

Evaluation of the removal efficiency of PFASs in a full-scale drinking water treatment plant

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The problem: Contaminated groundwater

Guideline drinking water:

$$\Sigma_{11} < 90 \text{ ng/L}$$

Conventional DW treatment:

$$\text{PFAS}_{\text{in}} \approx \text{PFAS}_{\text{out}}$$

The solution (?):

Granular activated carbon (GAC)



PFAS contamination in Uppsala; according to Gyllenhammar et al. (2015)

The study: What we want(ed) to know



Full-scale performance:
Filtrisorb[®] 400 vs. AquaSorb[®] 2000?



Optimal flow rate through full-scale DWTP

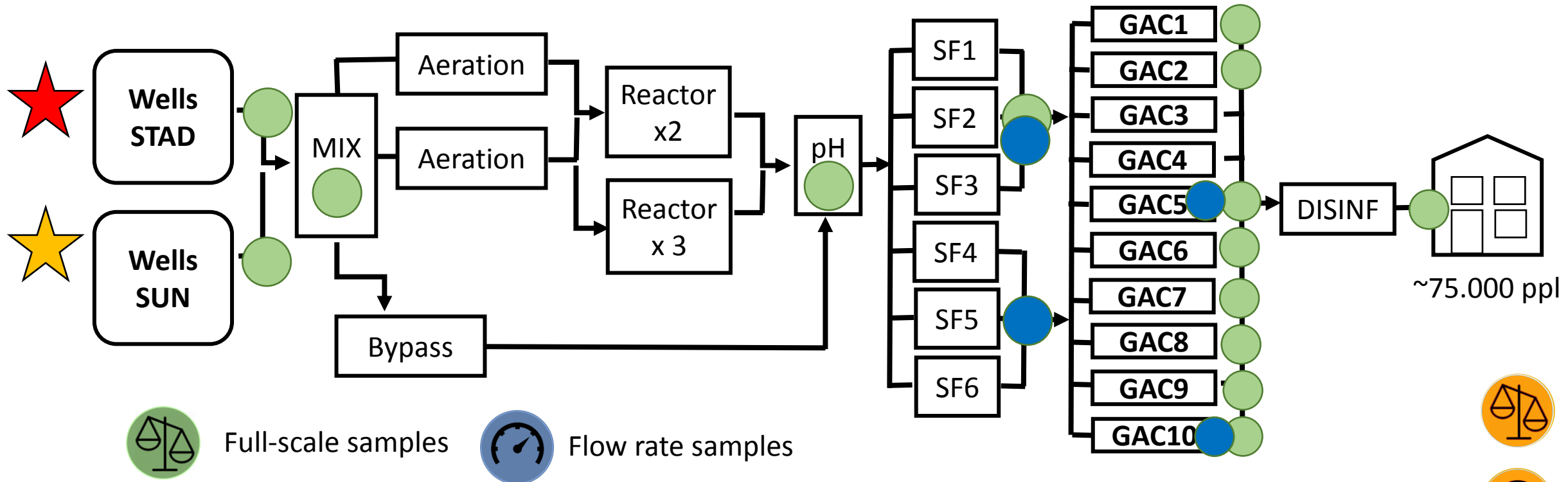


Temporal trends in PFAS contaminated groundwater



Ongoing projects

Methods: Bäcklösa DWTP



- 27 target PFASs: solid phase extraction → LC-MS/MS
- TOC and UV measurements to ensure equilibrium
- Long term data: April 2015 until February 2017 (15 target PFASs)

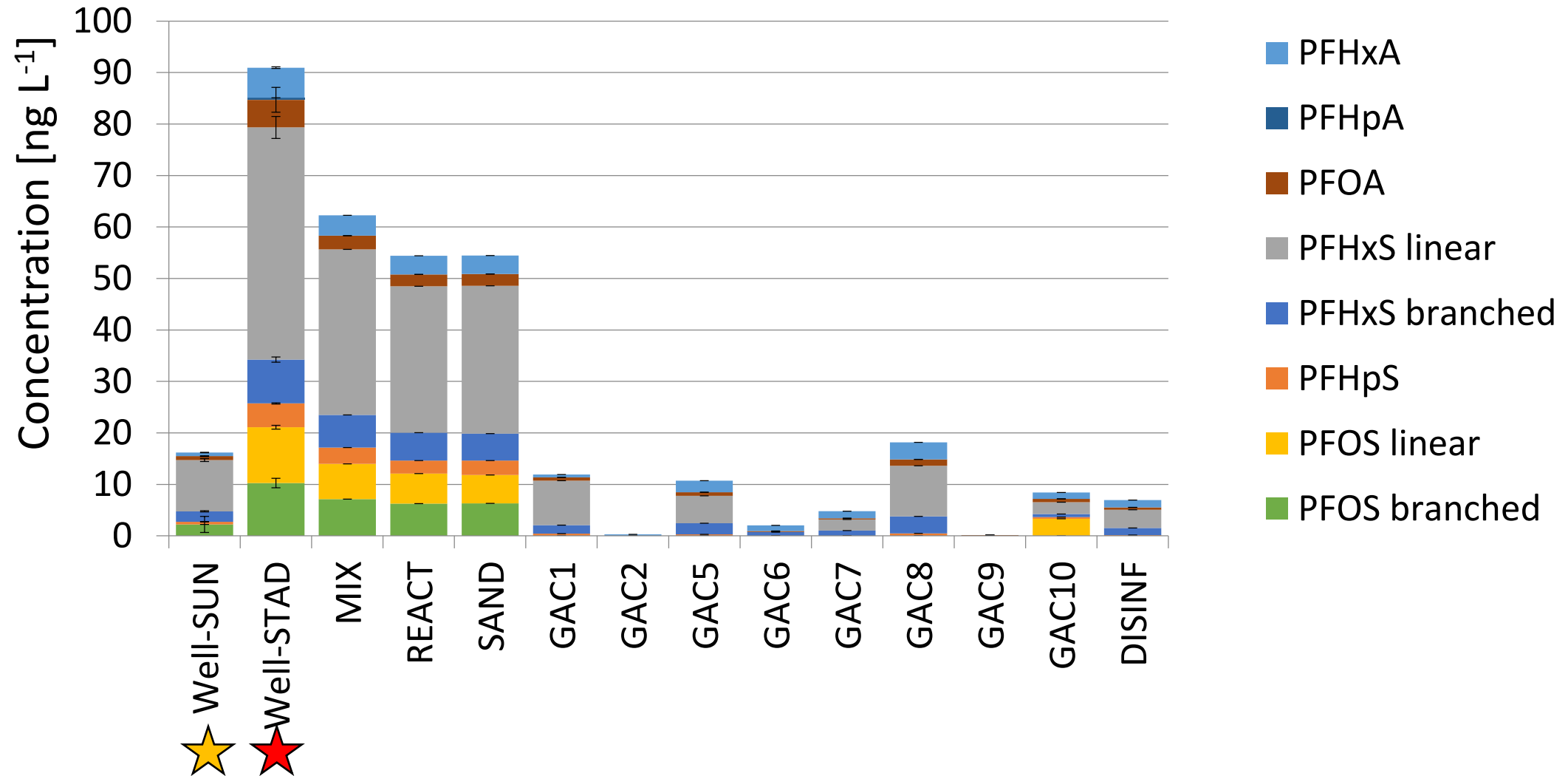
DWTP: drinking water treatment plant; LC-MS/MS: liquid chromatography tandem mass spectrometry; TOC: total organic carbon



