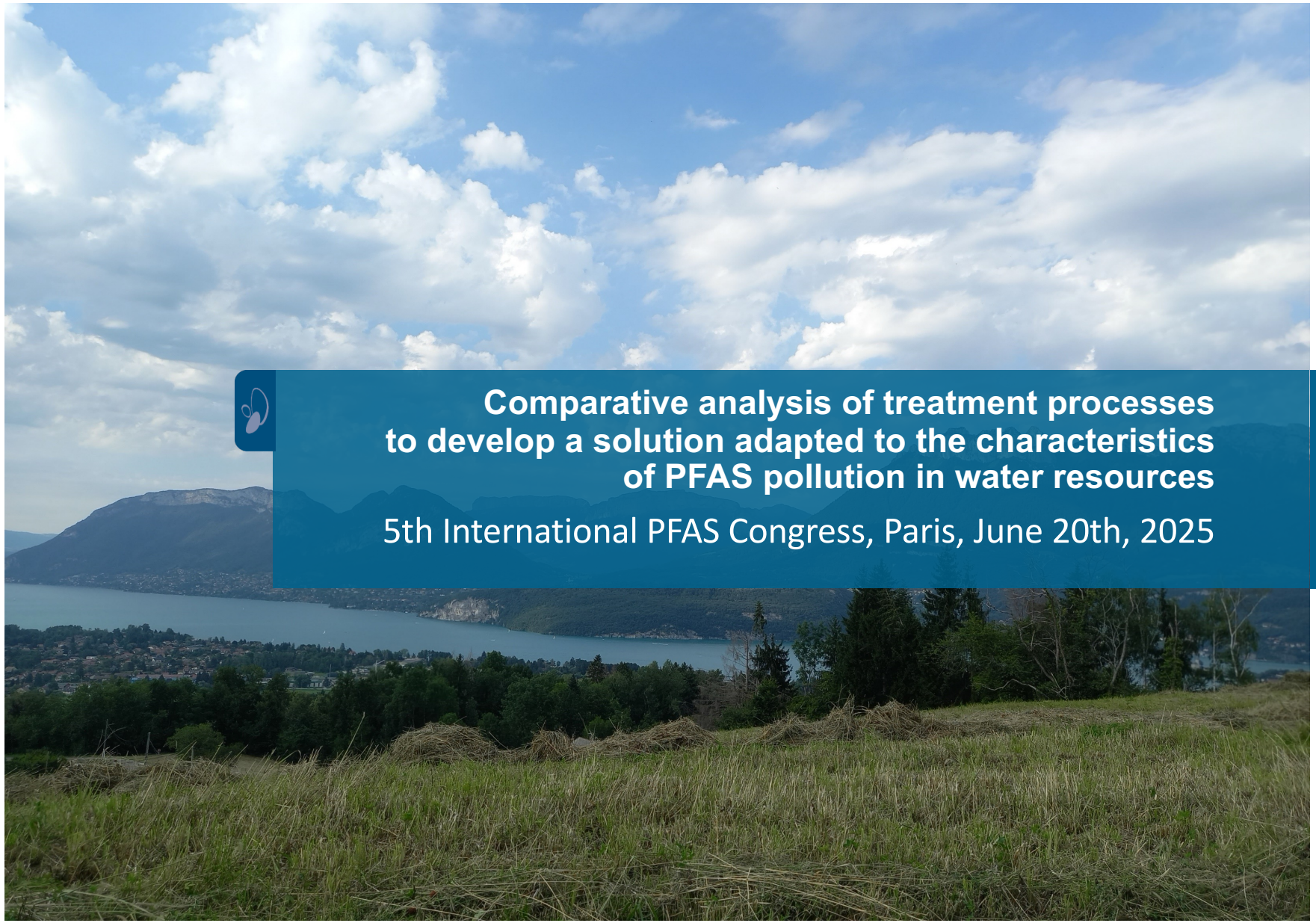

Comparative analysis of treatment processes to develop a solution adapted to the characteristics of PFAS pollution in water resources

5th International PFAS Congress, Paris, June 20th, 2025

Antea®Group

Comprendre aujourd'hui.
Améliorer demain.

Comprendre aujourd'hui.
Améliorer demain.

