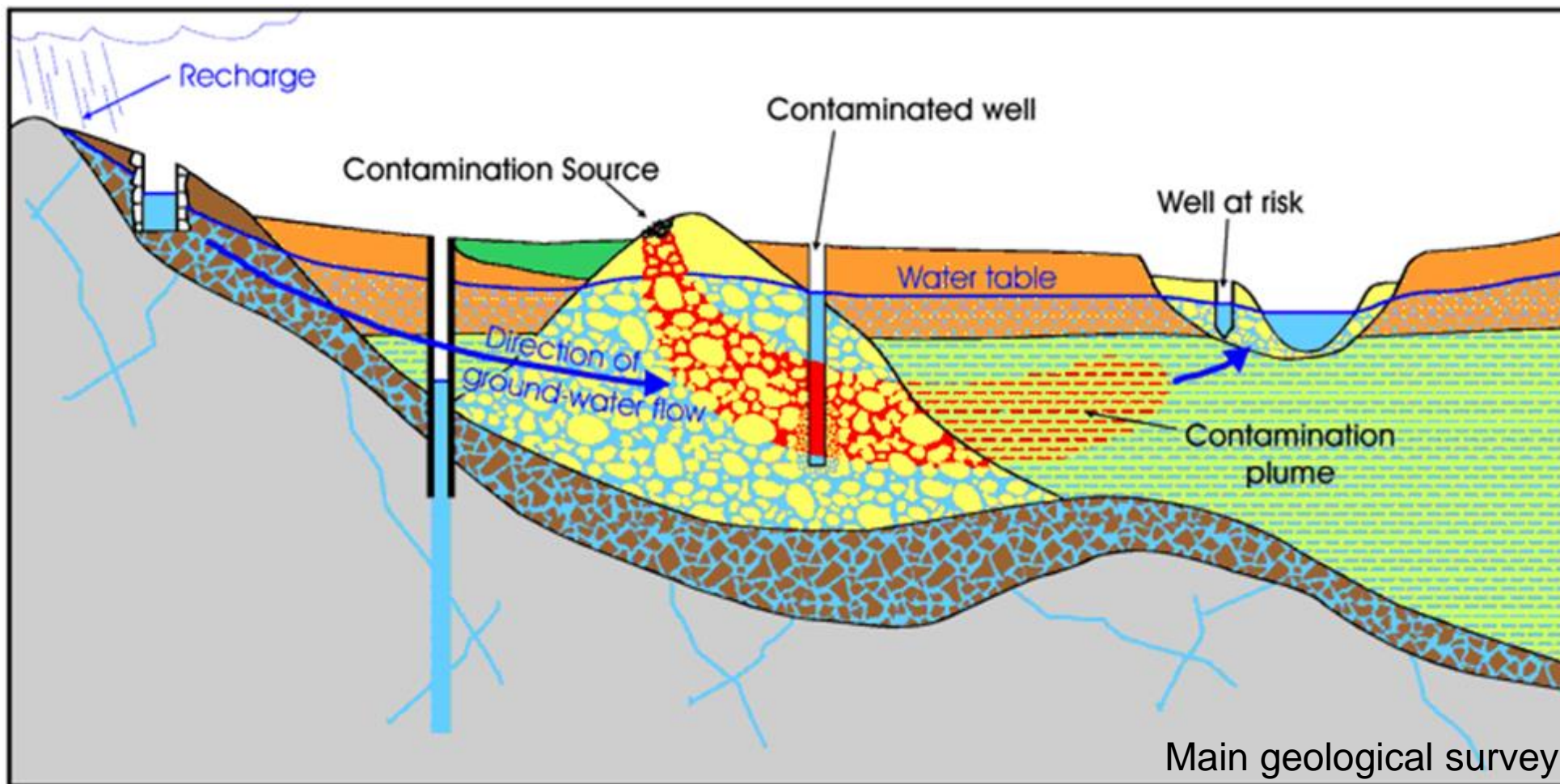


PFAS

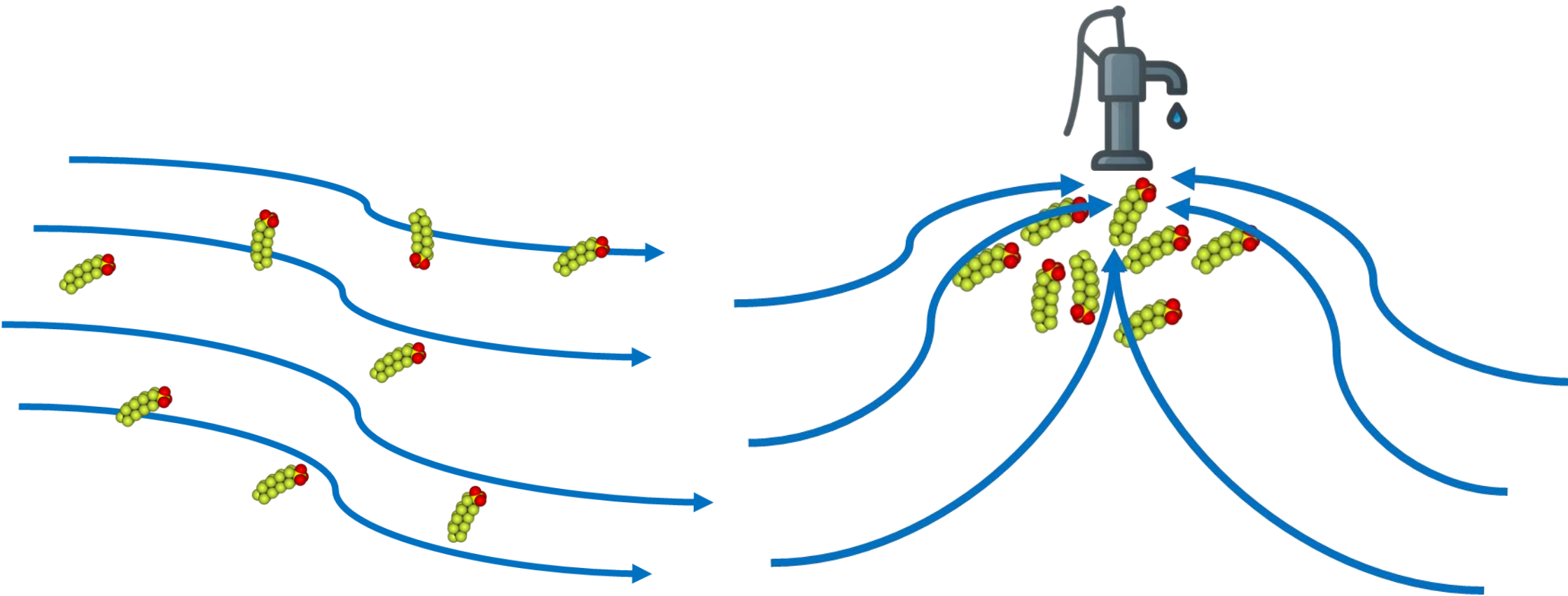
- Length of perfluorinated carbon chain important for physiochemical properties
 - Longer chain length
 - Higher bioaccumulation factor
 - Lower mobility



Aquifer infiltration and spread



Pump and treat?



The EU LIFE SOuRCE project

- *Demonstrate two series of treatment trains for pump and treat treatment of PFAS contaminated groundwater*
- *Test on different sites*
 - *A Swedish waste management facility*
 - *A Spanish fire training site*

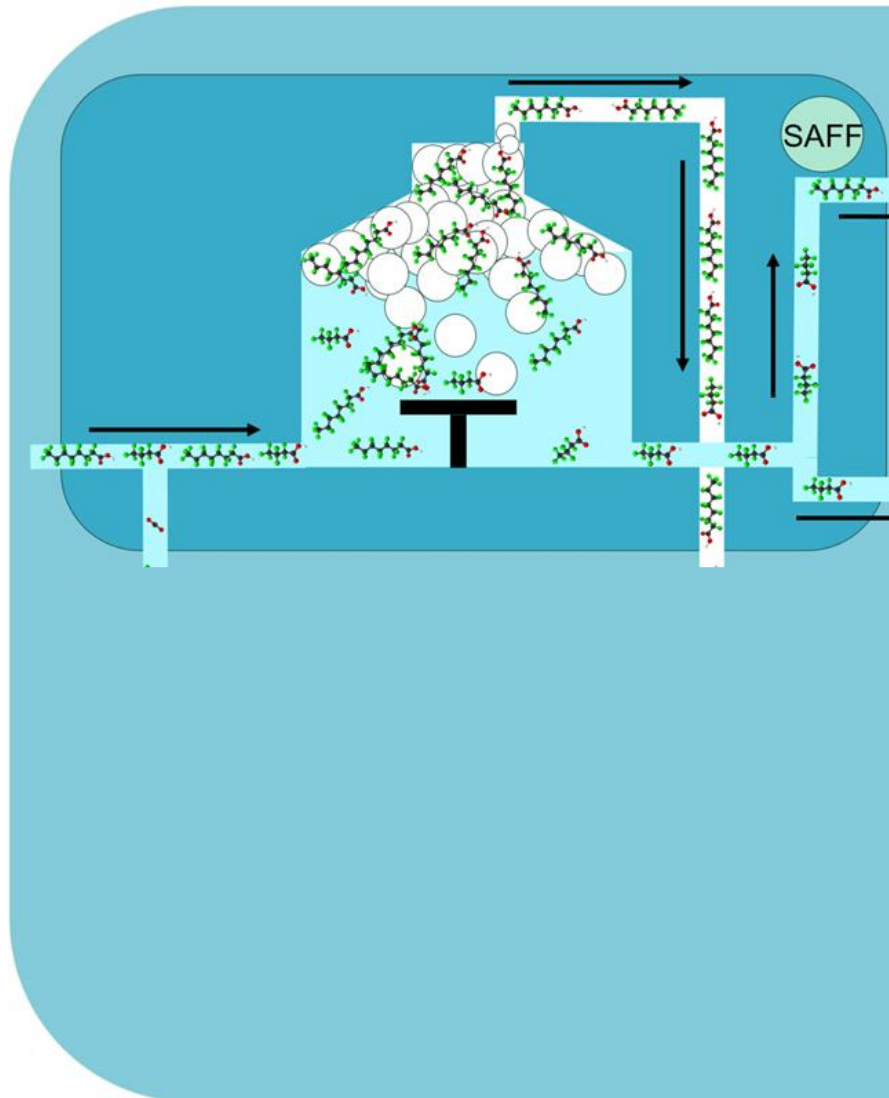


The SOuRCE treatment train



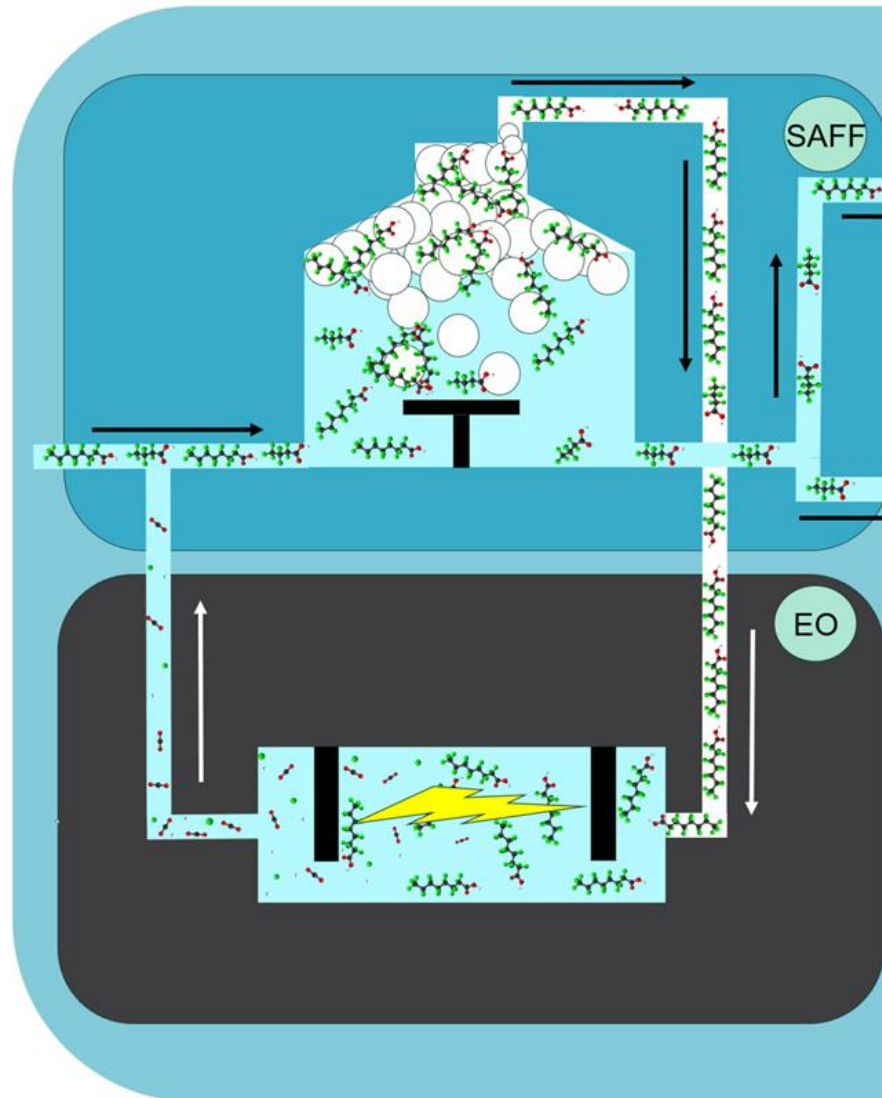
The SOuRCE treatment train

- Separation
 - Surface active foam fractionation (SAFF)