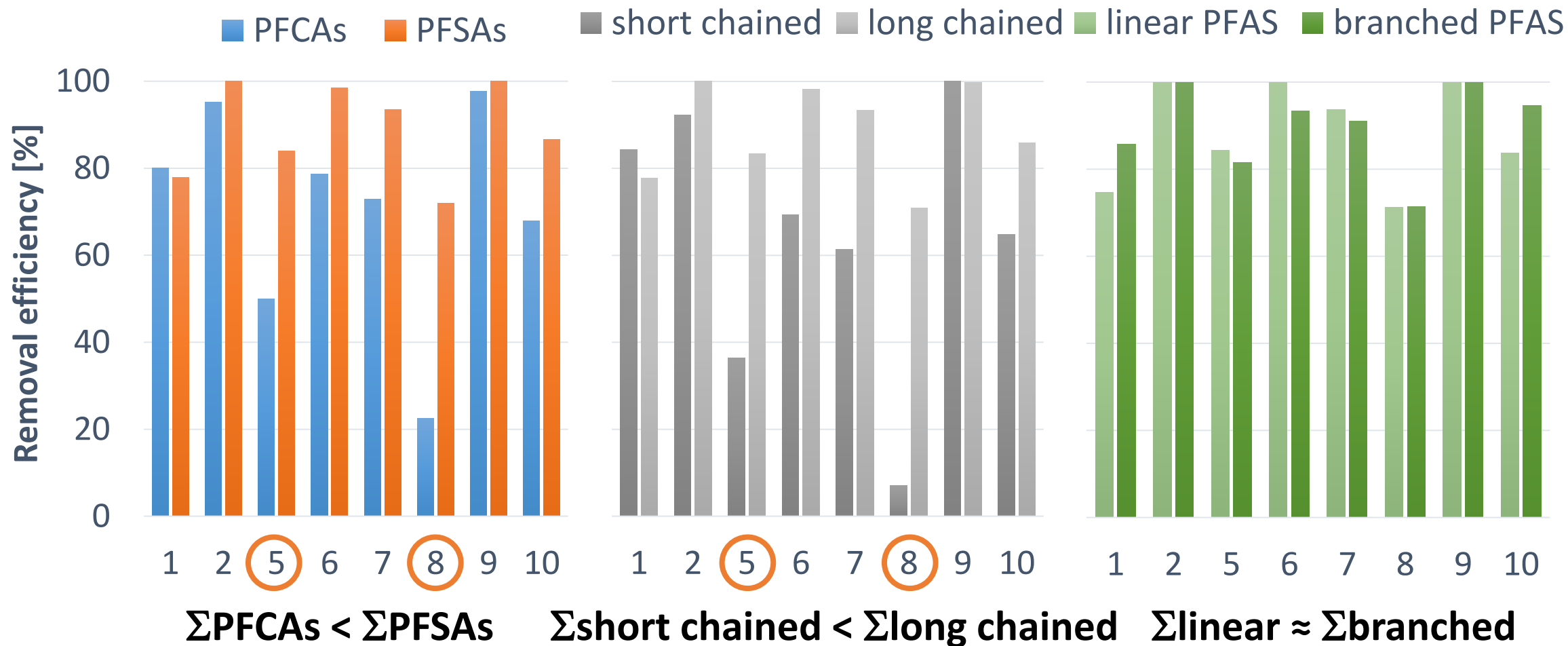


PFAS removal in the full-scale drinking water treatment plant

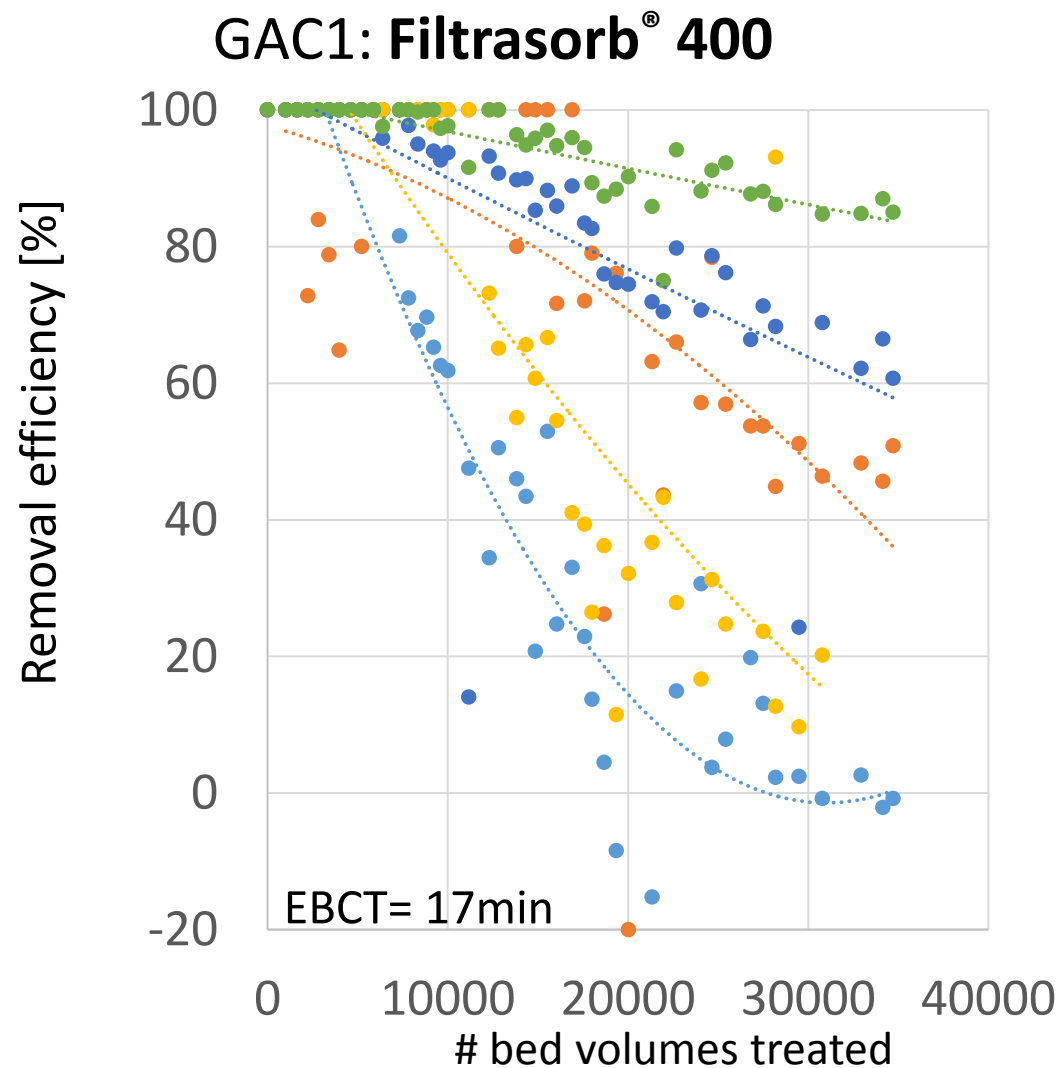
