



**PFAS in the water cycle –
learnings from the
EU H2020 project PROMISCES**

EMPEREST Project Meeting

11 June 2024

PROMISCES: iPM(T)s & PFAS



PROMISCES: **P**reventing **R**ecalcitrant **O**rganic **M**obile Industrial chemical**S** for **C**ircular Economy in the **S**oil-sediment-water system

Duration: November 2021 – April 2025

Coordinated by BRGM

27 partners from 9 countries

7 case studies

~12 Mio € funding

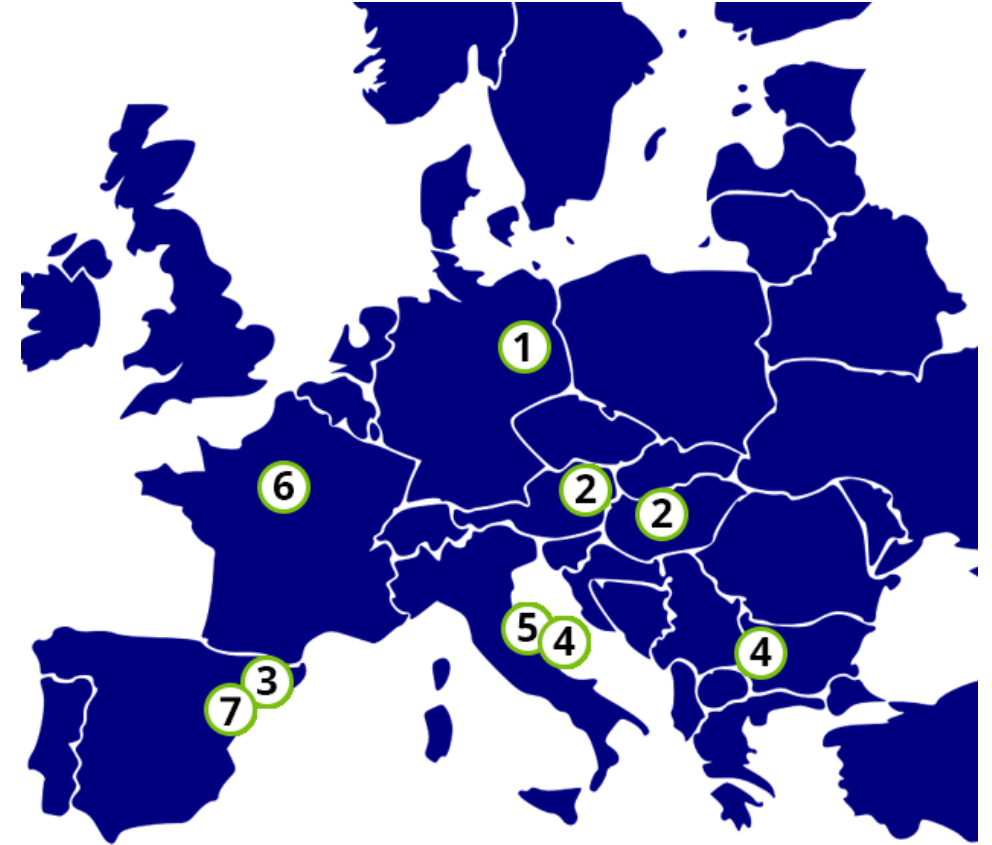
Sister projects:



The PROMISCES project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101036449

PROMISCES' Goals

- Identify how industrial pollution in the soil-sediment- water system hinders the circular economy with a focus on per- and polyfluoroalkyl substances (PFAS)
- Provide innovative technologies to prevent and remediate chemical pollution in the environment
- Develop new analytical methods and tools to provide data on persistent, mobile (PM) substances
- Assess risks for human health from PM substances
- Create a decision support tool and policy recommendations



Circular economy routes

- 1) Semi-closed water cycle for drinking water supply
 - Berlin
 - Danube
- 2) Wastewater reuse for agricultural irrigation
 - Spain
- 3) Nutrient and energy recovery from treated sludge for fertilisers
 - Italy
 - Bulgaria
- 4) Material recovery from dredged sediment for eco-materials
 - Italy
- 5) Groundwater and soil remediation to protect the water cycle
 - Spain
 - France



PROMISCES' Technologies

Soil	Sediment	Water
Ultracavitation & biological treatment	Ultracavitation	<i>Conventional advanced wastewater treatment</i>
<i>In situ</i> : Non-newtonian fluids		E-peroxone AOP & constructed wetlands
		RO/NF membranes
		GAC, AIX, surface modified clay
		(Pyrolysis)
		Plasma
		Chemical oxidation & reduction

CEC (& PFAS?) removal

5 WWTPs located in Germany, Switzerland and Sweden:

2x WWTPs with ozonation and biological post-treatment,

2x WWTPs with powdered activated carbon prior to filtration

1x WWTP with a combination of ozonation and granular activated carbon filtration

Samples were collected as 24-hour mixed samples

Samples collected only at influent and effluent of advanced water treatment technology

WWTP	Country	AWWT type	Sampling type	DOC (mg/L)	UVA ₂₅₄ (1/m)	Nitrite (mg-N/l)	Dosage [#] (mg/l)	Specific dosage [#] (mg/mgDOC)
A	SE	O ₃	24h	12.8	22.0	0.66	5.1	0.42 (0.24 [*])
B	CH	O ₃ +GAC	24h	7.6	13.9	0.05	1.1	0.15 (0.13 [*])
C	CH	O ₃	24h	5.7	12.0	-	2.2	0.39
D	CH	PAC	24h	5.9	12.2	-	5.8	0.99
E	DE	PAC	grab	6.0	14.7	-	13.2	2.21