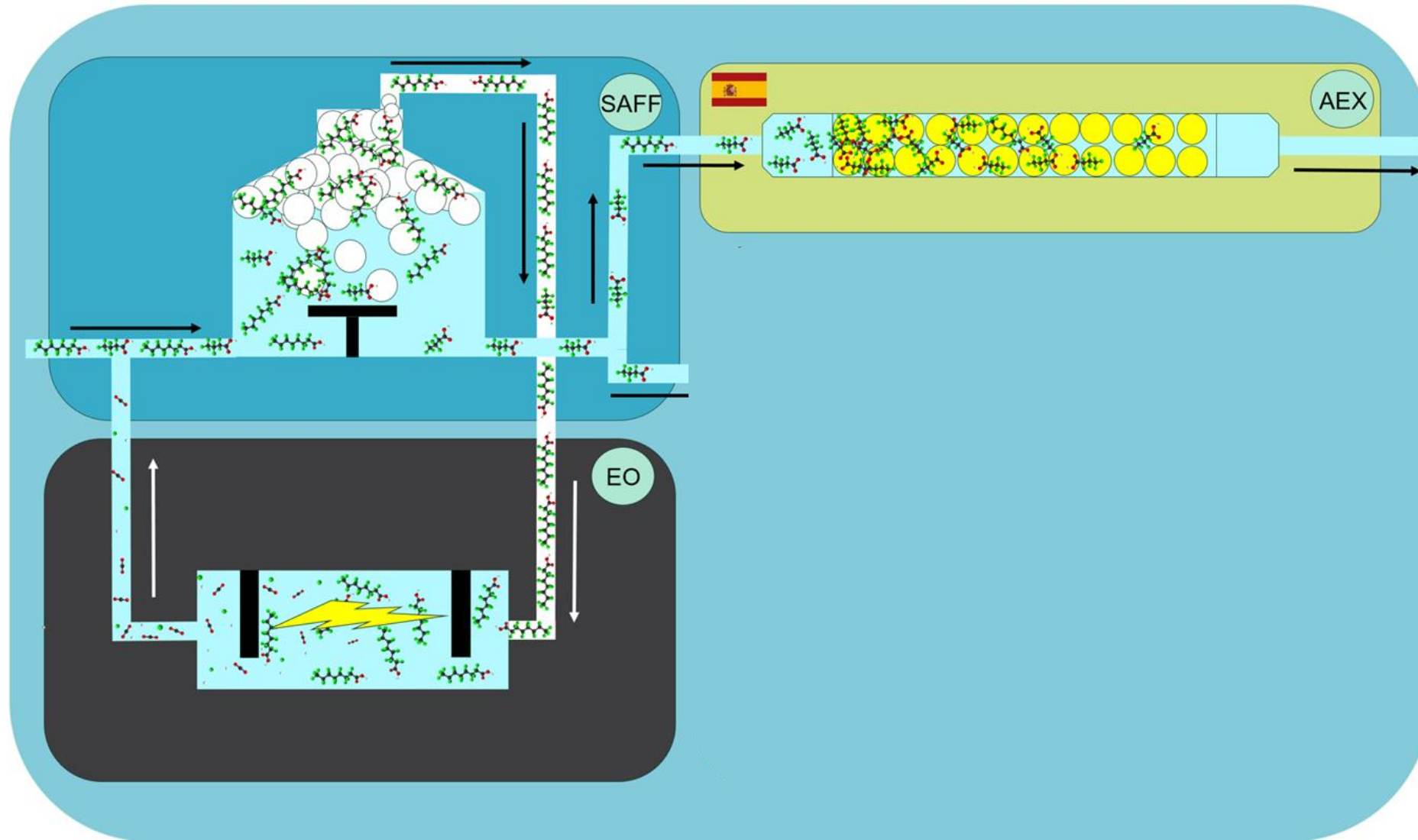
The SOuRCE treatment train

- Separation
 - Surface active foam fractionation (SAFF)
- Destruction
 - Electrochemical oxidation (EO)



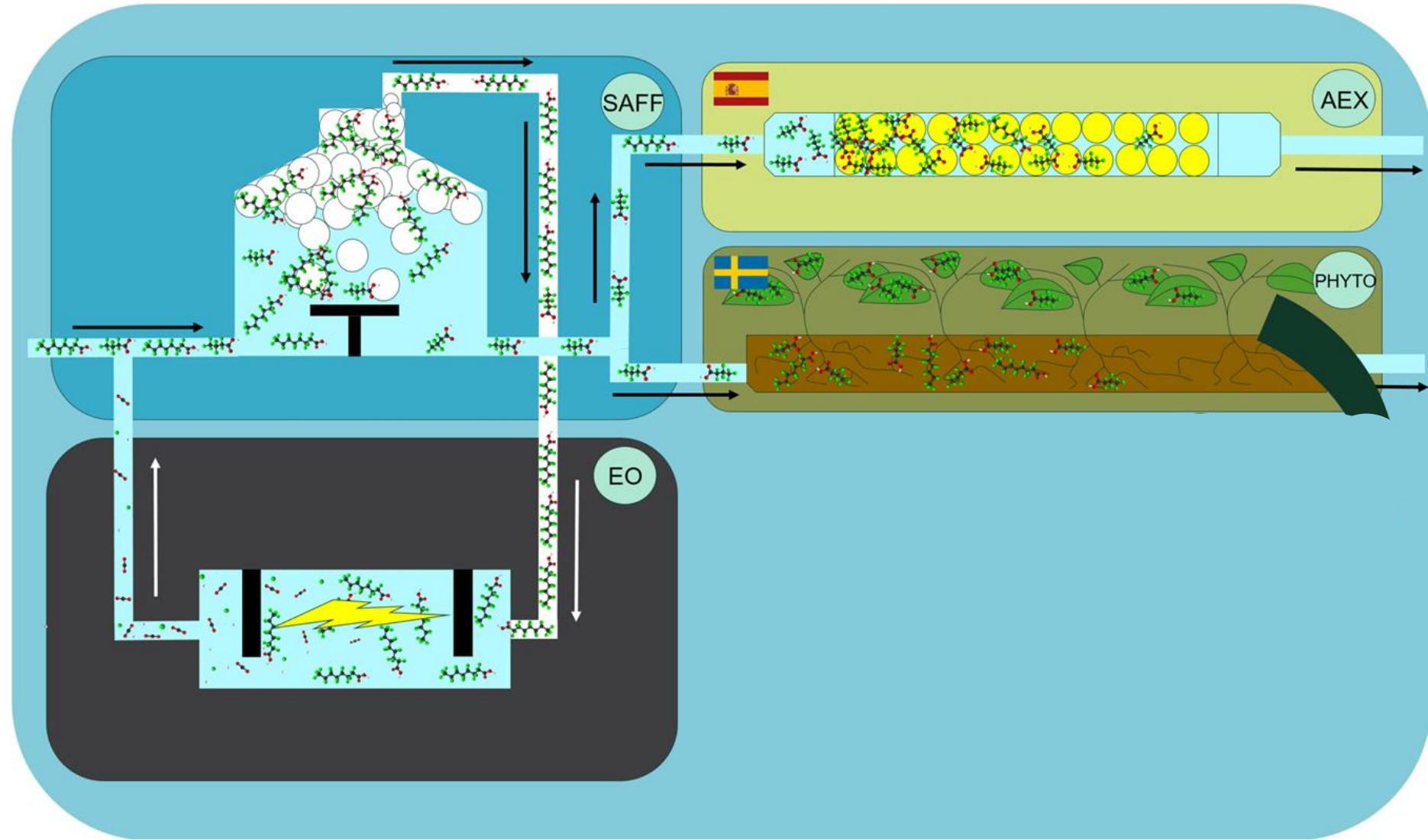
The SOuRCE treatment train

- Separation
 - Surface active foam fractionation (SAFF)
 - Ion exchange (AEX)
- Destruction
 - Electrochemical oxidation (EO)



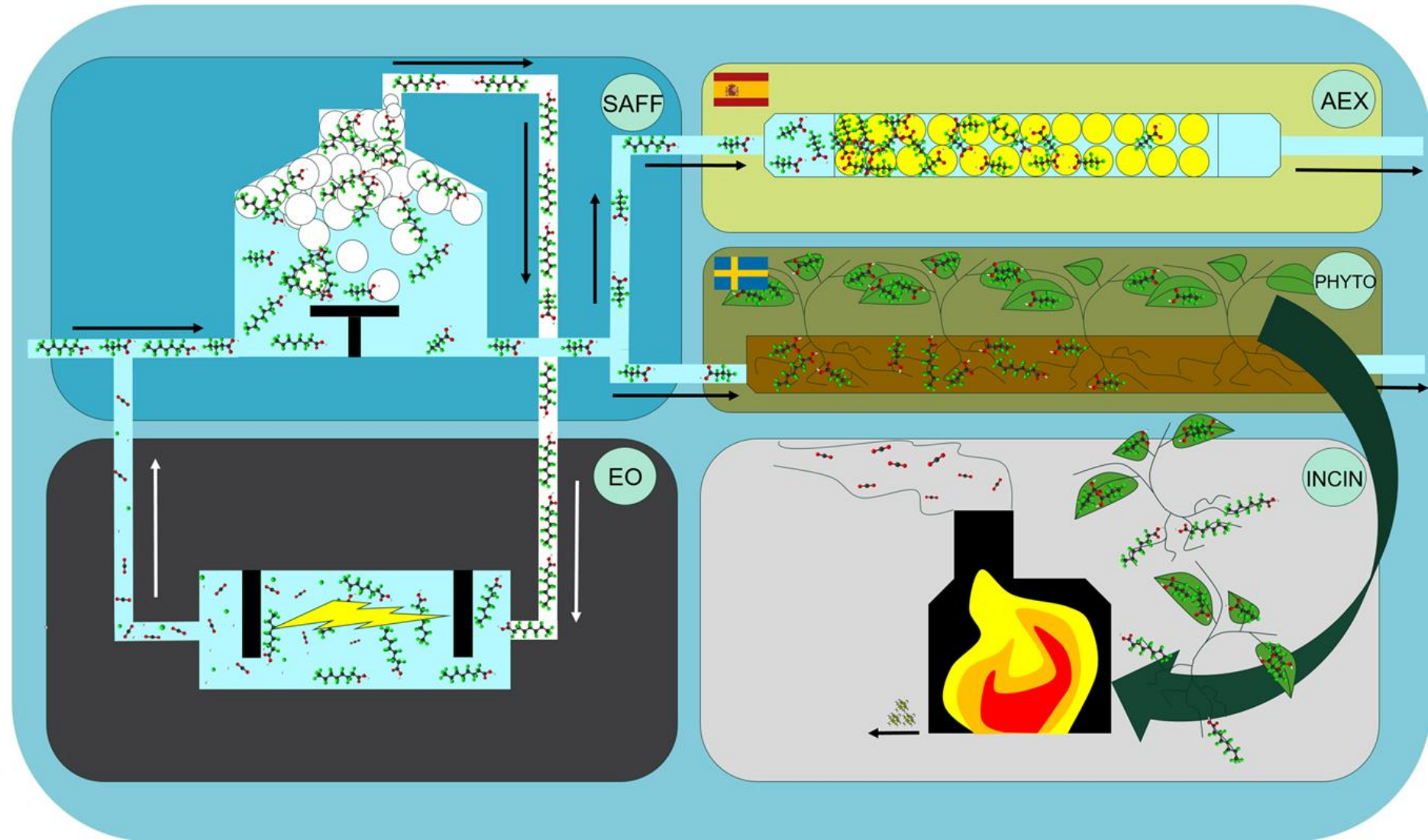
The SOuRCE treatment train

- Separation
 - Surface active foam fractionation (SAFF)
 - Ion exchange (AEX)
 - Phytoremediation (PHYTO)
- Destruction
 - Electrochemical oxidation (EO)