Speakers

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Laure BRICHET
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Antea Group in France

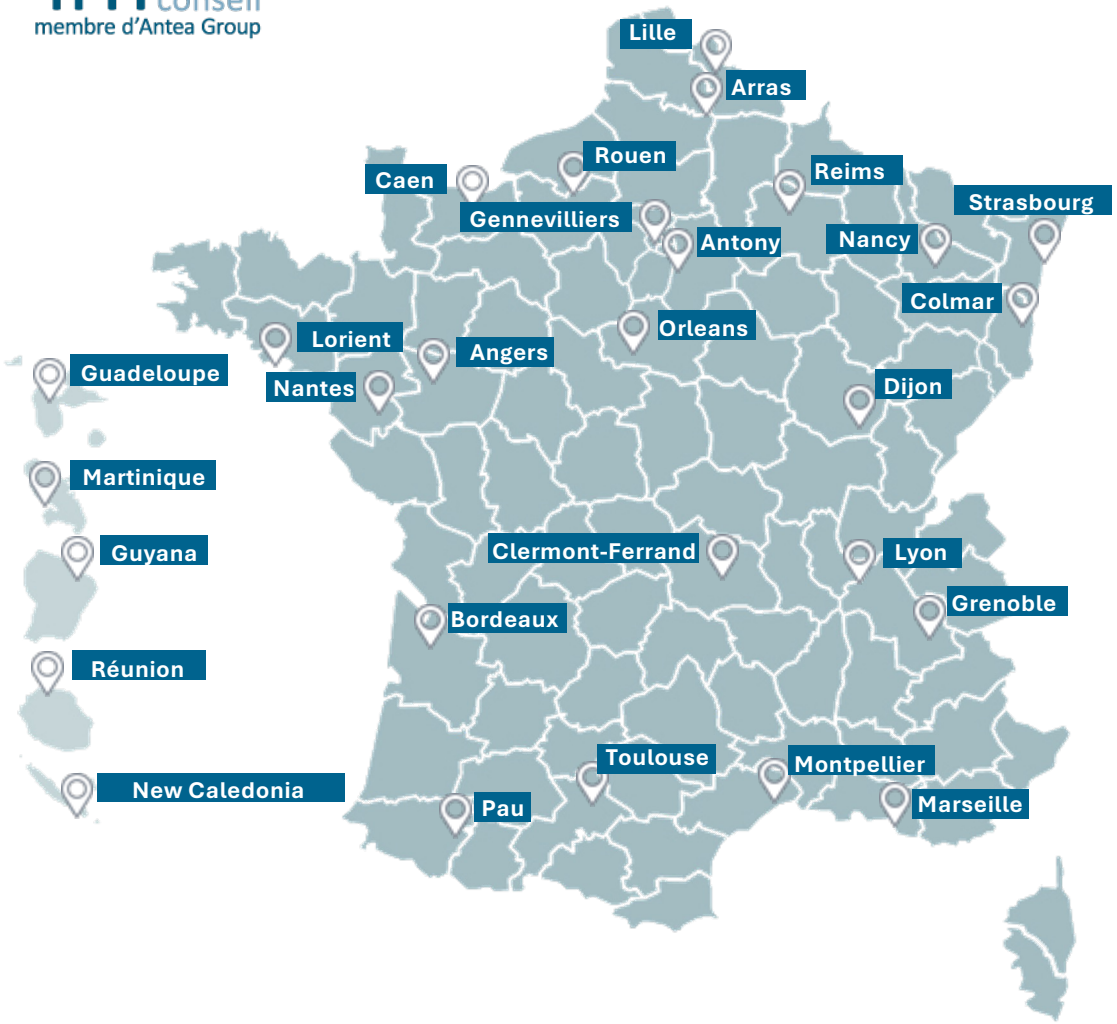
€137 million
2024 turnover

1 100
employees

30
Locations in mainland France
and overseas territories

irh ingénieur conseil
membre d'Antea Group

anteagroup



Grand Annecy Overview

- 539 km² territory
- 34 municipalities, including mountainous areas
- 216,600 inhabitants
- 5 main missions:
  - economic development
  - land planning
  - mobility
  - **environment**
  - elderly care

Grand Annecy
Drinking Water Department Overview

130 employes across 5 services:

* operations
* project management
* water quality/resources
* admin/logistics
* customer relations