Project ID N°: 101036449

Call: H2020-LC-GD-2020-3

Topic: LC-GD-8-1-2020 - Innovative, systemic zero-pollution solutions to protect health, environment, and natural resources from persistent and mobile chemicals



Preventing Recalcitrant Organic Mobile Industrial chemicals for
Circular Economy in the soil-sediment-water System

Start date of the project: 1st November 2021

Duration: 42 months

D4.4: Guidance document for upgrade and
optimization of advanced wastewater treatment

Authors: Michael Stapf (KWB), Tobias Hensel (BWB), Fiona Rückbeil (BWB), Alexander Sperlich (BWB), Alicia Hartmann (BfG), Christian Dietrich (BfG)

Lead Beneficiary: KWB

Type of delivery: R

Dissemination Level: PU

Filename: PROMISCES_D4-4_GuidanceForImprovingWastewaterTreatment_V2 (Version 2)

Website: <https://promisces.eu/Results.html>

Due date: 30 April 2023

Date of revision: 19 September 2023

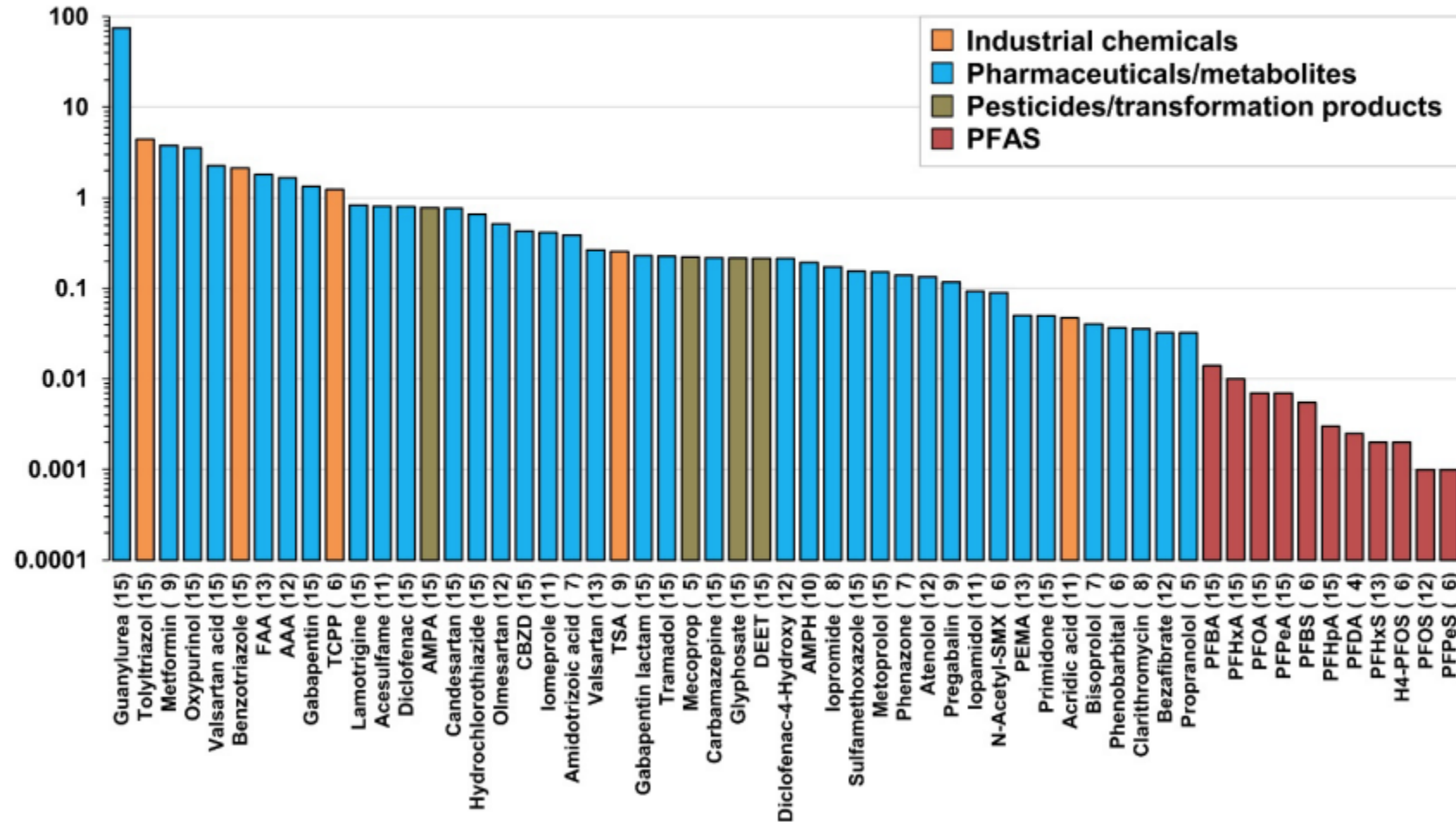
D4.4 - Guidance document for upgrade and optimization of advanced wastewater treatment