PFAS concentrations in full-scale



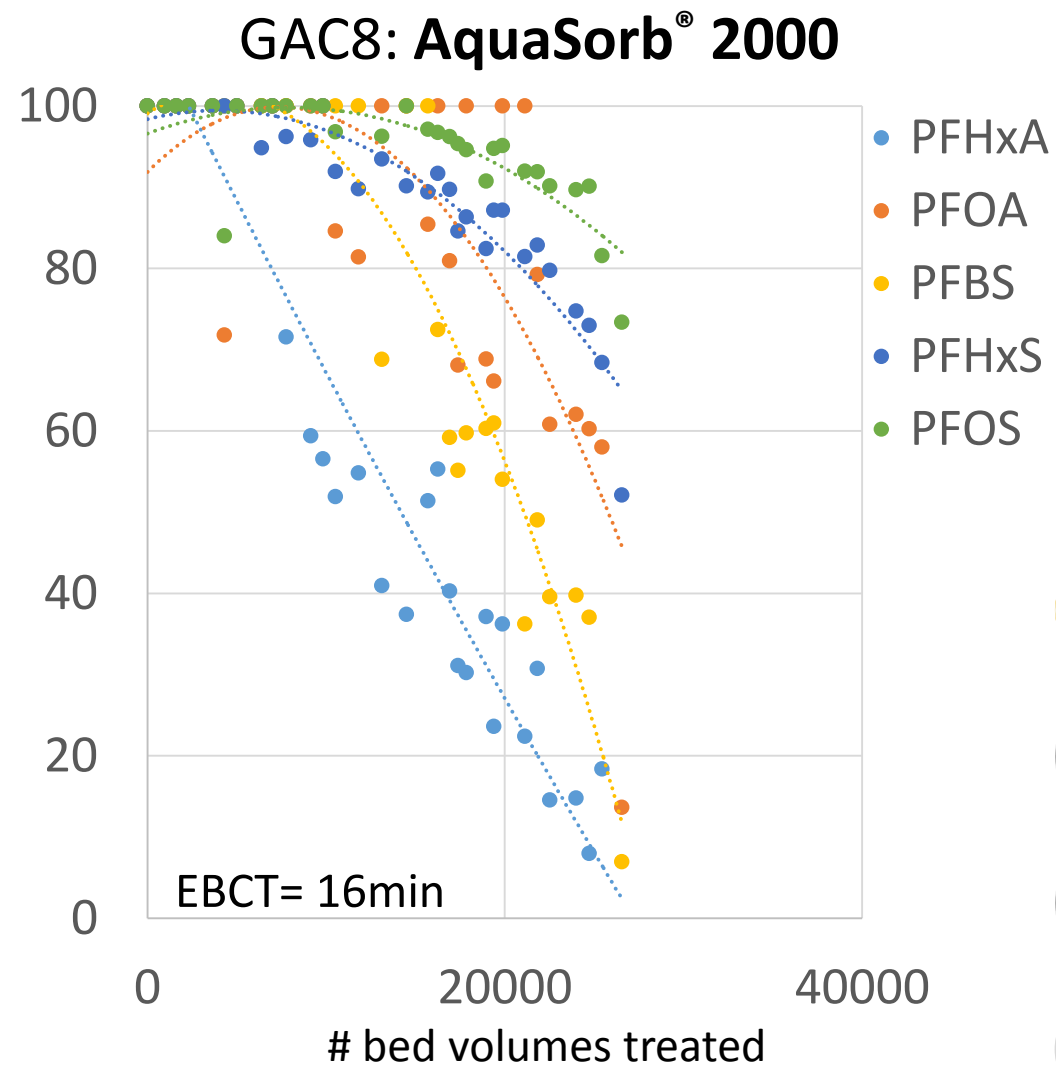
Full-scale experiment



Removal of PFAS by granular activated carbon



vs.