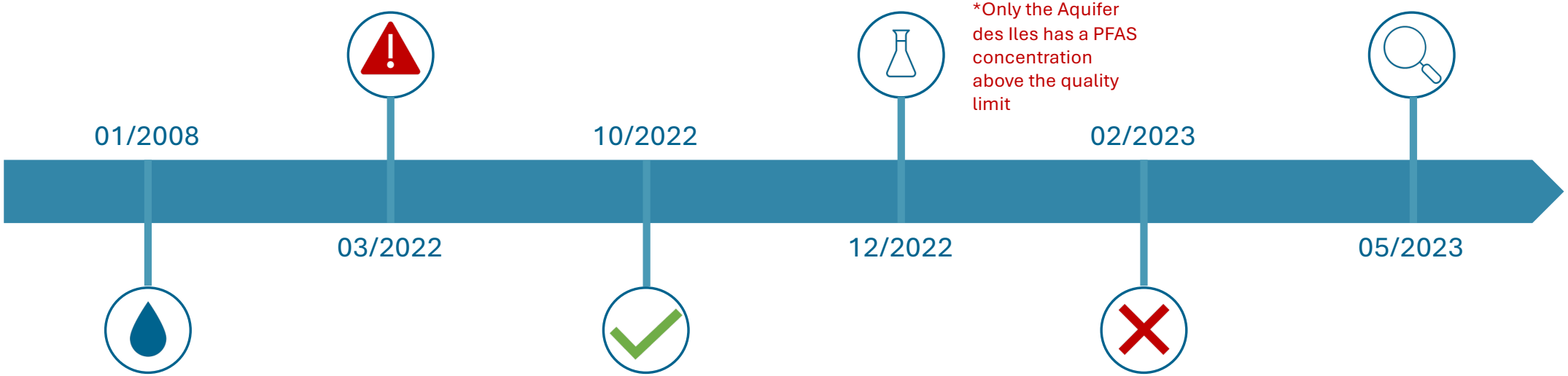
- **120,800** subscribers / 216,600 inhabitants
- **15 million m^3** produced drinking water, incl. ~ 75% pumped from Annecy Lake
- **11 million m^3** drinking water sold to subscribers of Grand Annecy
- **1 million m^3** water exported to neighboring communities

- **1,500 km** of network
- **60** catchments
- **11** boreholes
- **5** lake pumping stations
- **117** reservoirs

- Production potential: 1,500 m^3/d (normal) to 15,000 m^3/d (exceptional)
- Serves 15,000 inhabitants in the municipalities of Poisy and Epagny, Metz, Tessy

- First aid of the Lac network

Chronological reminder



Commissioning of the Aquifer des Iles / Eau du Lac mixture (objective: reduction of the hardness of the water distributed)

Preventive cessation of the use of the Aquifer des Iles due to the Thermocompact alert / [Nickel]

Restart of the Aquifer des Iles (Rey Grange Well) and mixing with the Lake)