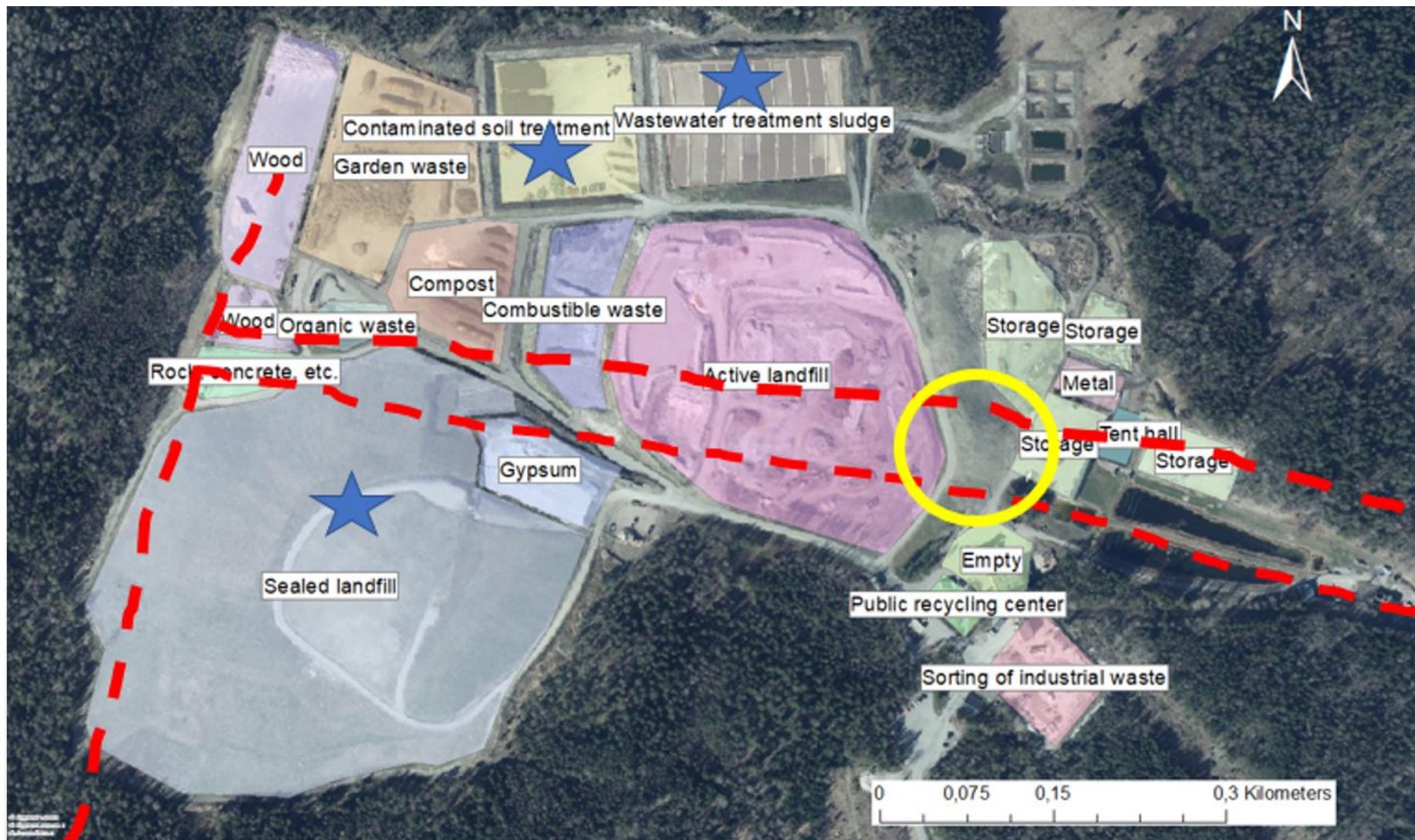


The SOuRCE treatment train

- Separation
 - Surface active foam fractionation (SAFF)
 - Ion exchange (AEX)
 - Phytoremediation (PHYTO)
- Destruction
 - Electrochemical oxidation (EO)
 - Incineration (INCIN)



The Swedish site



Research questions

Research questions

Q1. How does the mobility of PFAS in GW saturated zone depend on its physicochemical properties, water quality and soil characteristics?

Q2. Can PFAS be removed from contaminated GW and be destroyed using an innovative treatment train combining SAFF, EO and PHYTO?

Q3. Can the innovative treatment train be more cost efficient than conventional treatment techniques?

Q4. Can PFAS accumulated in plant matter during PHYTO be degraded during incineration for energy production?

Paper 1

Soil/Water partitioning, kinetics and transport of PFAS in groundwater saturated zones

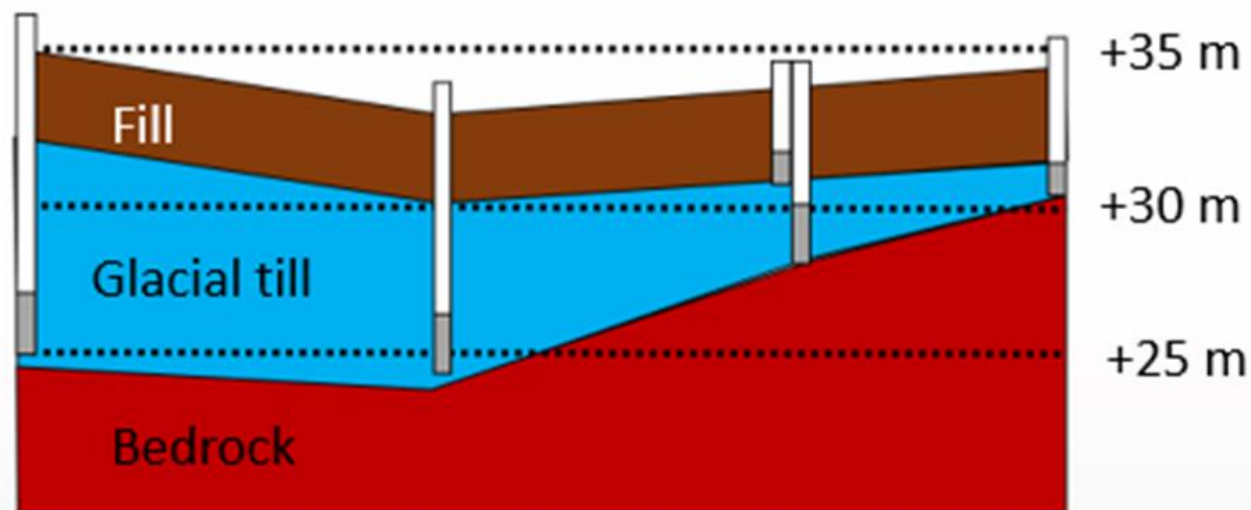
Research aims

- *Investigate mobility of PFAS in groundwater aquifers*
 - *Transport*
 - *Soil / Water partitioning coefficient*
 - *Sorption kinetics*
- *Relate PFAS mobility in GW to*
 - *PFAS physio chemistry*
 - *Water quality*
 - *Soil properties*



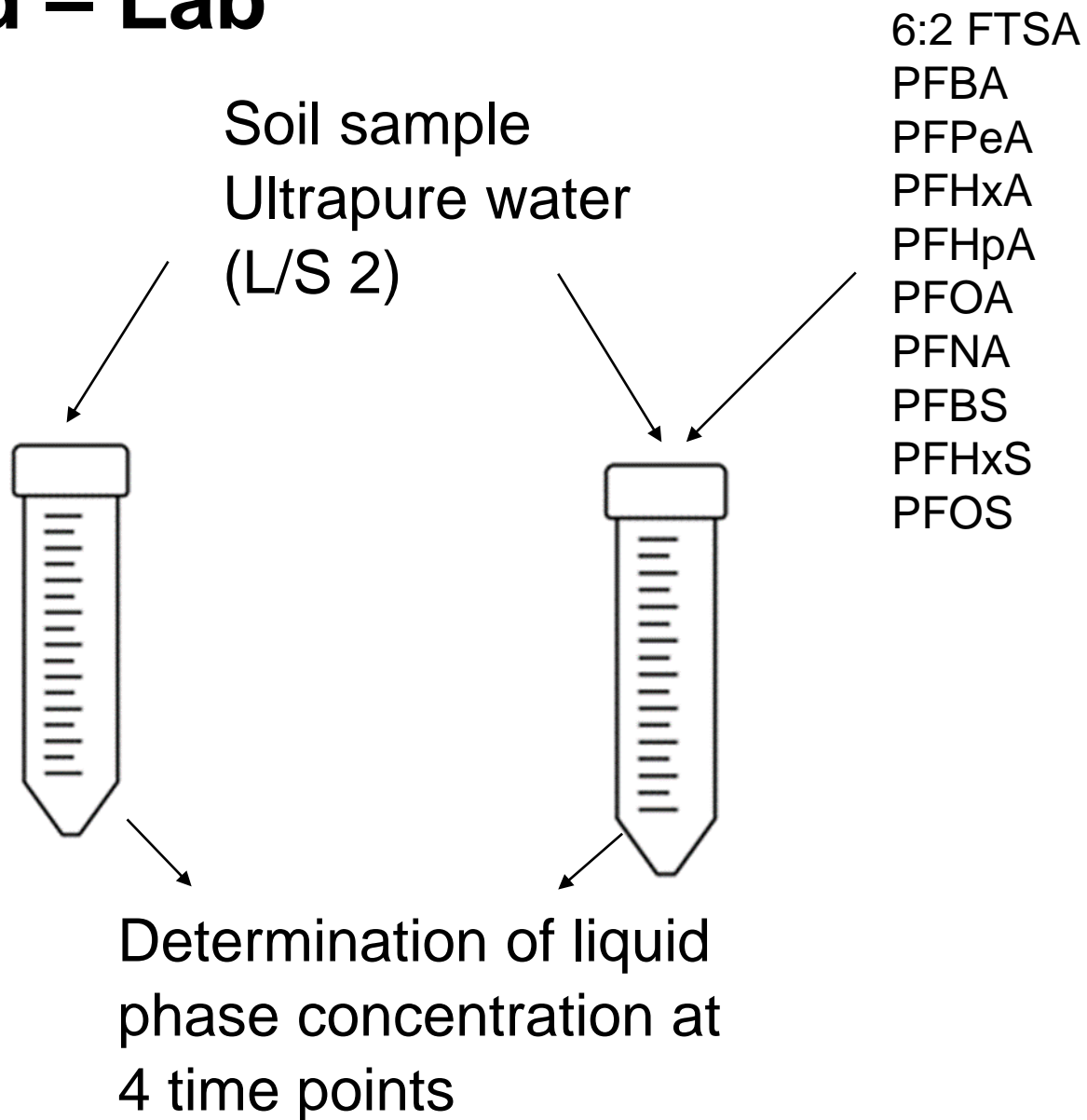
Method - Field

- Establish GW wells
- Collect drill cores
- Determine a field K_d (C_s/C_w)
- Monitor the GW