1

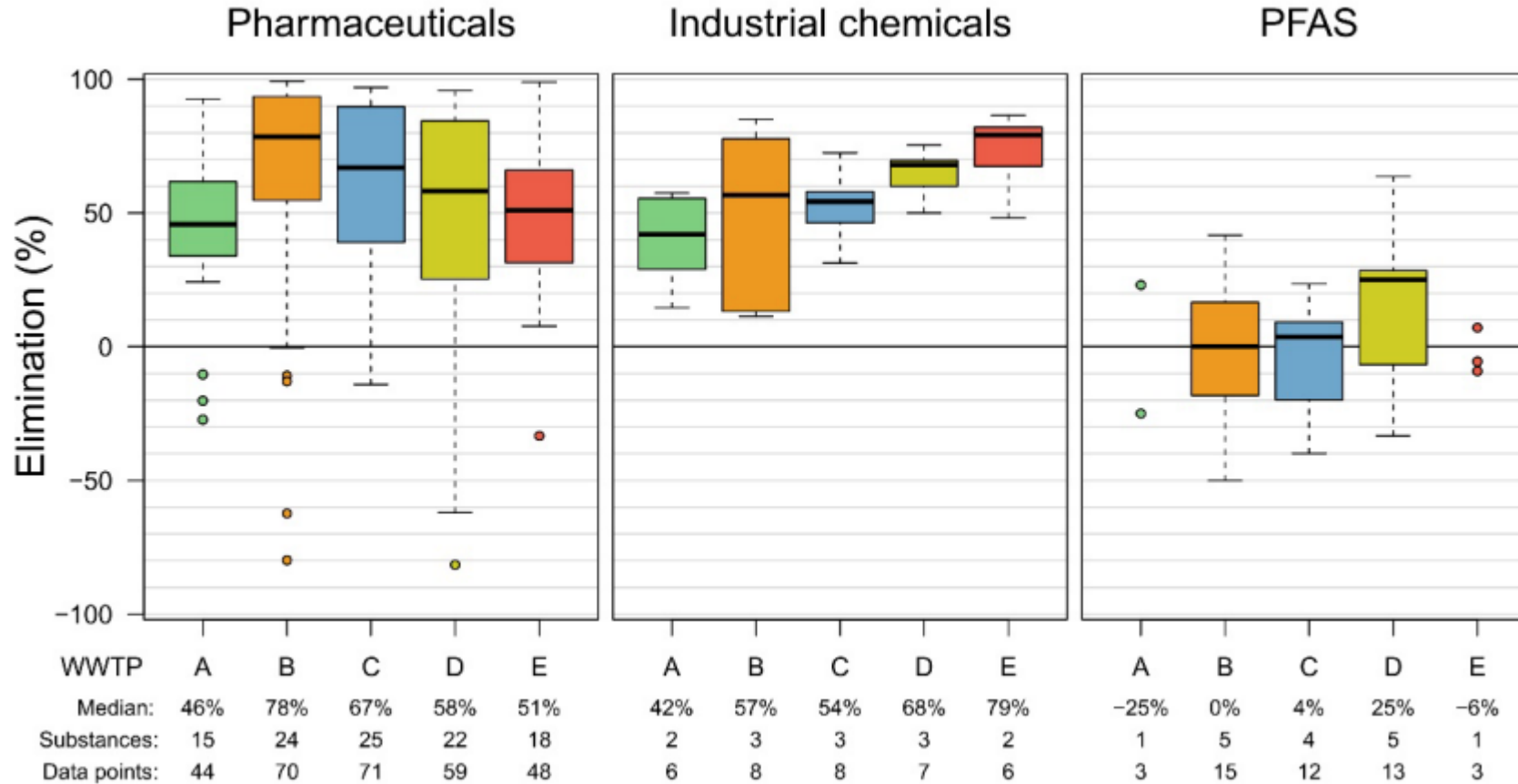


CEC (& PFAS?) removal

Median concentrations at secondary effluent (µg/l)



CEC (& PFAS?) removal



CEC (& PFAS?) removal



Ozonation

Poor reactivity between PFAS and ozone/OH-radicals

Even high specific ozone doses (~ 0.7 mg O_3 /mg DOC) unlikely to reduce PFAS

Powdered activated carbon (PAC)

PAC dosing prior to filtration showed limited PFAS removal (med. removal $\leq 25\%$)

Higher PAC dose ($> 1 - 2$ mg PAC/mg DOC) could increase PFAS removal, but hydraulic capacity of the filter system limits removal

PAC recycling (flushing the PAC from the filter system back into the main biology of the WWTP) was not evaluated



Rößler and Launay (2019) showed that removal of 4 PFAS in 14 WWTPs increased between 50 – 65% after full-scale PAC system with a dedicated recirculation tank and transfer of PAC to the biology was installed ('Ulmer Process')

CEC (& PFAS?) removal

Granular activated carbon (GAC)

GAC filters = BAT for PFAS removal from drinking water / contaminated groundwater

DWT: short-chain PFAS (e.g. PFBA) show >20% breakthrough after 6.000 bed volumes (BV), while PFOA still is removed >80% after 20.000 BV (Riegel et al., 2023).

For GAC filters designed to remove >80 % of micropollutants according to the proposed UWWTD list, typically 20.000 - 30.000 BV are possible (Böhler et al., 2020)

→ results applicable to DW/GW

General conclusion: removal of long-chain PFAS will occur (but dependent on TOC) removal of short-chain PFAS will be minimal

Stapf et al., 2023: <https://zenodo.org/records/10304377>

Böhler, M., Joss, A., McArdell, C. and Meier, A. 2020 Hinweise zur Planung und Auslegung von diskontinuierlich gespülten GAK-Filtern zur Elimination organischer Spurenstoffe aus kommunalem Abwasser. Konsenspapier zum Ergebnis eines Workshops mit Fachexperten aus der Schweiz und Deutschland, Eawag und VSA, Dübendorf