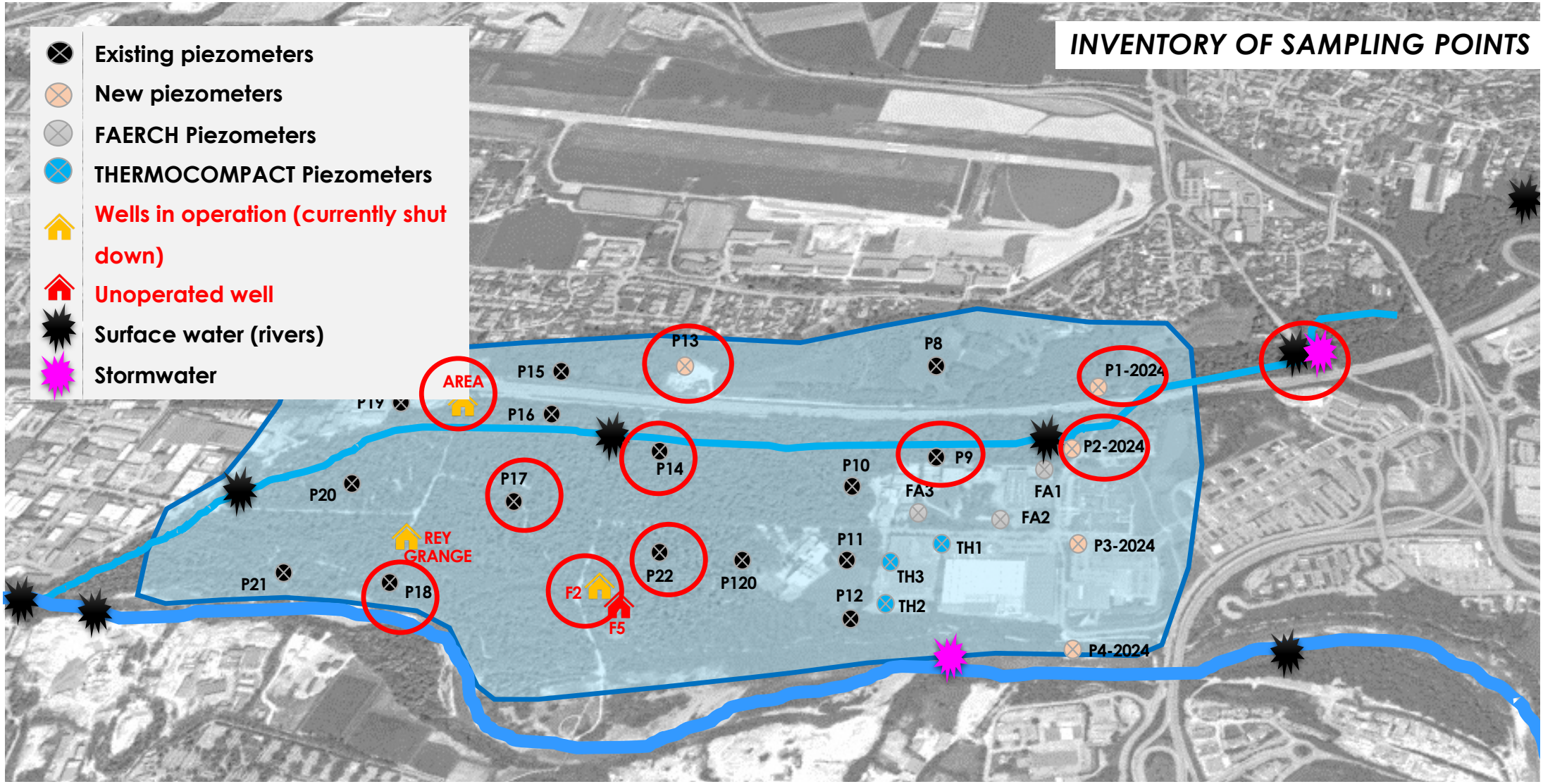
Campaign of preventive measures by PAFS on the main resources or exposed to an industrialist in Greater Annecy*

*Only the Aquifer des Iles has a PFAS concentration above the quality limit

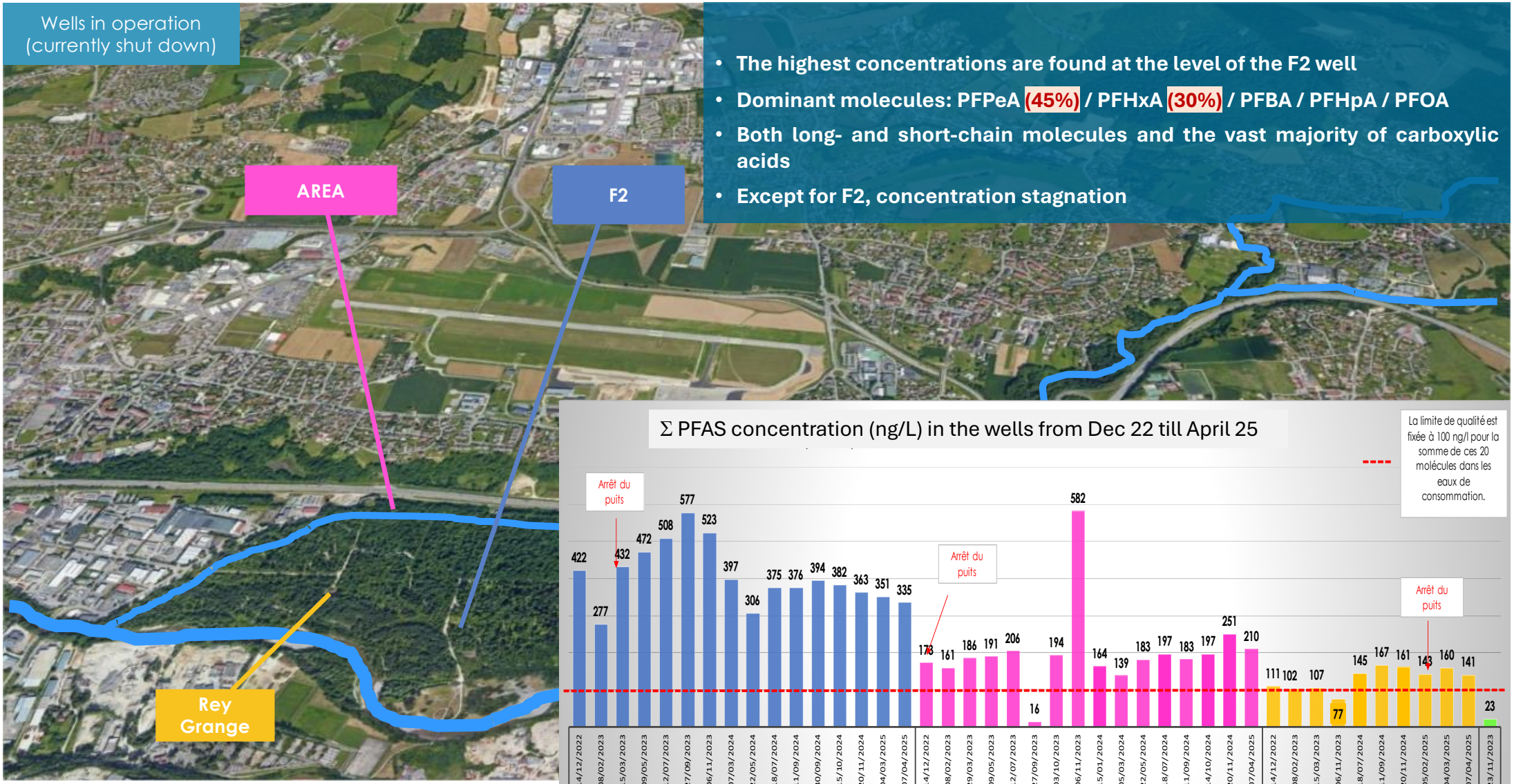
Cessation of the use of the Nappe des Iles