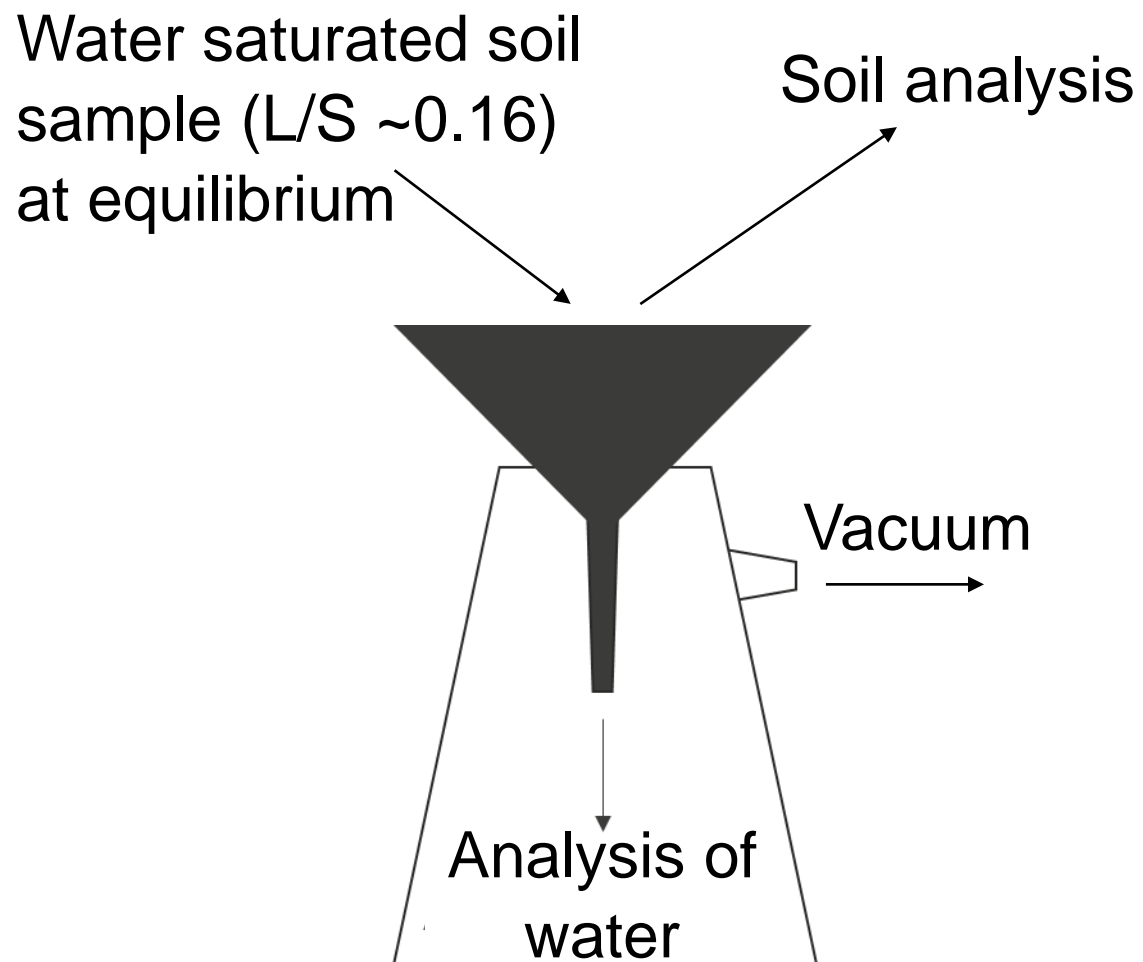
Method – Lab

- Sorption Shake tests
- Desorption
 - K_d (C_s/C_w)
 - Kinetics
- Adsorption
 - K_d (C_s/C_w)
 - Kinetics



Method – Lab

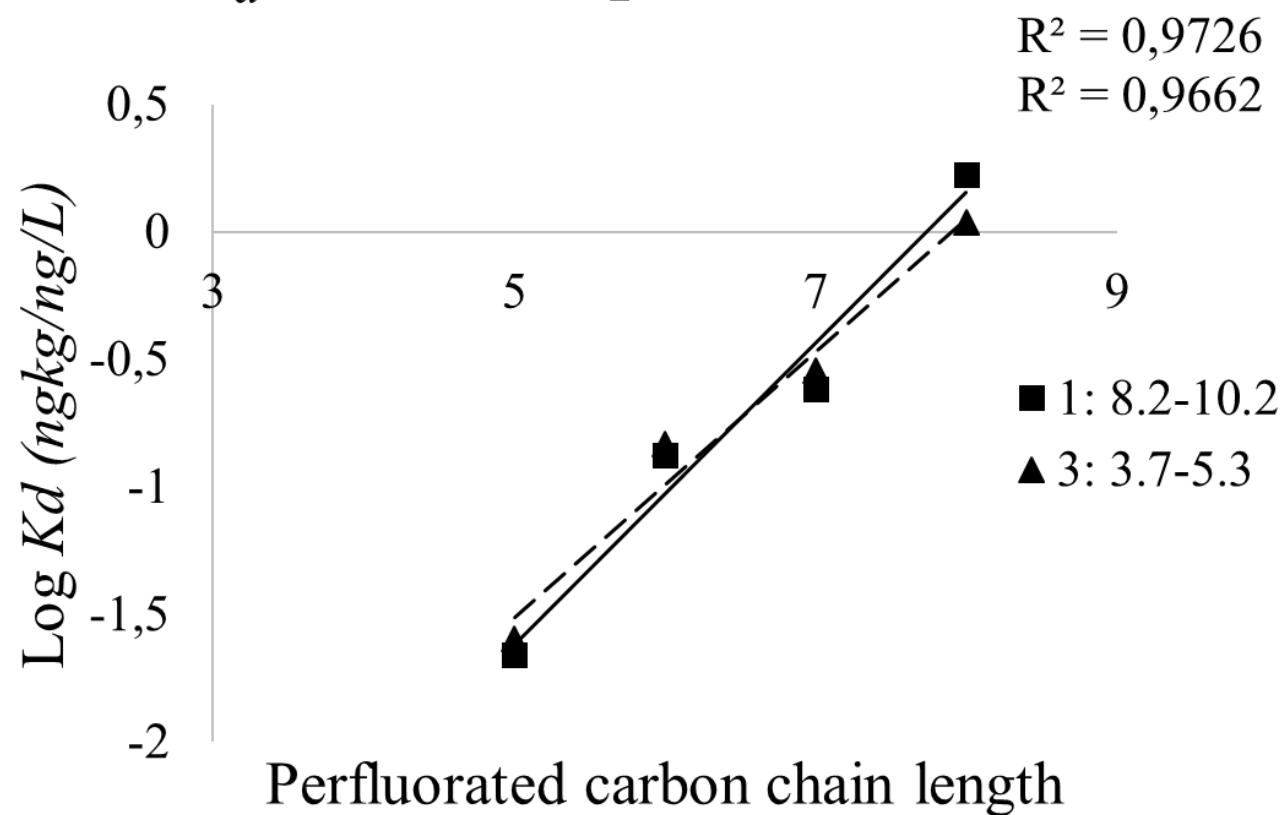
- Saturated paste extraction
– $K_d (C_s/C_w)$