Riegel, M., Haist-Gulde, B. and Sacher, F. 2023. DOI: 10.1186/s12302-023-00716-5



CEC (& PFAS?) removal

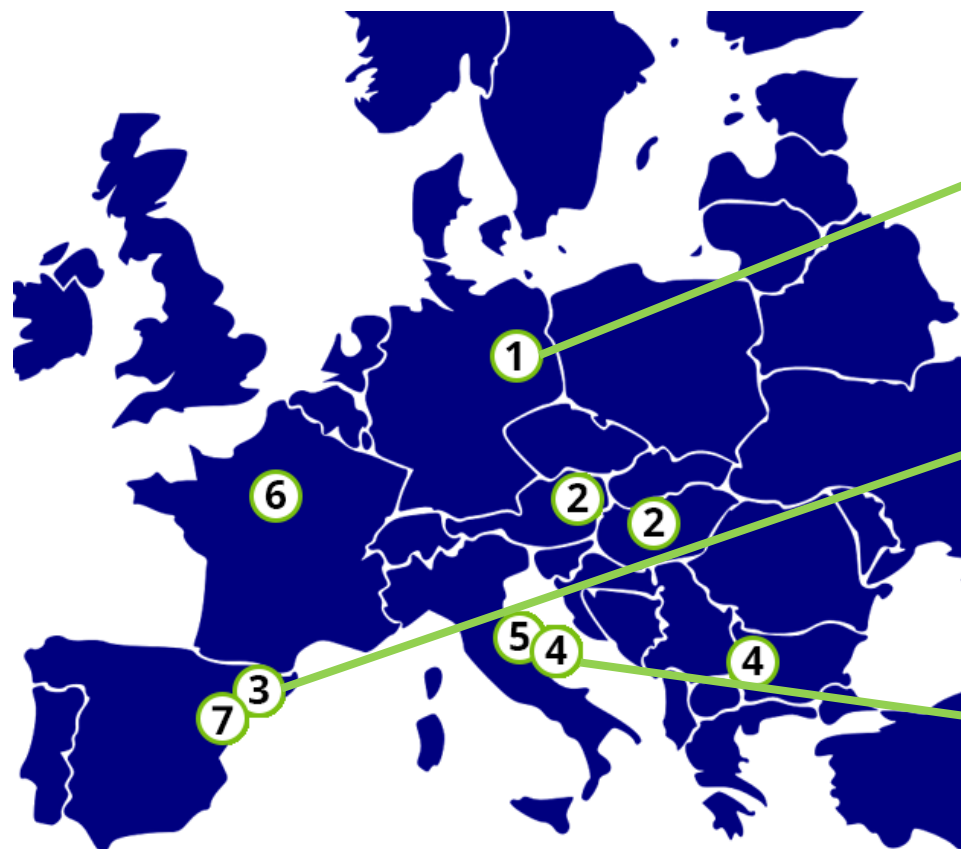
Although the results of this study regarding PFAS elimination are limited, they indicate that **AWWT properly implemented for micropollutant removal may fail to effectively remove PFAS**. Consequently, catchment areas that have elevated PFAS concentrations will not be able to rely on such end-of-pipe measures at municipal WWTPs and may need to focus their efforts on PFAS source control.

Especially for **ozonation**, both monitoring results as well as literature data demonstrate its **unsuitability for PFAS removal**.

Adsorption technology has more potential but may require a significant change of PAC dosing conditions or GAC runtimes.

The highest potential for further investigation in terms of PFAS removal seems to be GAC filters or PAC systems with dedicated recirculation tanks, including PAC transfer, back to the biological treatment step.

PFAS removal in 3 case studies



1

PFAS and PM(T) fate and remediation in the semi-closed urban water cycle – Berlin (Germany)

3

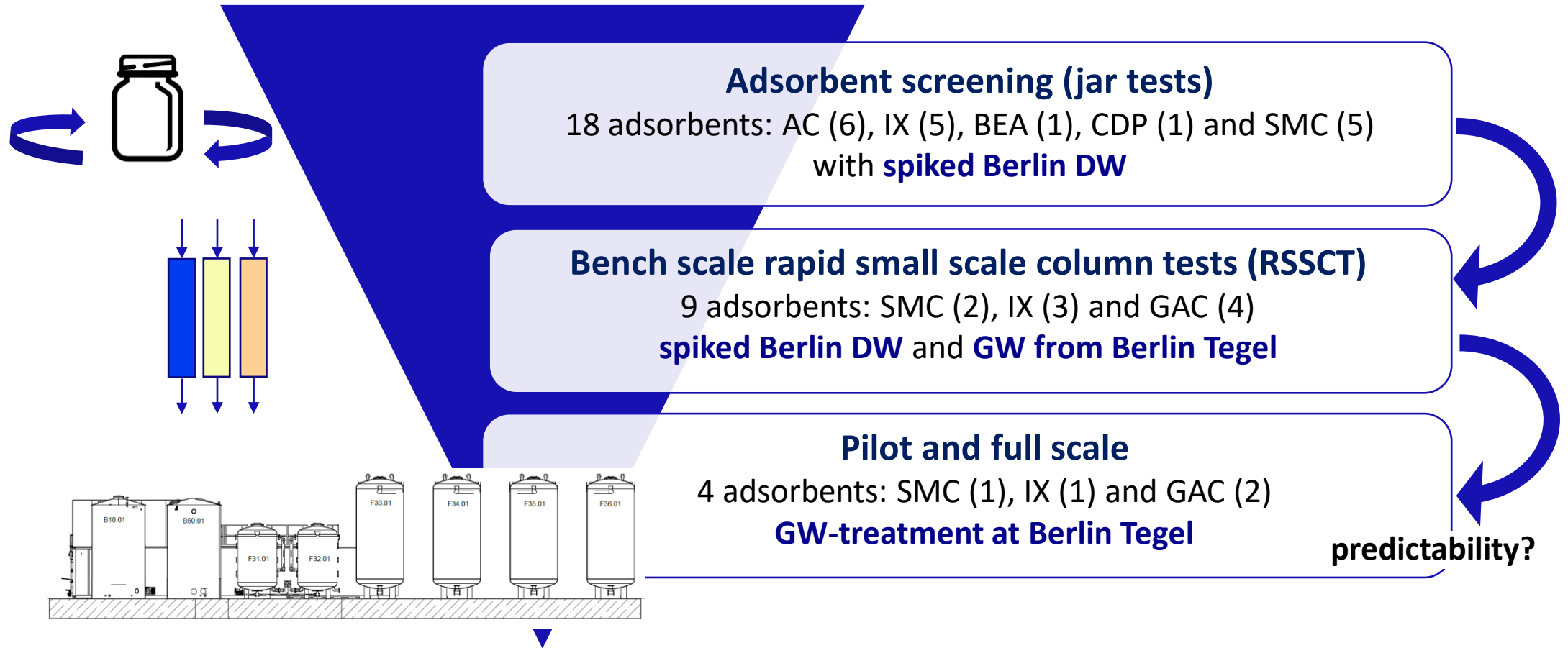
Water reuse from a wastewater treatment plant with a high share of industrial wastewater – Barcelona Province (Spain)