Flow rate optimization

Flow rate experiment

Days	Date	EBCT [min]	Flow [L s^{-1}]
1	24-11-2016	full scale	full scale
4	28-11-2016	13	45
6	30-11-2016		
8	02-12-2016		
11	05-12-2016	20	30
13	07-12-2016		
15	09-12-2016		
18	12-12-2016		
21	15-12-2016	40	15
22	16-12-2016		
25	19-12-2016		
27	21-12-2016		

"New" GAC filter

85 operation days
7220 bed volumes
treated

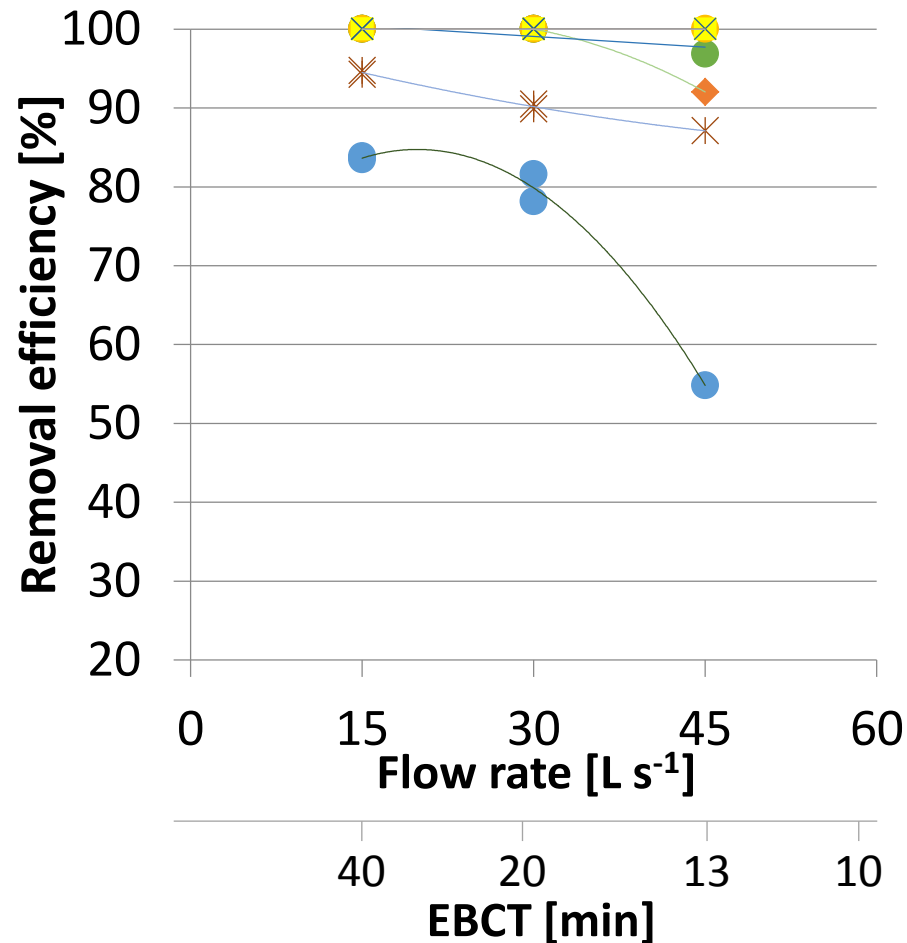
"Old" GAC filter

275 days in operation
22600 bed volumes