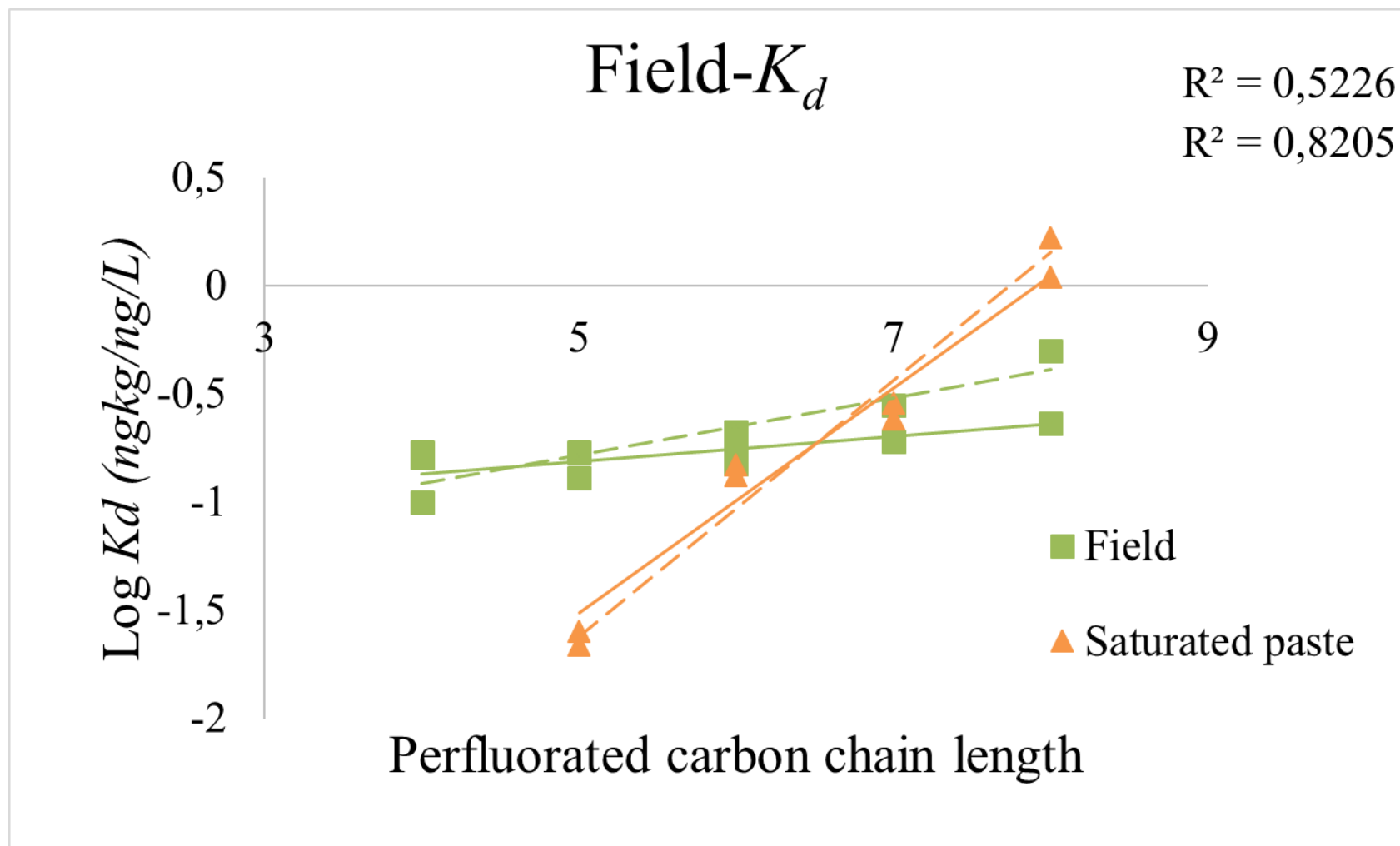
Results

Results - K_d

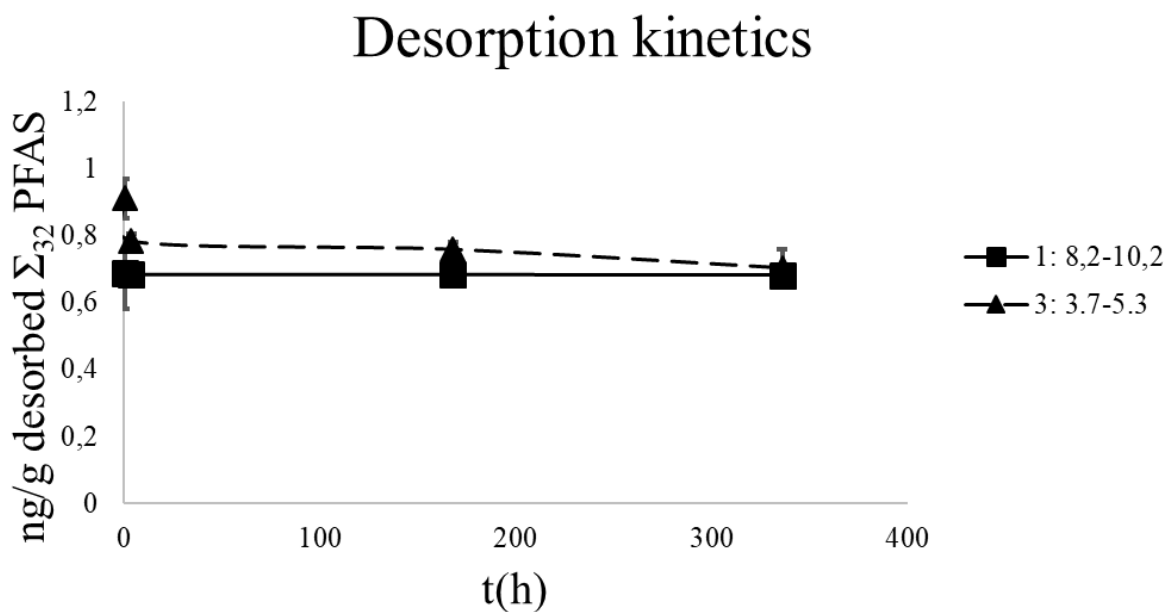
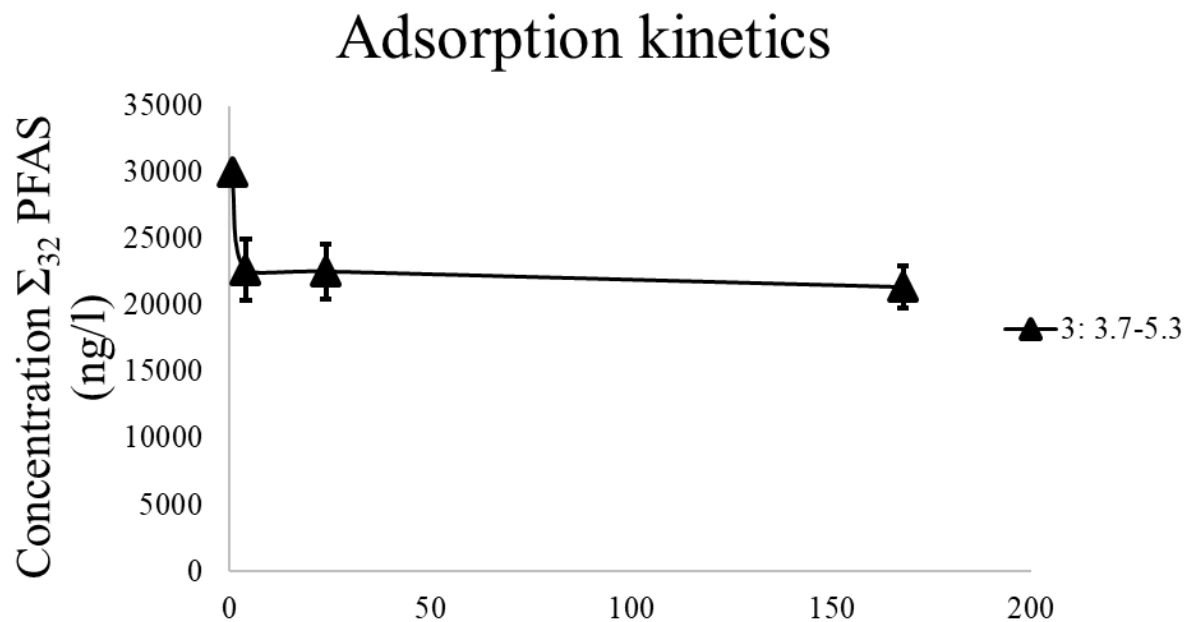
K_d Saturated paste extraction