4

Landfill leachate treatment to enable resource recovery from wastewater treatment plants – Ancona (Italy) and Sofia (Bulgaria)

PFAS and PM(T) fate and remediation in the semi-closed urban water cycle – Berlin (Germany)

Searching for GAC alternatives



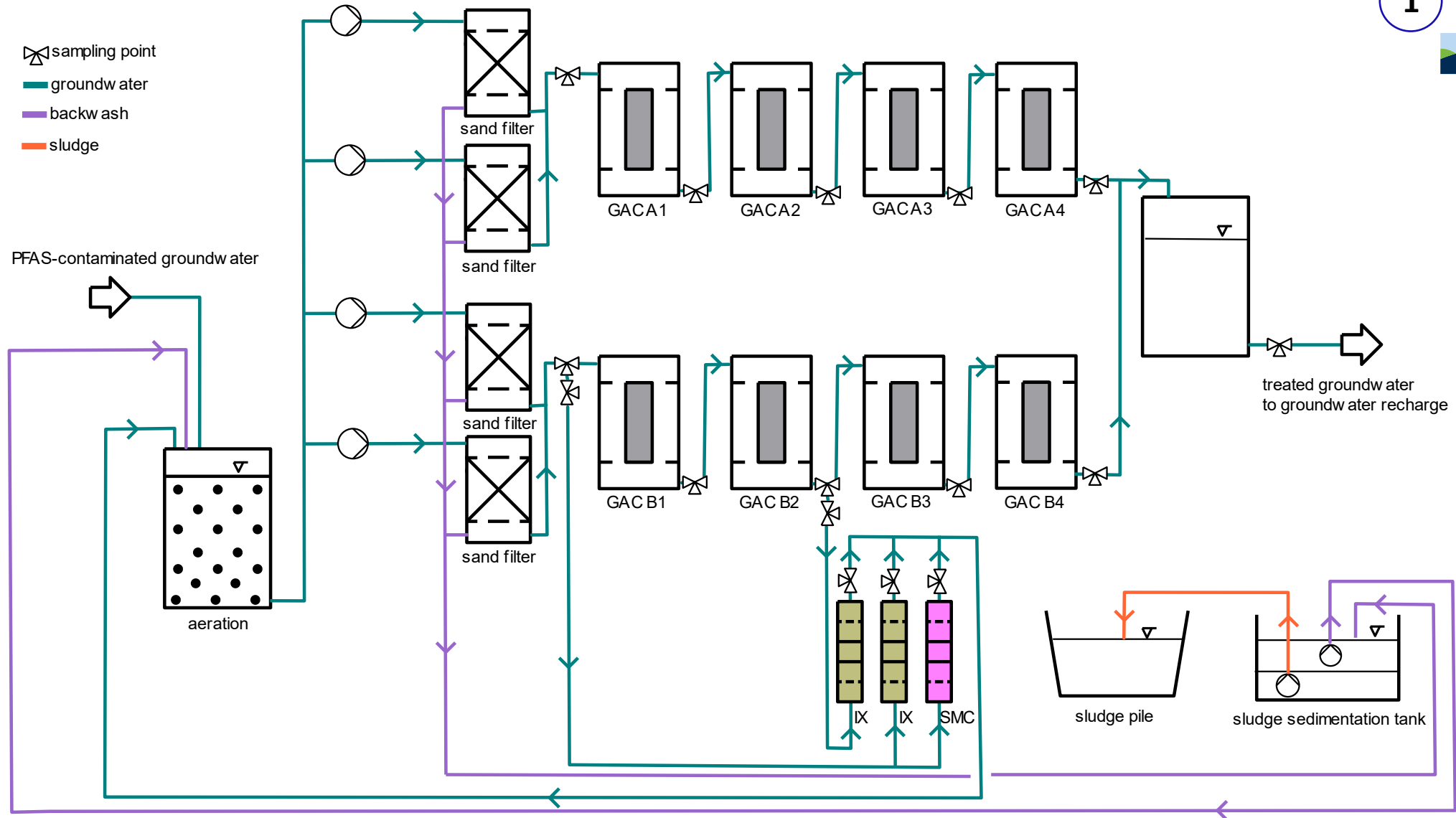
(G)AC: (granular) activated carbon, IX: ion exchange resin, BEA: BEA zeolite, CDP: cyclodextrin polymer, SMC: surface modified clays

Groundwater treatment (Berlin Tegel)



<https://www.rbb24.de/politik/beitrag/2022/07/berlin-flughafen-tegel-txl-pfas-grundwasser-urban-tech-republic-Wasserbetriebe-pumpe.html>

Groundwater treatment (Berlin Tegel)



Adsorbent screening & outlook

SMC and IX could be suitable alternatives to existing GAC at Berlin Tegel

Optimization potential via use of a different GAC is probably low

Pilot-scale testing of IX1 and SMC1 at Berlin Tegel begun (02/24)