treated

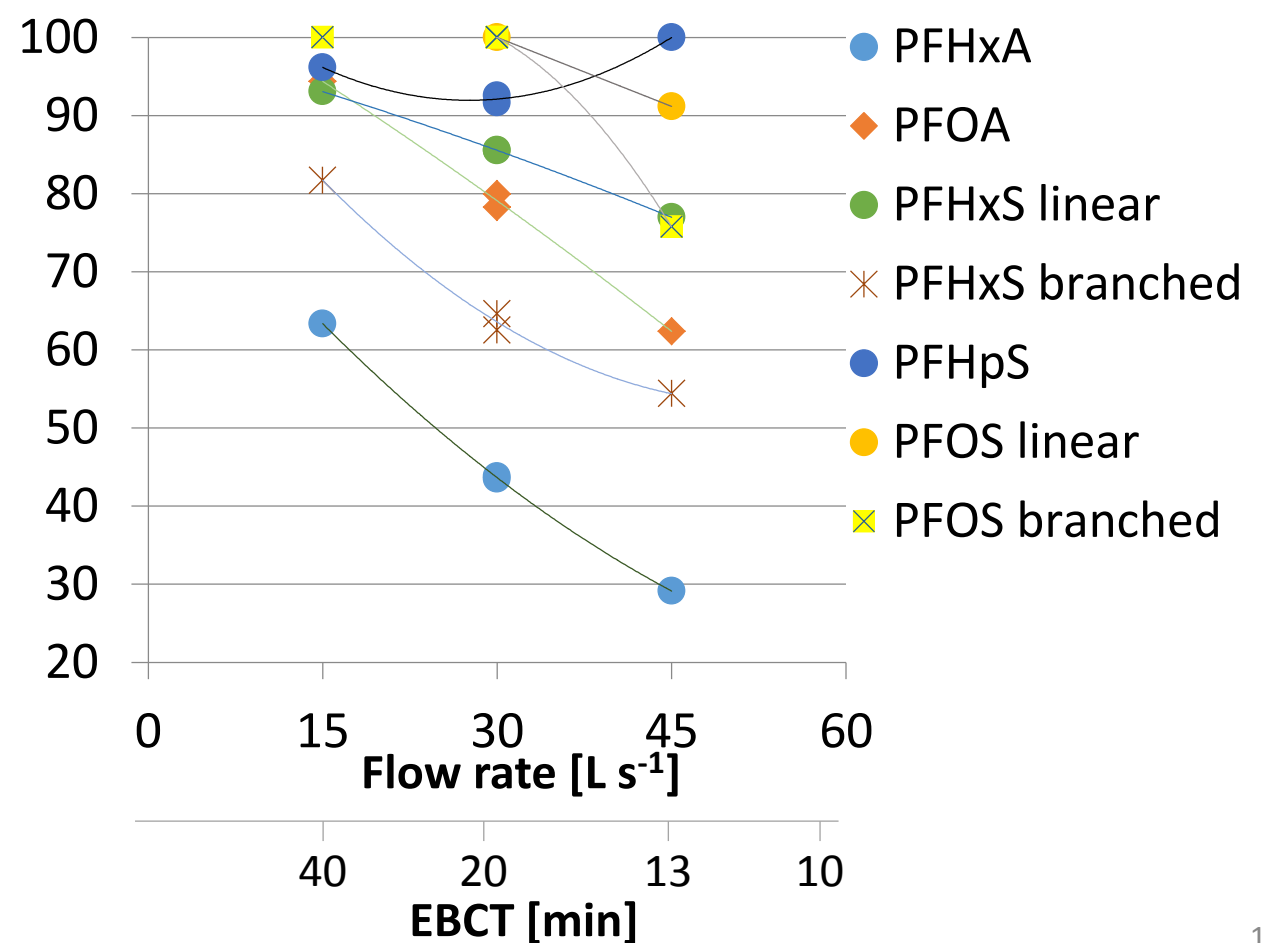


Flow rate experiment

"New" GAC filter



"Old" GAC filter





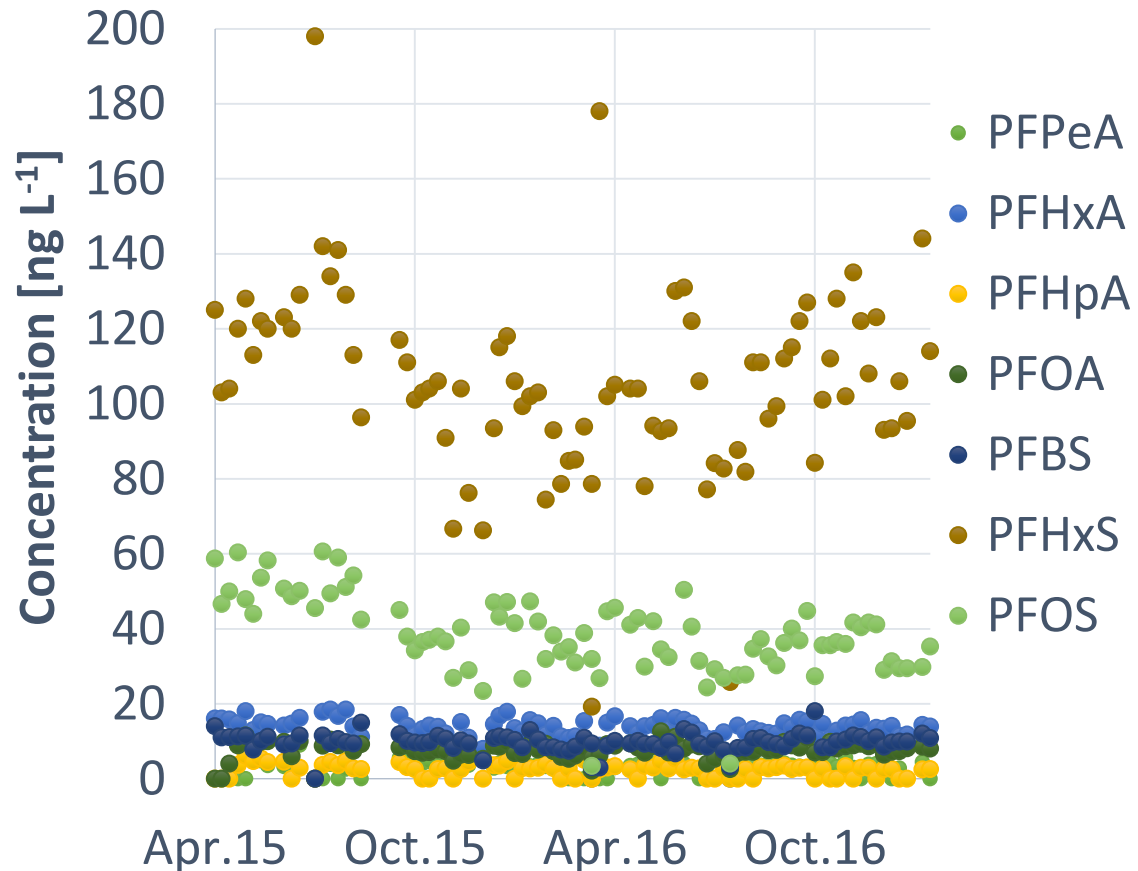
Temporal trend analysis

Temporal trend analysis



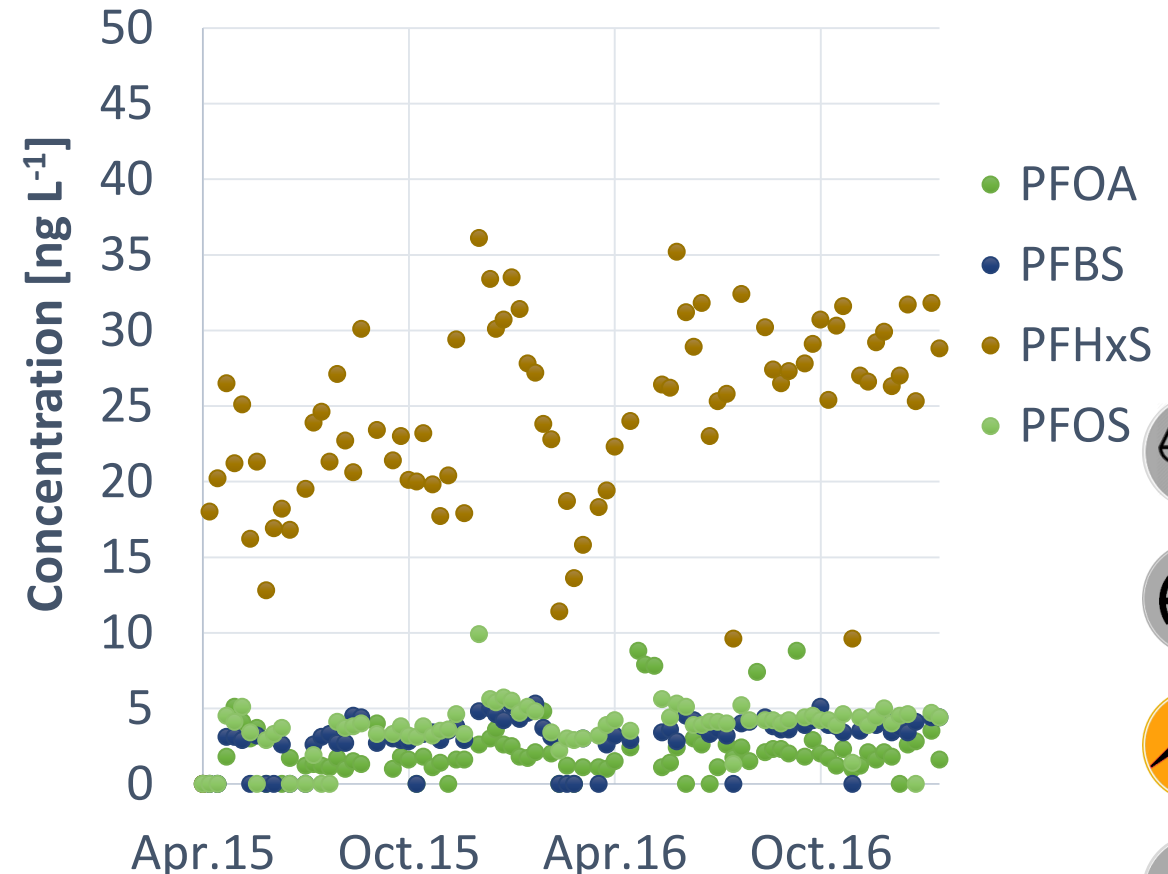
Wellfield STAD

~5 km from AFFF source



Wellfield SUN

~12 km from AFFF source



Temporal trend analysis

↓ ★ Wellfield STAD
~5 km from AFFF source

PFHpA:

Half-time:
 1650 ± 449 d

PFOS:

Half-time:
 2210 ± 868 d