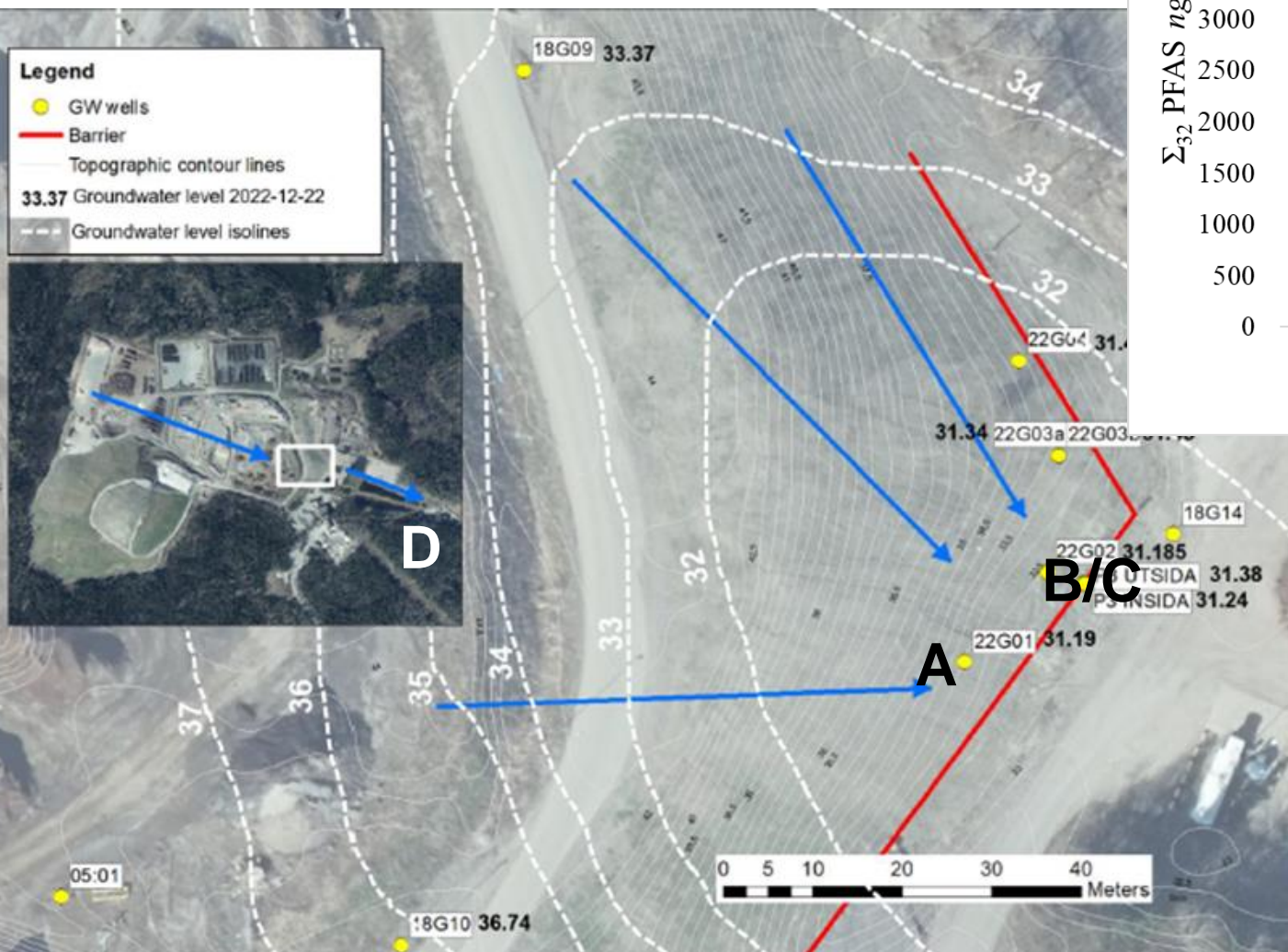
Results - K_d



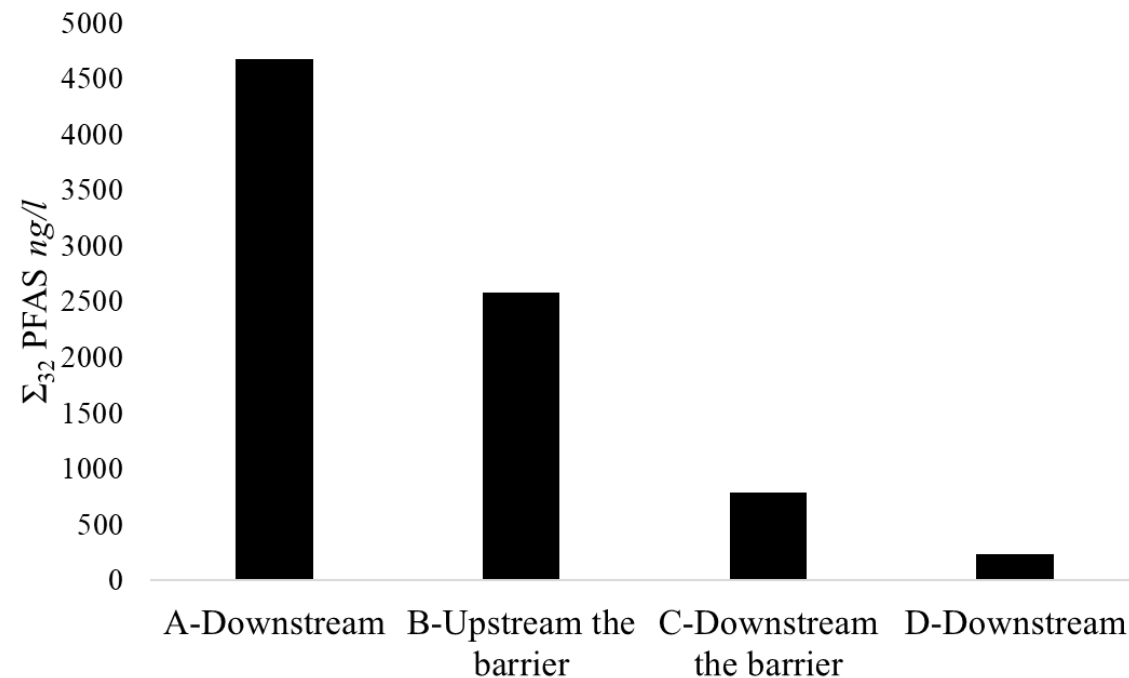
Results - Kinetics



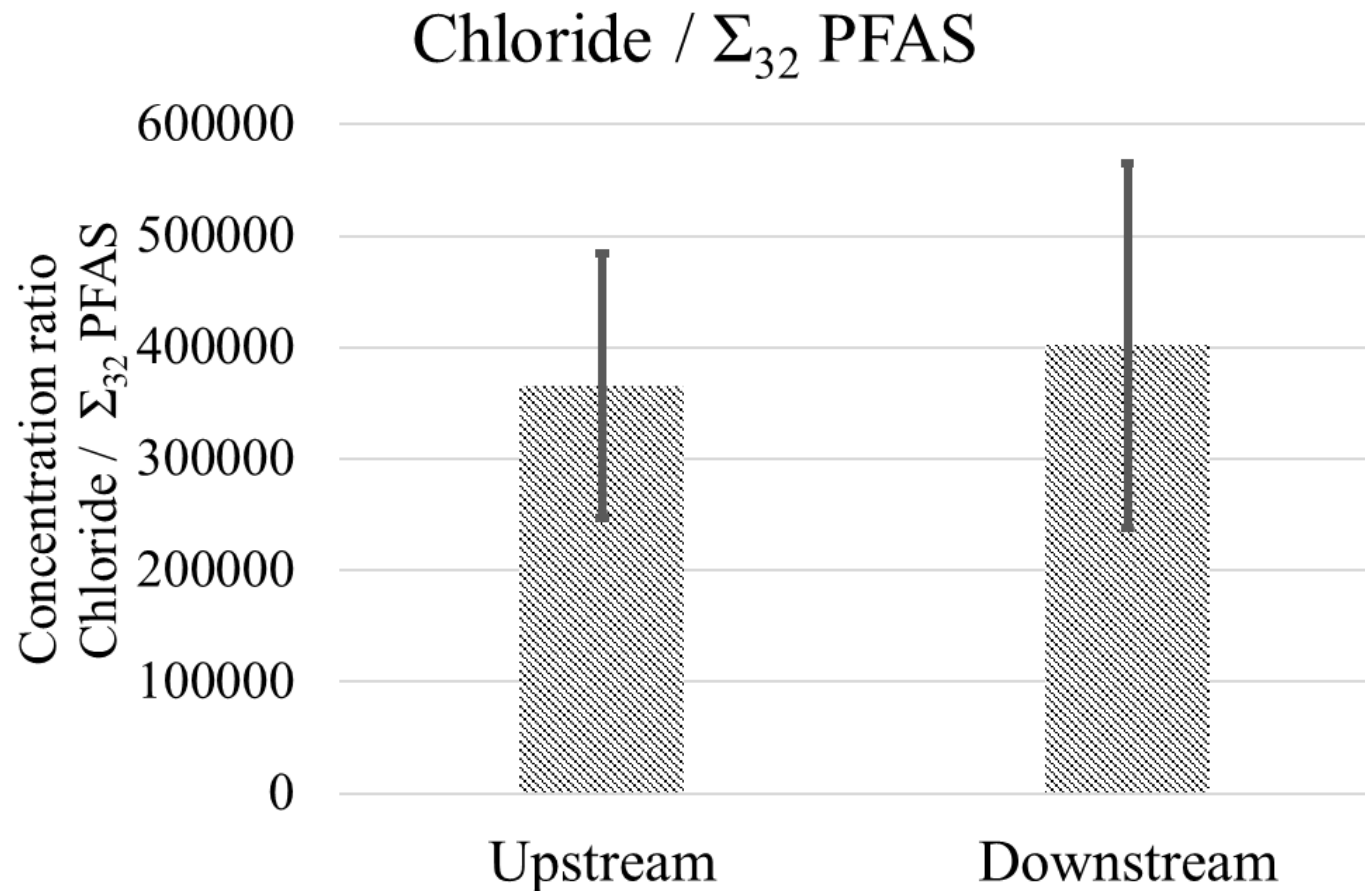
Results – GW monitoring



Average Σ_{32} PFAS



Results – GW monitoring



Moving forward

- SGI are characterizing two additional sites
 - GW monitoring
 - Field and lab K_d
- Data interpretation
 - Correlations between PFAS mobility and soil/water properties
- Write manuscript

Papers 2-3

Pilot scale
biofiltration/phytoremediation
treatment of PFAS contaminated
groundwater using various plant
species

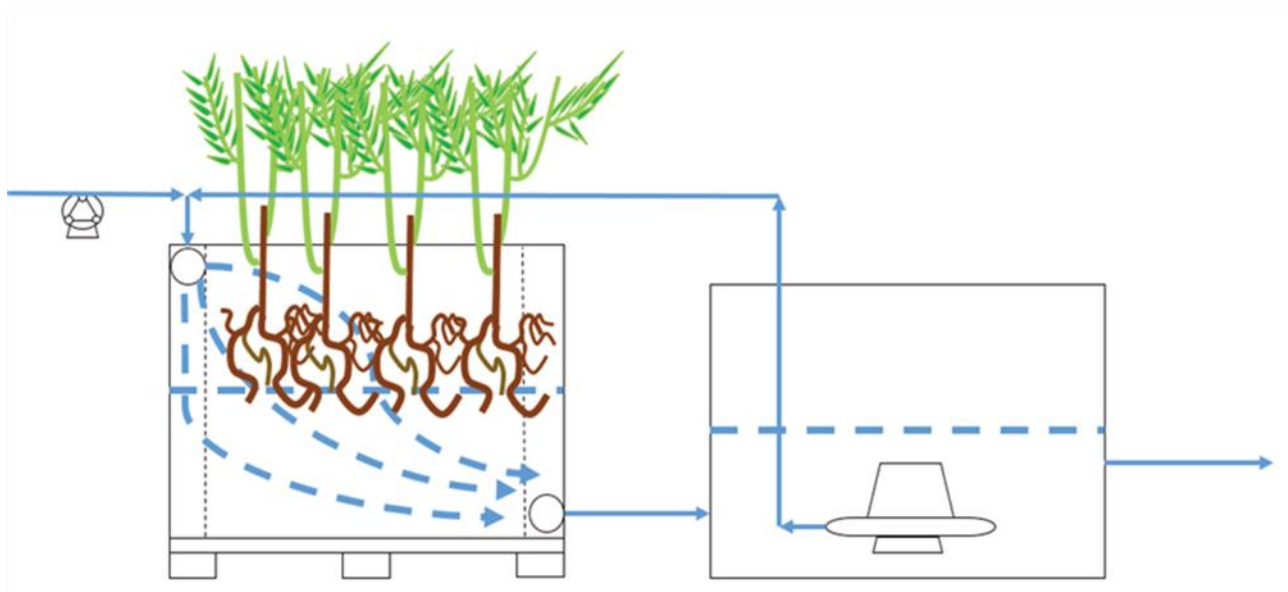
Research aims

- Investigate PFAS uptake in plant tissue
 - Different species
 - Distribution in plant tissues
- Investigate PFAS sorption to a growth substrate of LECA, peat and biochar
- Investigate the removal efficiency of a PHYTO unit for PFAS contaminated groundwater during field conditions



Method – biofilter unit

- 0.48 m³
LECA/peat/biochar
mix with growing
plants



Method – biofilter unit

- *Salix spp*
 - Loden
 - Wilhelm
- *Carex elata*
- *Cannabis sativa*
 - Futura 75

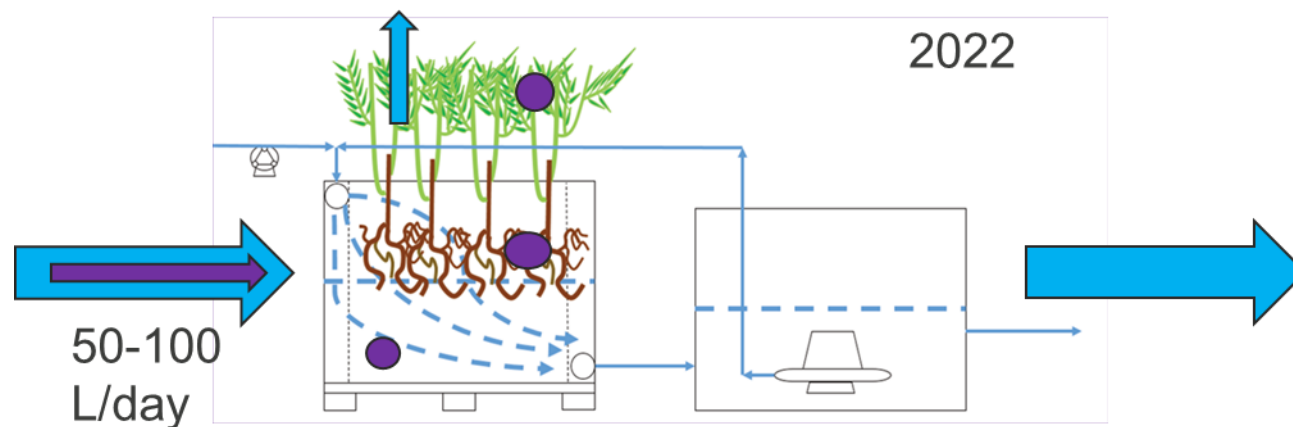


Method – biofilter units



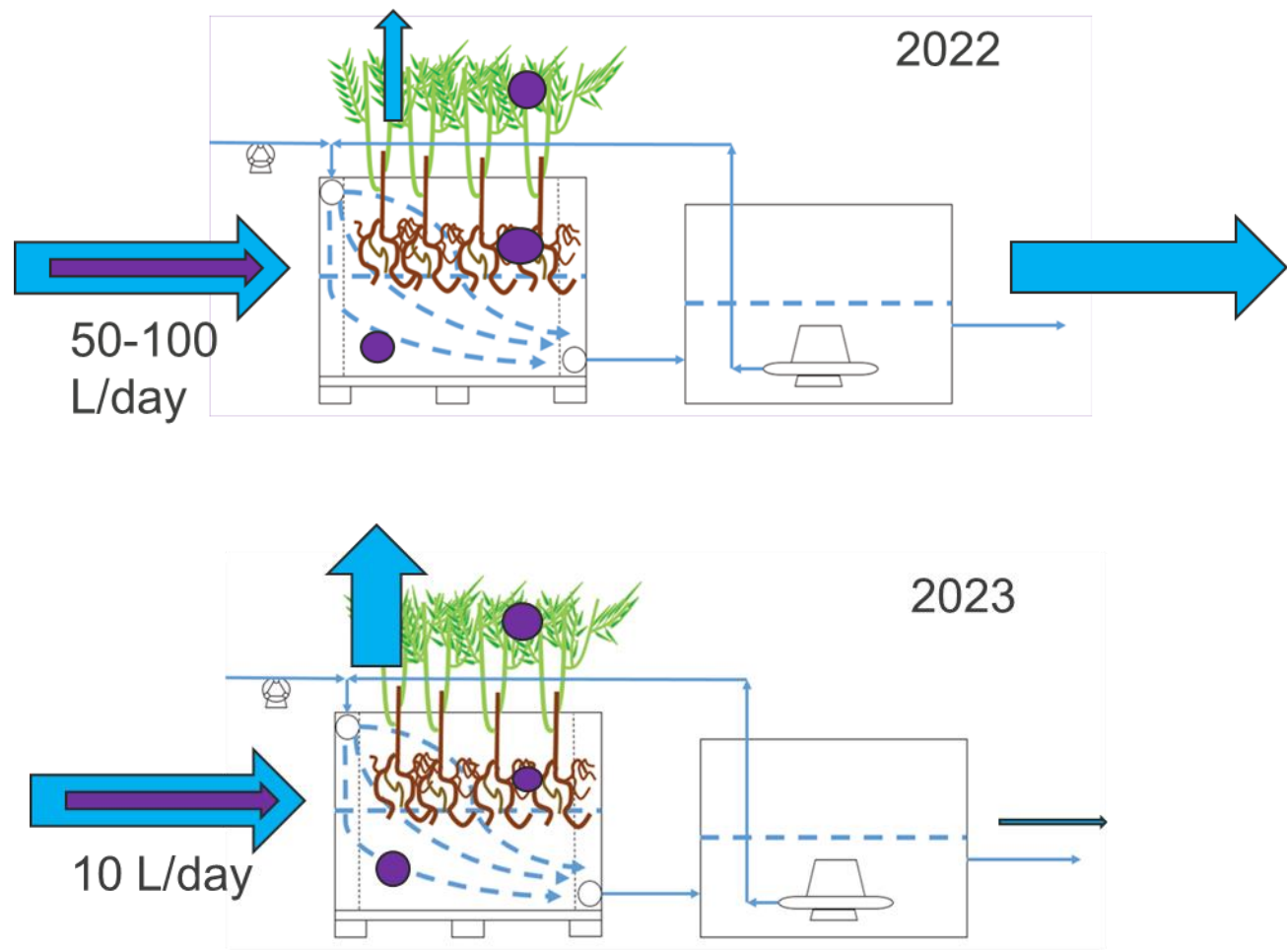
Method - load

- High flow filter configuration
– Manuscript 2



Method - load

- High flow filter configuration
– Manuscript 2
- Low flow evapotranspiration configuration
– Manuscript 3