- Target analysis: PFAS, pharmaceuticals, DOC, UV₂₅₄, anions
- Suspect-screening (BfG)
- PFAS CALUX (UBA)
- Retrospective evaluation of RSSCT scaling-approach
- Comprehensive assessment under realistic conditions



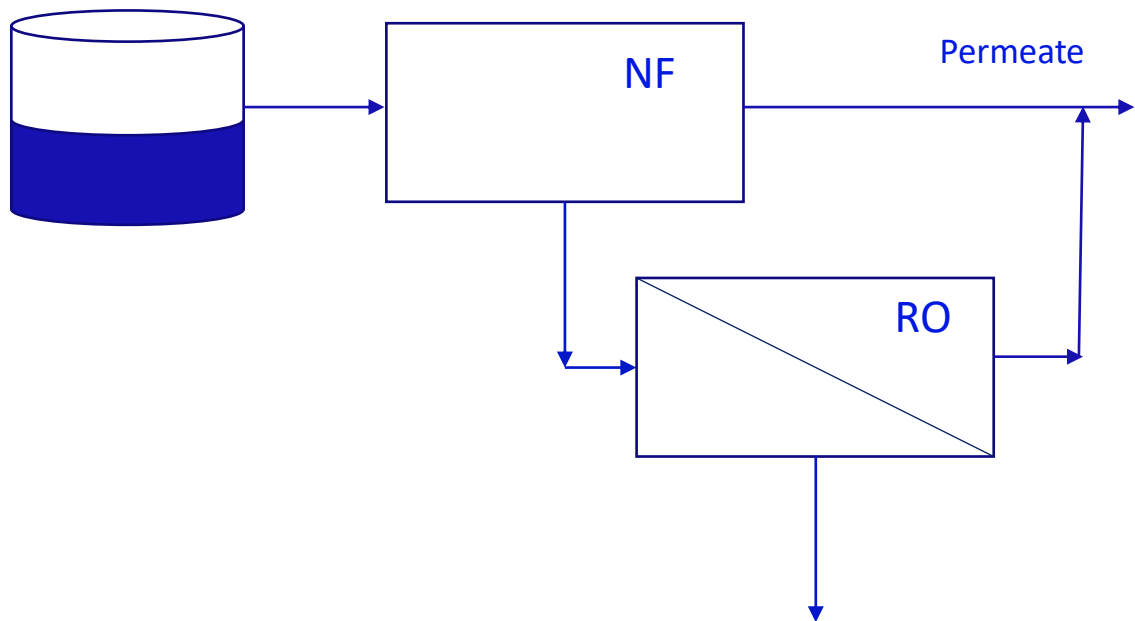
© BWB

IX and SMC pilot plant at Berlin Tegel

Landfill leachate treatment to enable resource recovery from wastewater treatment plants – Ancona (Italy)

Comparing RO and NF for LL

NF/RO Pilot Plant



Parameters	NF	RO
Permeate Flow (m ³ /h)	0.76	0.52
Perm. Cond. (μS/cm)	5039	66
Concentrate Flow (m ³ /h)	1.28	1.51
Concentrate Cond. (μS/cm)	9642	11971
Operation Pressure (bar)	21.97	48.40
Recovery (%)	37.16%	25.67%
Energy Consumption (kWh/m ³)	2.7	5.4