↑ ★ Wellfield SUN
~12 km from AFFF source

PFBS:

Doubling-time:
 1820 ± 554 d

PFHxS:

Doubling-time:
 1620 ± 456 d

PFOS:

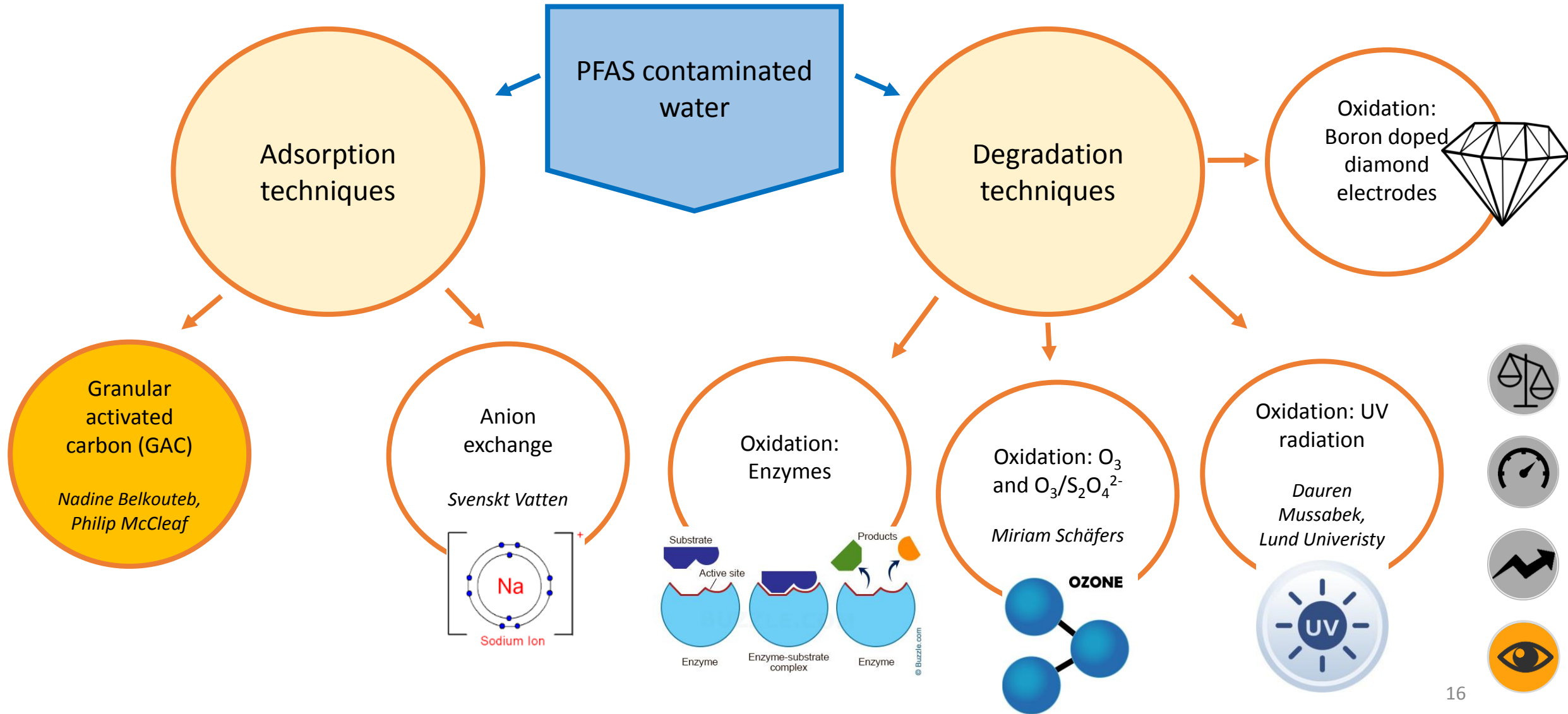
Doubling-time:
 1270 ± 467 d





More projects in the pipeline

Ongoing projects



Conclusions: what we found



Σ short chained PFASs < Σ long chained PFASs; Σ PFCAs < Σ PFSAAs
Filtrisorb[®] 400 > AquaSorb[®] 2000



Lower flow rates: removal efficiency ↑



PFASs in ★STAD↓ and ★SUN↑



Stay tuned...