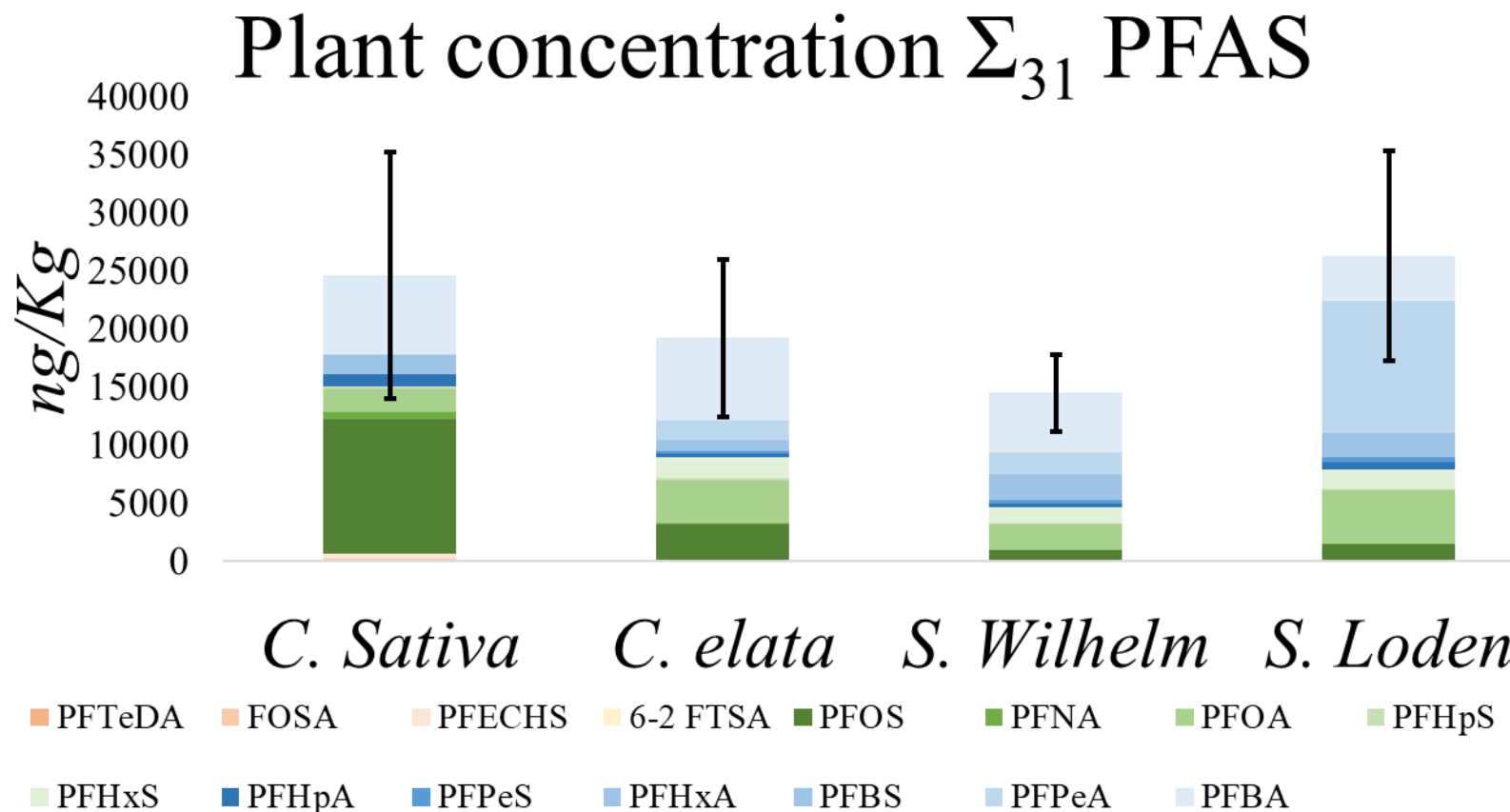


Results (manuscript 2)

Result – Survival rate

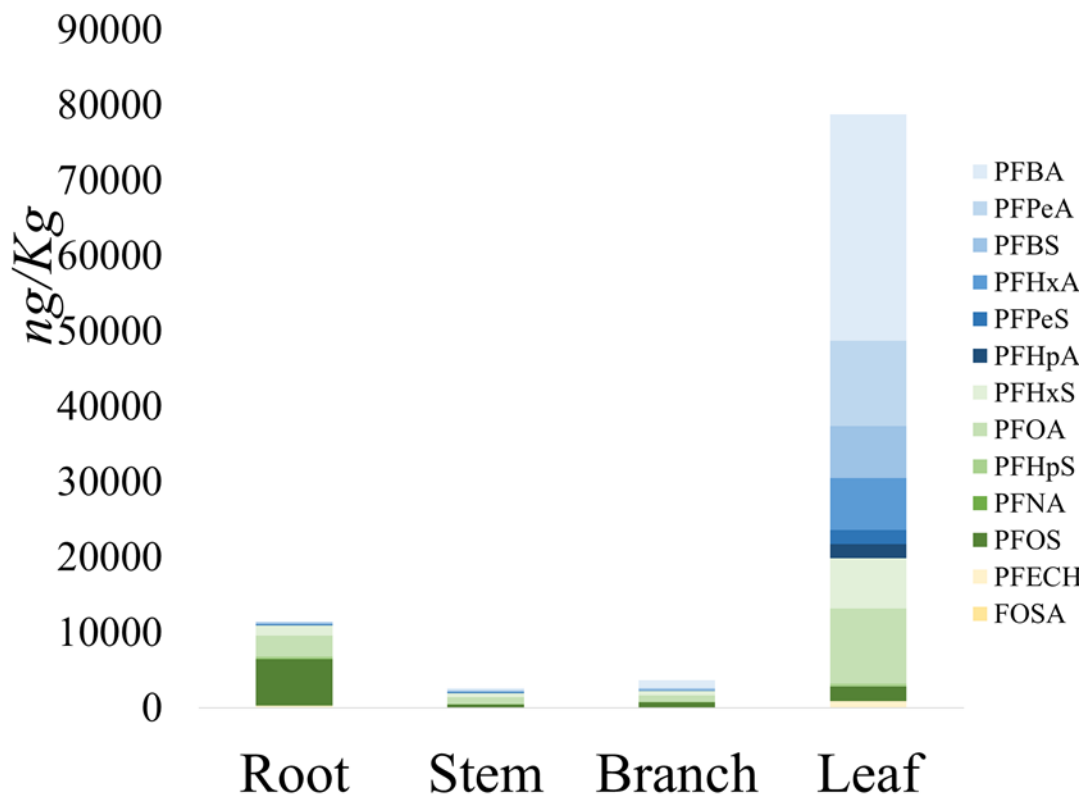
Species	Survival rate (%)
S. Wilhelm	100
S. Loden	83
<i>C. elata</i>	100
<i>C. Sativa</i>	35

Result – plant uptake

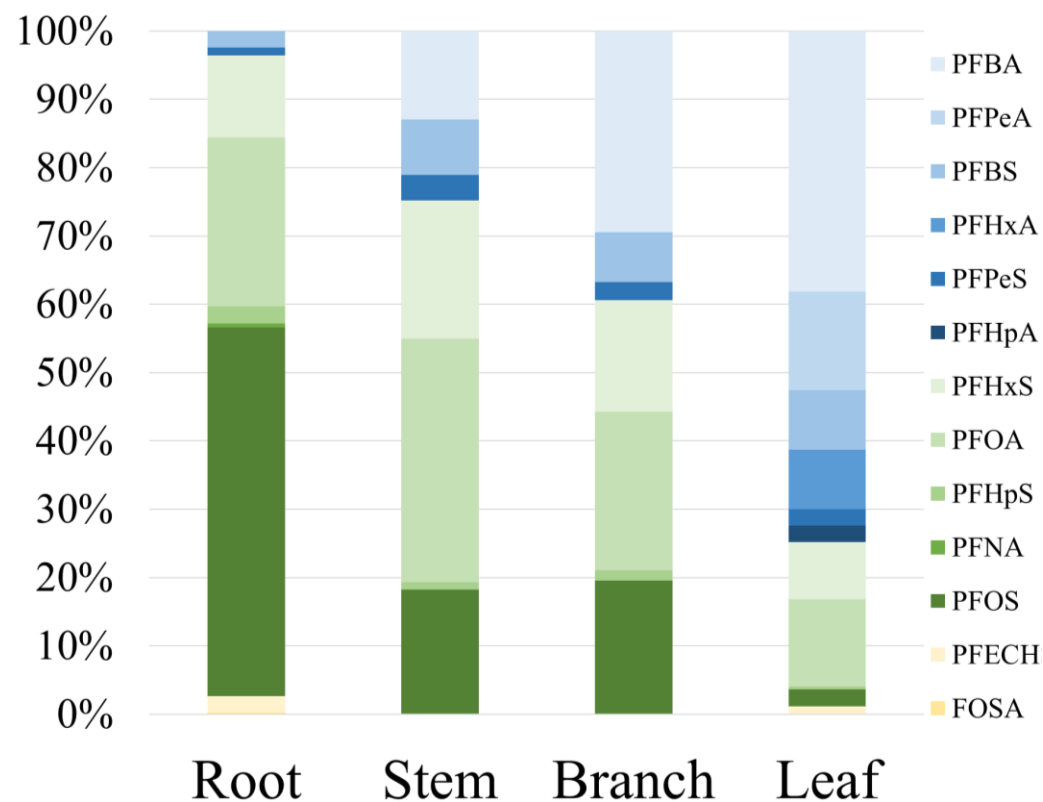


Result – tissue distribution

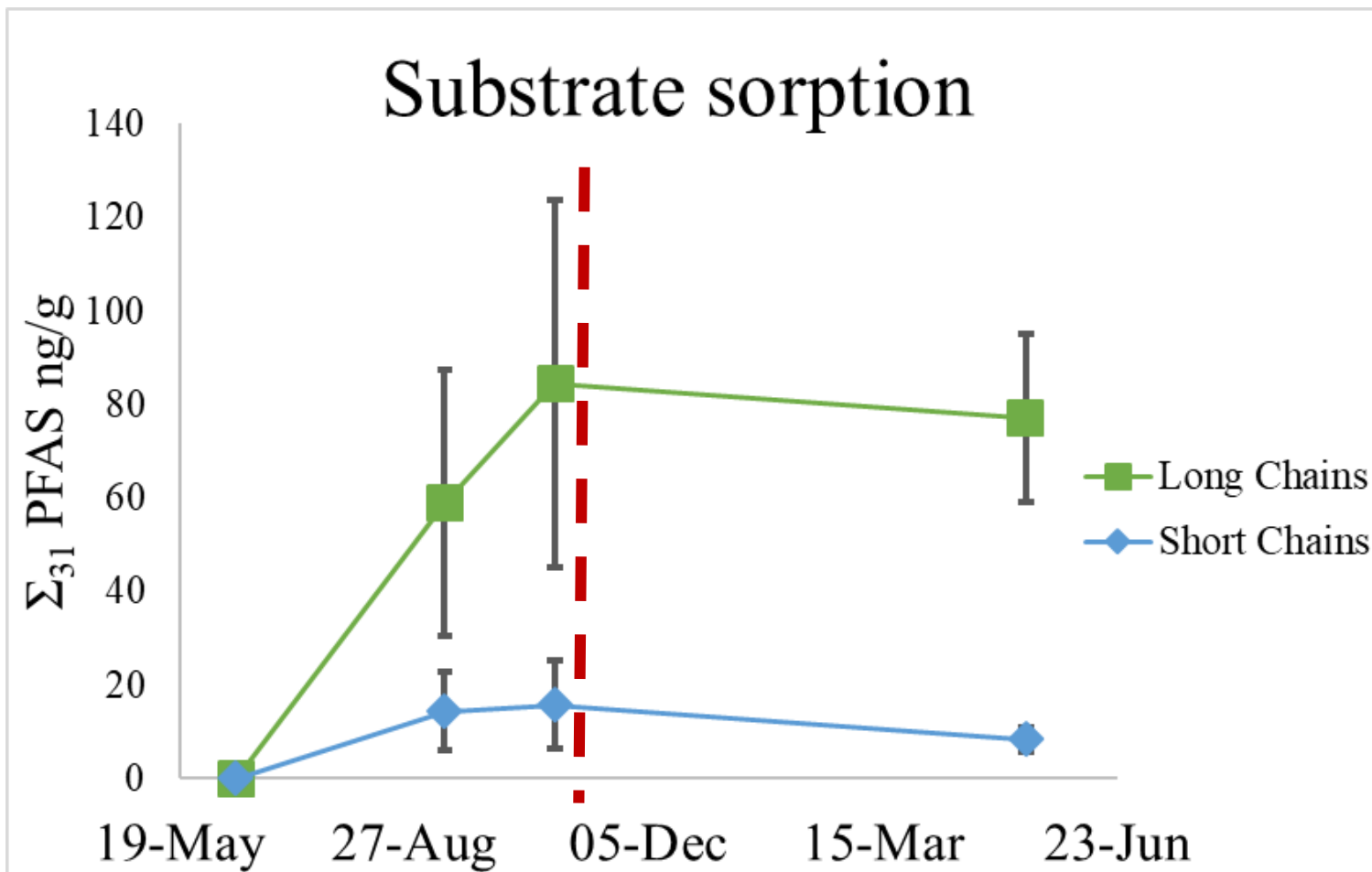
PFAS concentrations in plant tissue
S. Wilhelm