Comparing RO and NF for LL



© UNIVPM



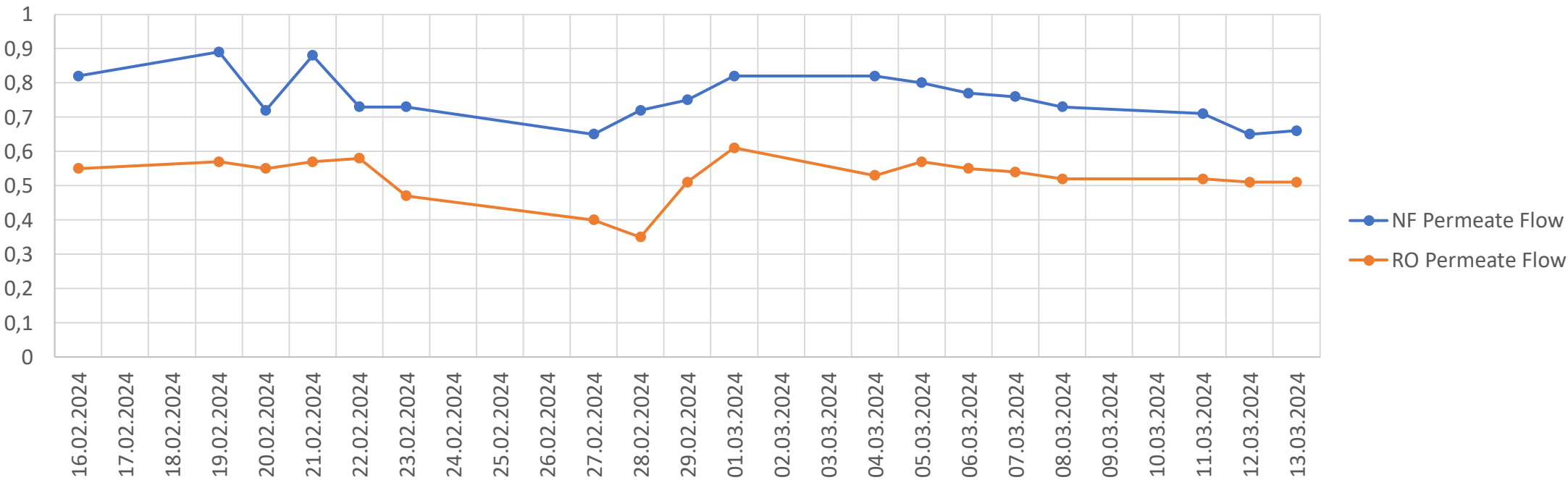
© UNIVPM



© UNIVPM



Comparing RO and NF for LL



Comparing RO and NF for LL

Name	NF Influent*	NF Permeate**	NF Concentrate*	RO Permeate**	RO Concentrate*	NF Rejection	RO Rejection
PFBA (ng/l)	1133	33	2200	<	3033	97.06%	> 99.09%
PFPeA (ng/l)	<	30	1367	<	1933	-	> 98.54%
PFHxA (ng/l)	1400	23	2633	<	3733	98.33%	> 99.24%
PFBS (ng/l)	4900	230	8400	<	11700	95.31%	> 99.76%
PFHpA (ng/l)	<	<	<	<	1000	-	> 98.00%
PFOA (ng/l)	3267	57	7533	<	10233	98.27%	> 99.73%
Σ PFAS (ng/l)	10700	373	22133	-	30967	96.51%	> 99.91%

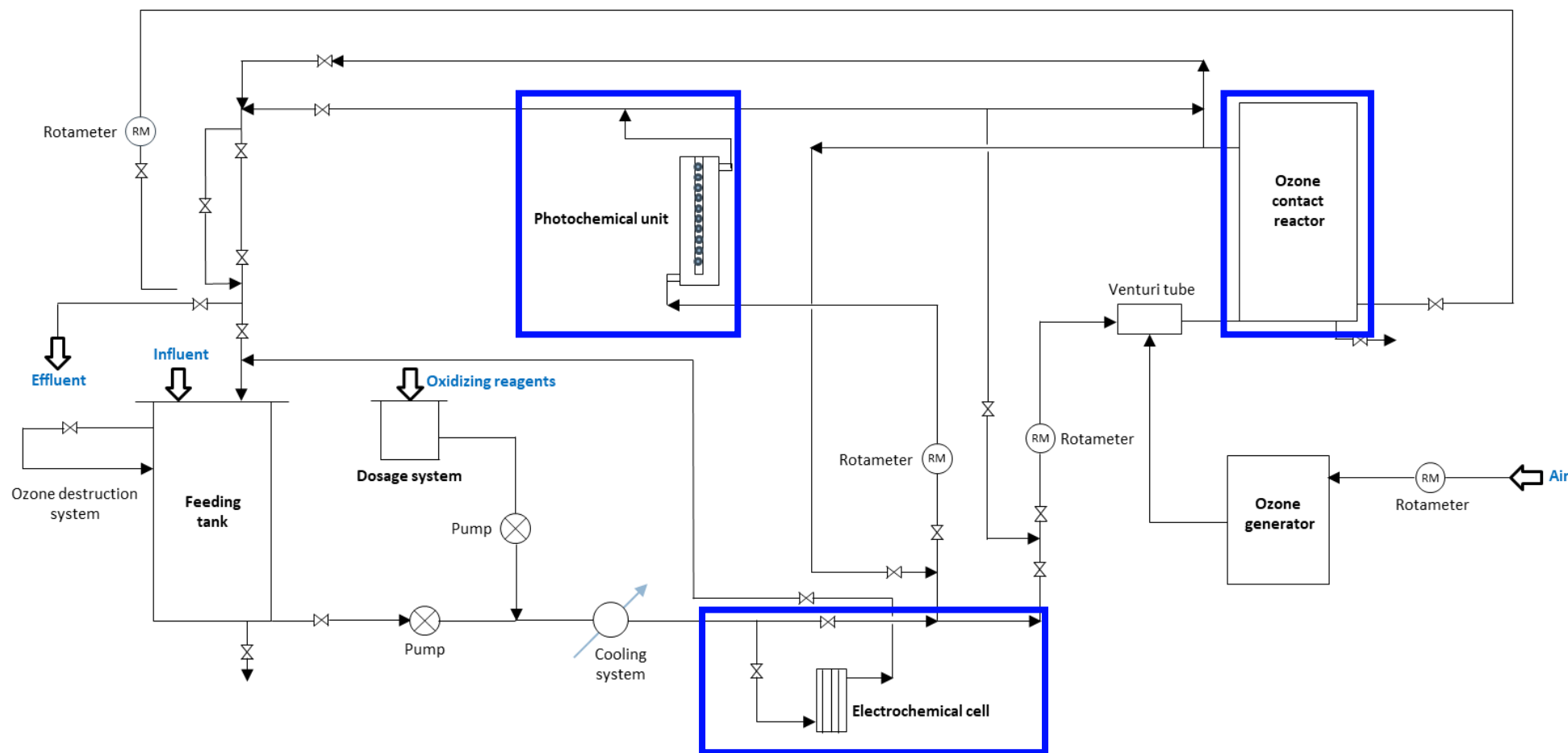
Only 6 of 30 PFAS were detected, all others were below LOQ.