The people behind the study



**Nadine Belkouteb,
Master of Science**



**Dr. Lutz Ahrens,
Professor**

**Philip McCleaf,
Process engineer**



**Dr. Stephan J. Köhler,
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Thank you for your attention



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Group	Acronym	Perfluorocarbon atoms	
PFSAs	PFBS	4	Perfluorobutane sulfonic acid
	PFHxS	6	Perfluorohexane sulfonic acid
	PFHpS	7	Perfluoroheptane sulfonic acid
	PFOS	8	Perfluorooctane sulfonic acid
	PFDS	10	Perfluorodecane sulfonic acid
PFCAs	PFBA	3	Perfluorobutanoic acid
	PFPeA	4	Perfluoropentanoic acid
	PFHxA	5	Perfluorohexanoic acid
	PFHpA	6	Perfluoroheptanoic acid
	PFOA	7	Perfluorooctanoic acid
	PFNA	8	Perfluorononanoic acid
	PFDA	9	Perfluorodecanoic acid
	PFUnDA	10	Perfluoroundecanoic acid
	PFDoDA	11	Perfluorododecanoic acid
	PFTriDA	12	Perfluorotridecanoic acid
	PFTeDA	13	Perfluorotetradecanoic acid
	PFHxDA	15	Perfluorohexadecanoic acid
	PFOcDA	17	Perfluorooctadecanoic acid

Group	Acronym	Carbon atoms	
FOSAs	FOSA	8	Perfluorooctanesulfonamide
	N-MeFOSA	8	<i>N</i> -methylperfluorooctanesulfonamide
	N-EtFOSA	8	<i>N</i> -ethylperfluorooctanesulfonamide
FOSAAs	FOSAA	8	Perfluorooctanesulfonamidoacetic acid
	N-MeFOSAA	8	<i>N</i> -methylperfluorooctanesulfonamidoacetic acid
	N-EtFOSAA	8	<i>N</i> -ethylperfluorooctanesulfonamidoacetic acid
FOSEs	N-MeFOSE	8	<i>N</i> -methylperfluorooctanesulfonamido-ethanol
	N-EtFOSE	8	<i>N</i> -ethylperfluorooctanesulfonamido-ethanol
FTSA	6:2 FTSA	6	6:2 fluorotelomer sulfonic acid

		PFAS analysis	PFAS analysis
		SLU	ALS
PFBS	Perfluorobutane sulfonic acid	X	X
PFHxS	Perfluorohexane sulfonic acid	X	X
PFHpS	Perfluoroheptane sulfonic acid	X	
PFOS	Perfluorooctane sulfonic acid	X	X
PFDS	Perfluorodecane sulfonic acid	X	X
PFBA	Perfluorobutanoic acid	X	X
PFPeA	Perfluoropentanoic acid	X	X
PFHxA	Perfluorohexanoic acid	X	X
PFHpA	Perfluoroheptanoic acid	X	X
PFOA	Perfluorooctanoic acid	X	X
PFNA	Perfluorononanoic acid	X	X
PFDA	Perfluorodecanoic acid	X	X
PFUnDA	Perfluoroundecanoic acid	X	X
PFDODA	Perfluorododecanoic acid	X	X
PFTriDA	Perfluorotridecanoic acid	X	
PFTeDA	Perfluorotetradecanoic acid	X	
PFHxDA	Perfluorohexadecanoic acid	X	
PFOcDA	Perfluorooctadecanoic acid	X	
FOSA	Perfluorooctanesulfonamide	X	X
N-MeFOSA	<i>N</i> -methylperfluorooctanesulfonamide	X	
N-EtFOSA	<i>N</i> -ethylperfluorooctanesulfonamide	X	
FOSAA	Perfluorooctanesulfonamidoacetic acid	X	
N-MeFOSAA	<i>N</i> -methylperfluorooctanesulfonamidoacetic acid	X	
N-EtFOSAA	<i>N</i> -ethylperfluorooctanesulfonamidoacetic acid	X	
N-MeFOSE	<i>N</i> -methylperfluorooctanesulfonamido-ethanol	X	
N-EtFOSE	<i>N</i> -ethylperfluorooctanesulfonamido-ethanol	X	
6:2 FTSA	6:2 fluorotelomer sulfonic acid	X	X

$$BV_{treated} = \frac{V_{treated}}{V_{GAC}} = \frac{r \cdot t}{V_{GAC}}$$

where

- $BV_{treated}$: bed volumes treated
- $V_{treated}$: treated volume during operation time [m³]
- V_{GAC} : volume of the GAC = 35 m³
- r : average flow rate [m³ s⁻¹]
- t : time [s]

$$EBCT = \frac{V_{GAC}}{r}$$

where

- EBCT: empty bed contact time
- V_{GAC} : volume of the GAC = 35 m³
- r : average flow rate [m³/s]

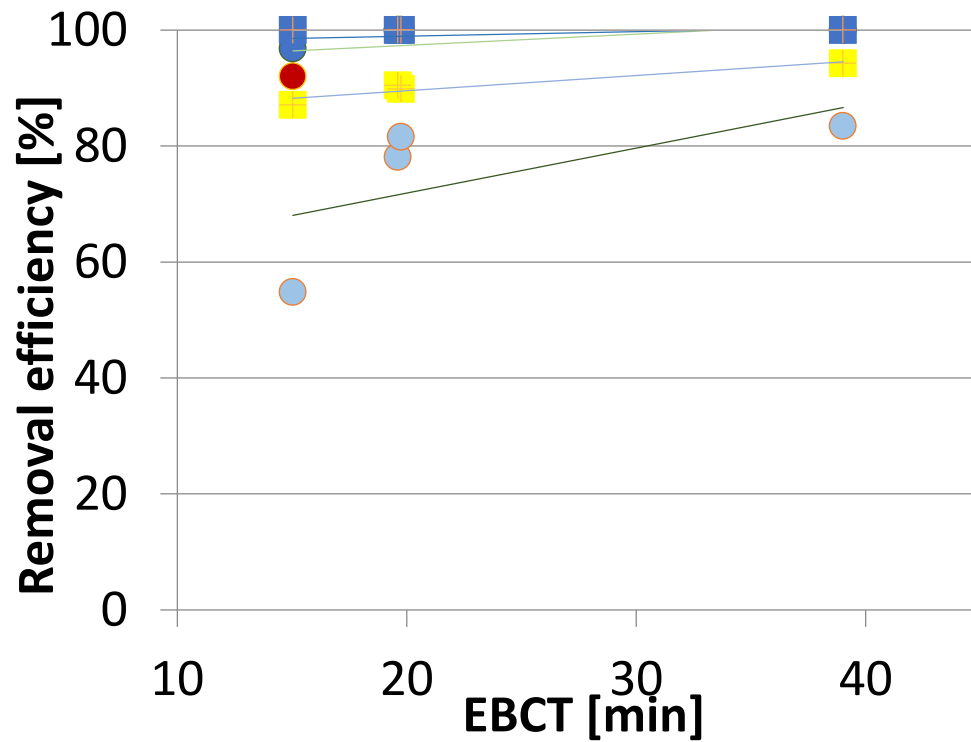
$$RE = \frac{c_0 - c}{c_0} \cdot 100 \text{ [%]}$$