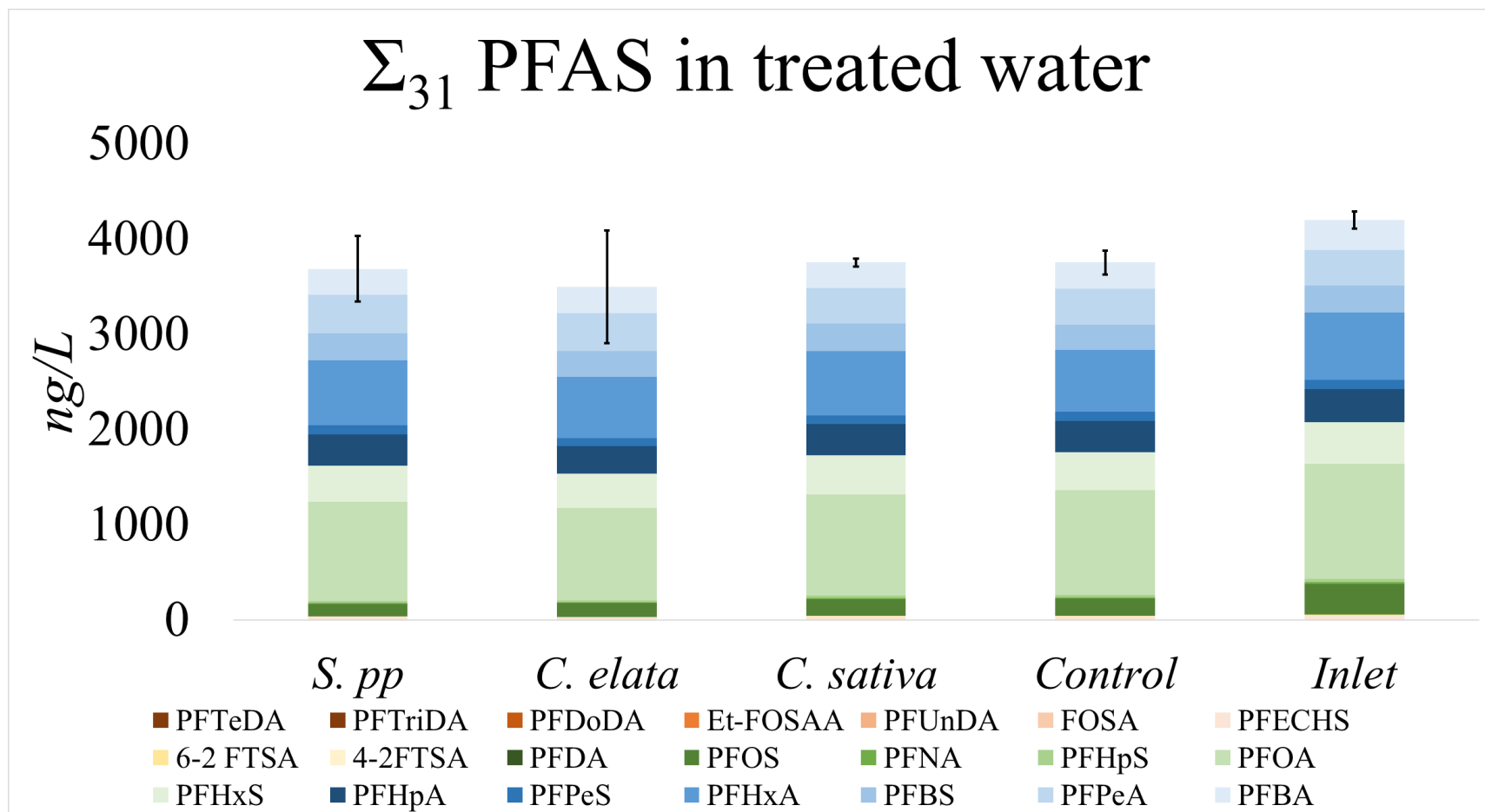
PFAS composition in plant tissue
S. Wilhelm



Result – sorption to biofilter substrate



Results – treatment efficiency of filter configuration



Moving forward

- Some data evaluation left
- Write manuscript 2
- Analyze samples from 2023 season
- Data evaluation and writing of manuscript 3

Paper 4

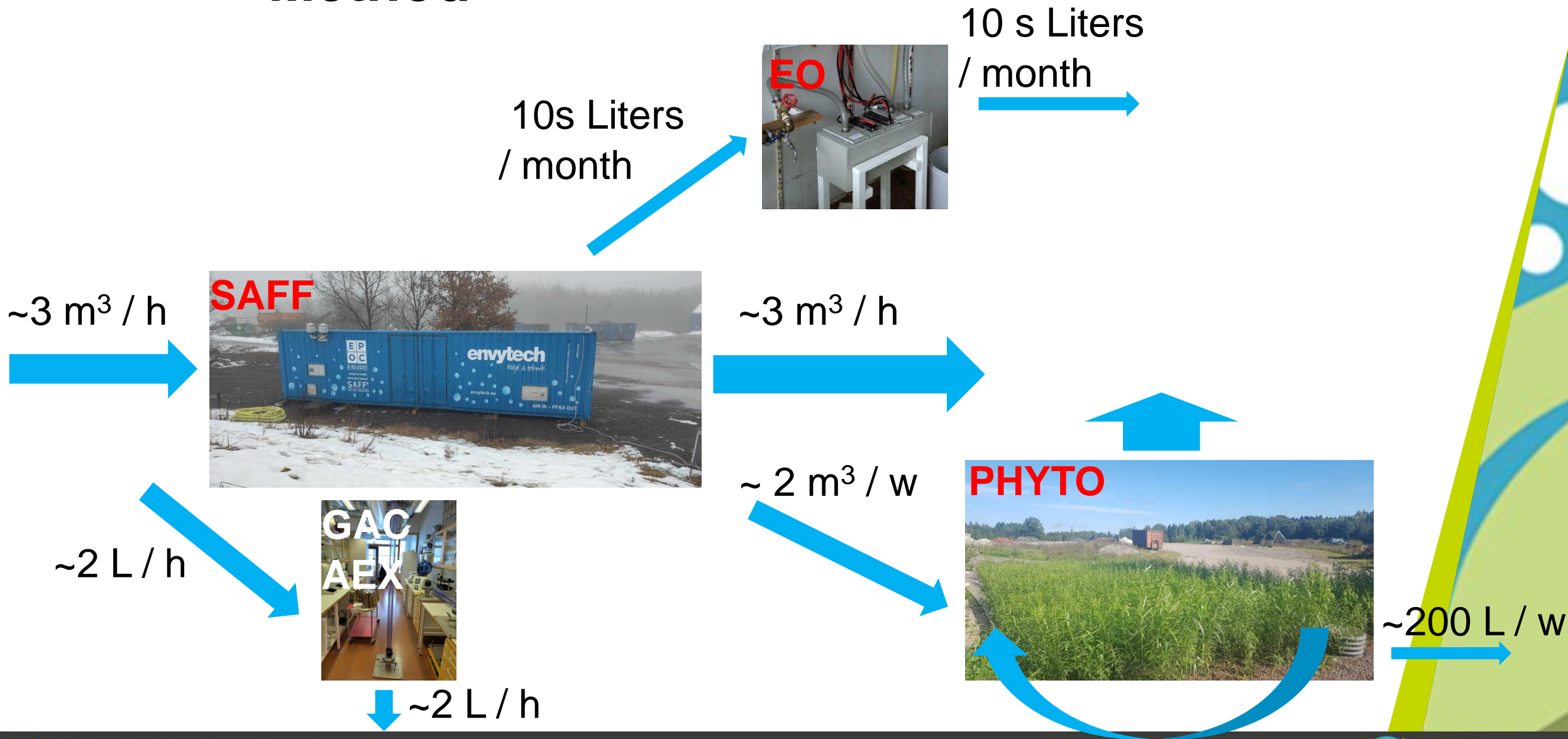
Evaluating a treatment train for
PFAS contaminated groundwater,
combining foam fractionation,
electrochemical oxidation and
phytoremediation

Research aims

- Assess the treatment efficiency of a pump and treat solution using a treatment train consisting of SAFF, EO and PHYTO when treating PFAS contaminated groundwater
- Compare the cost efficiency of the treatment train to conventional treatment methods
 - GAC
 - AEX



Method



Moving forward

- Get treatment train up and running
- Operate treatment train for 10 months
- Samples will be sent for analysis
 - In house plant sample preparation
- Data evaluation and writing of manuscript 4

Paper 5

Fate of PFAS in biomass incinerated for energy production

Research aims

- Investigate the fate of PFAS accumulated in plant biomass during incineration for energy production
- Investigate PFAS degradation at different temperatures
- Investigate the effect of a $\text{Ca}(\text{OH})_2$ additive on PFAS degradation



Method

- Conduct bench scale incinerations of the harvested biomass in cooperation with department of chemical engineering at KTH
 - 1.2 kg
 - 400, 850, 950 C
 - With $\text{Ca}(\text{OH})_2$ additive
- Analyze
 - Fly ash
 - Bottom ash
 - Flue gas
 - Condensate



Moving forward

- Incinerations will be performed in late autumn 2024



Conclusions

Conclusions

- PFAS is highly mobile in the GW saturated zone
 - Low K_d
 - Rapid sorption kinetics
 - Suitable for a pump and treat solution
- Correlation between mobility and chain length
- Uptake of PFAS in plant biomass
 - Similar concentrations in all species
 - Strong differentiation of PFAS composition in different plant tissues
- PFAS sorb to the peat and biochar substrate
- The bio filter tested is not efficient at treating PFAS contaminated water at investigated loads and time frames
 - High flow filtration configuration is not optimal for PFAS treatment



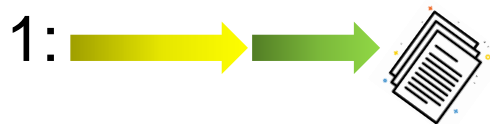
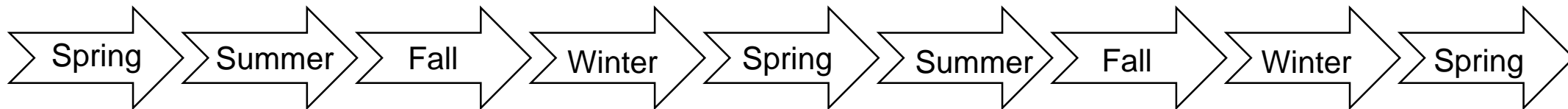
Time plan

Time plan

2024

2025

2026



Courses and conferences

Courses

Completed	Credits	In progress	Credits	Planned	Credits	Remaining
Introduction to programming in R	2	Department of Aquatic Sciences & Assessment: Literature Course in Environmental Assessment	5	Visualize your science	4	1.5
GIS introduction, learn to make your own map	1.5			Statistics 1	4	
Ethics and philosophy of science	4			Total	8	
Groundwater	5	Individual literature review	5			
Organic micropollutants in urban stormwater and wastewater	5	Total	10			
Plant growth monitoring and phenotyping	6					
Data analysis in python and R	2					
Total	25.5					

Conferences

Completed	
Renare Mark 2023	Poster
Renare Mark webinar 2023	Presentation
Flurors 2023	Poster
Dioxin 2023	Presentation
LIFE SOuRCE webinar 2023	Presentation
Inperationsdagarna för arbete med miljögifter 2024	Presentation
Renare Mark 2024	Presentation

Accepted	
Nordrocs 2024	Presentation + leading a study visit



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 - Lutz Ahrens
 - Dan Bergren Kleja
 - Anja Enell



Acknowledgements



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LIFE
SOuRCE





SCIENCE AND
EDUCATION **FOR**
SUSTAINABLE
LIFE