* LOQ is 1000 ng/l; ** LOQ is 20 ng/l



Water reuse from a wastewater treatment plant with a high share of industrial wastewater –
Barcelona Province (Spain)

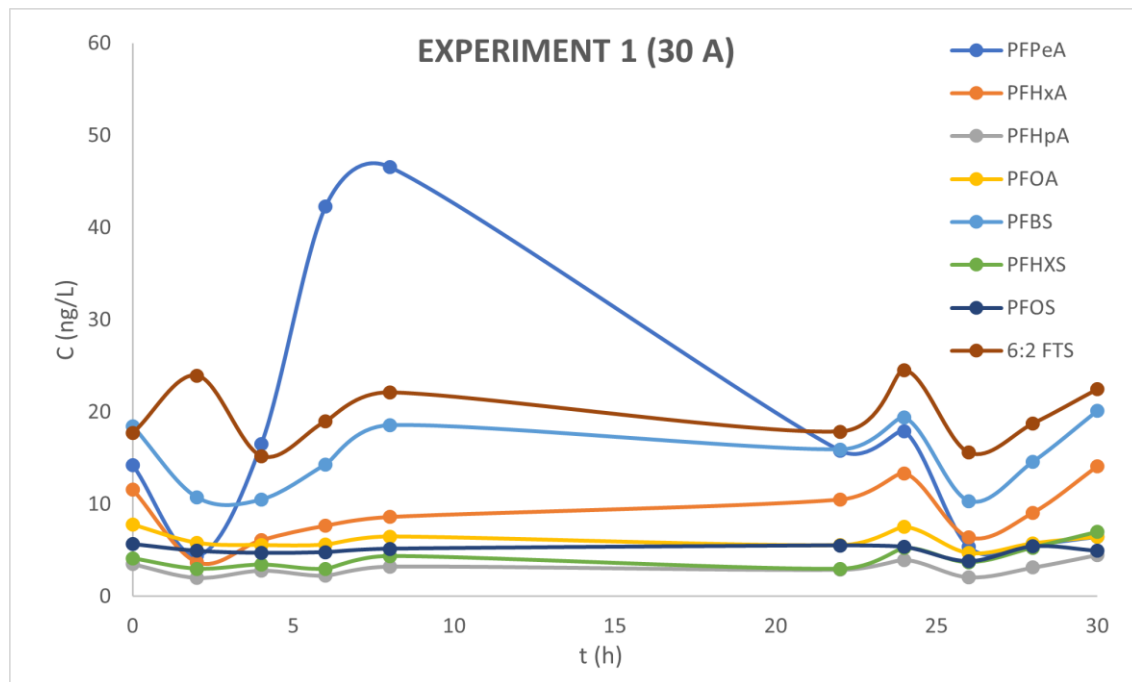
E-Peroxone AOP at lab scale



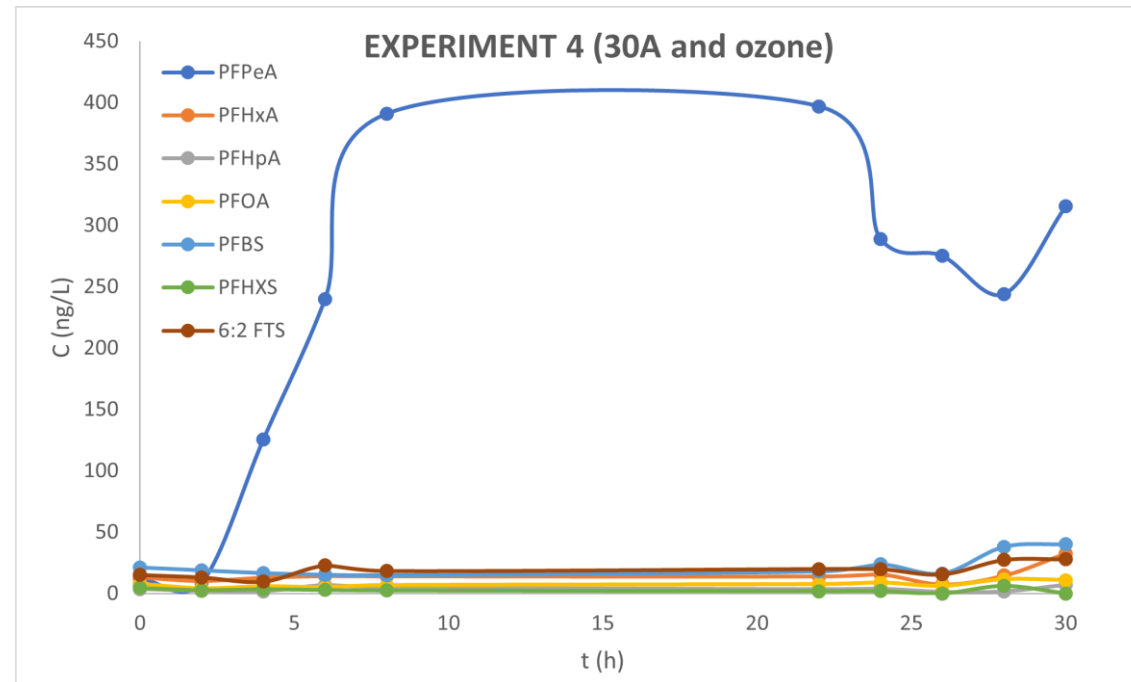
EAOP pilot © Eurecat

E-Peroxone AOP at lab scale

Electrooxidation (H_2O_2)



e-Peroxone ($\text{O}_3 + \text{H}_2\text{O}_2$)



No degradation of PFAS was seen

Oxidation byproducts were generated (ClO_2^- , ClO_4^-)

Increase of water temperature could affect ozone degradation



E-Peroxone AOP + wetlands



© CBT



© CBT

eAOP reduces COD, ammonium, total nitrogen levels

eAOP produces nitrate → should be mitigated by wetlands

Thank you to these people:



Ulf Miehe, Michael Stapf, Moritz Lembke-Özer, Sonja Sterling



Alexander Sperlich, Fiona Rückbeil



Francesco Fatone, Massimiliano Sgroi, Ali Hydar



Carme Bosch, Jessica Rodriguez



The PROMISCES project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101036449



Kompetenzzentrum Wasser Berlin gGmbH
Grunewaldstraße 61-62, 10825 Berlin

Dr. Veronika Zhiteneva

veronika.zhiteneva
@kompetenz-wasser.de

+ 49 (0)151 728 46845



www.kompetenz-wasser.de



@Kompetenzzentrum Wasser Berlin



@kompetenzwasser