where

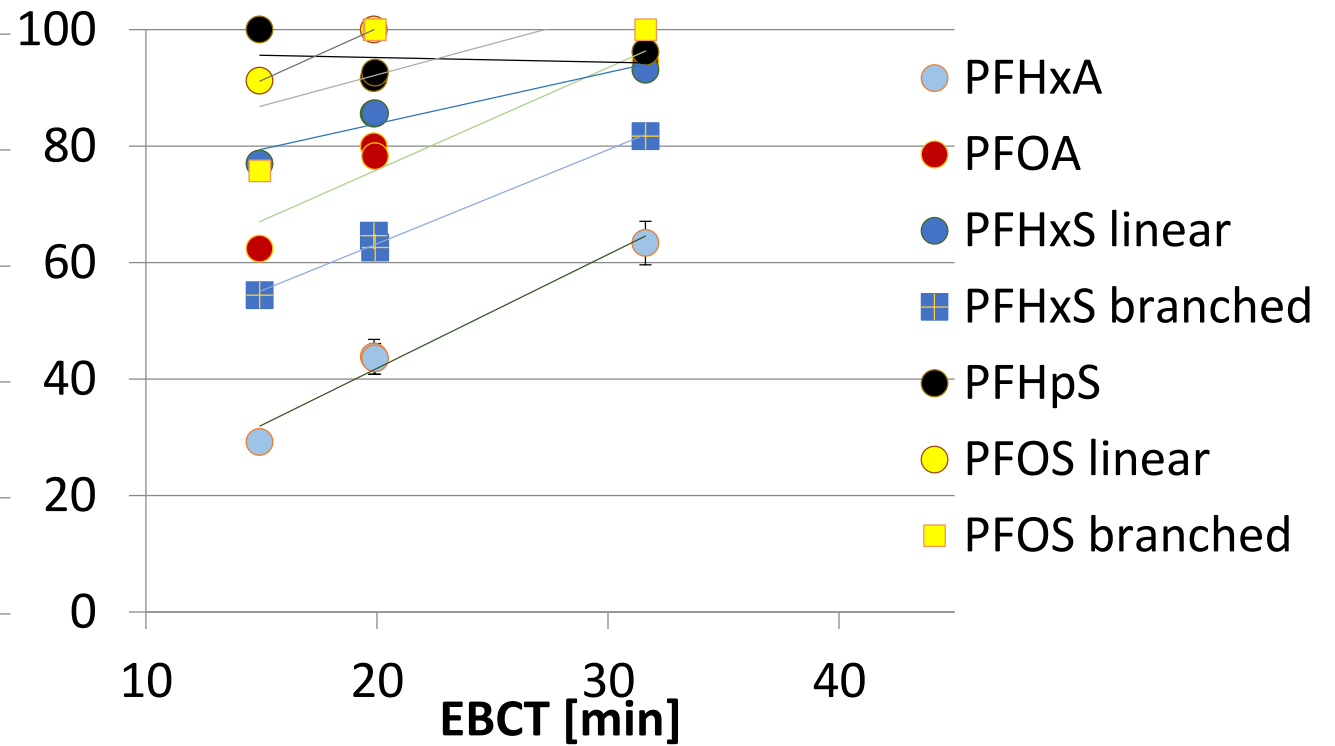
- c_0 : Concentration of a substance in the incoming water
- c : Concentration of a substance in the outgoing water

Flow rate experiment

"New" GAC filter

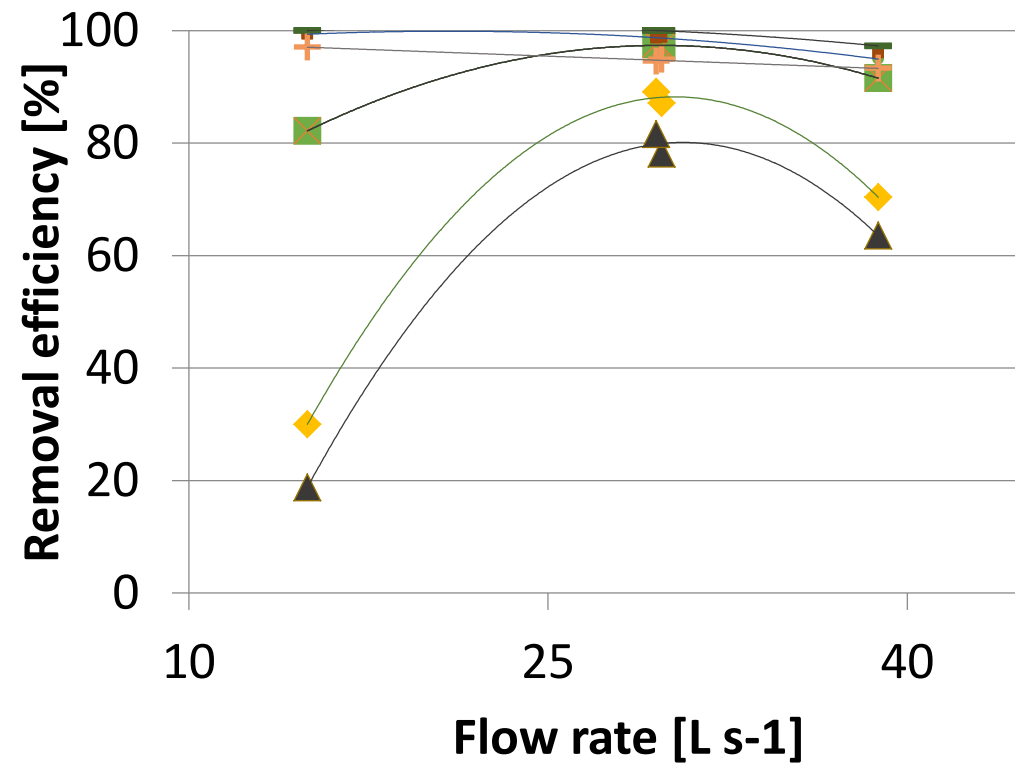


"Old" GAC filter



Flow rate experiment

"Old" GAC filter



"New" GAC filter