Beginning of investigations in the area of the Aquifer des Iles

As a reminder: the decree of 29/12/2022 sets the quality limit of the sum of the 20 PFAS at 100 ng/l for EDCH

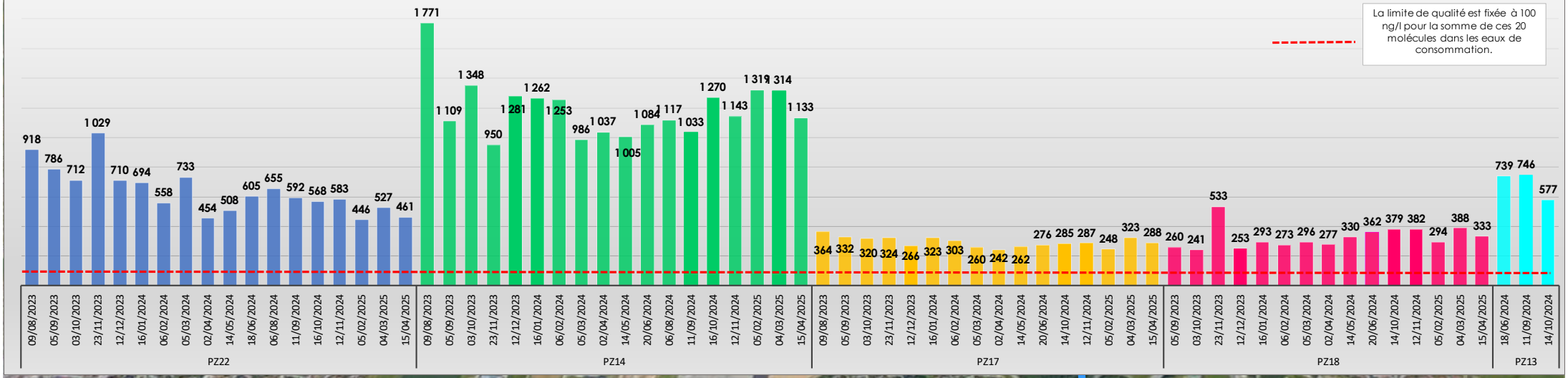

INVENTORY OF SAMPLING POINTS
Existing piezometers
New piezometers
FAERCH Piezometers
THERMOCOMPACT Piezometers
Wells in operation (currently shut down)
Unoperated well
Surface water (rivers)
Stormwater
AREA
REY GRANGE
F2
F5
P13
P8
P15
P1-2024
P16
P14
P2-2024
P9
P10
P17
P20
FA3
FA1
FA2
P11
TH1
P3-2024
P22
P120
TH3
P21
P18
P12
TH2
P4-2024

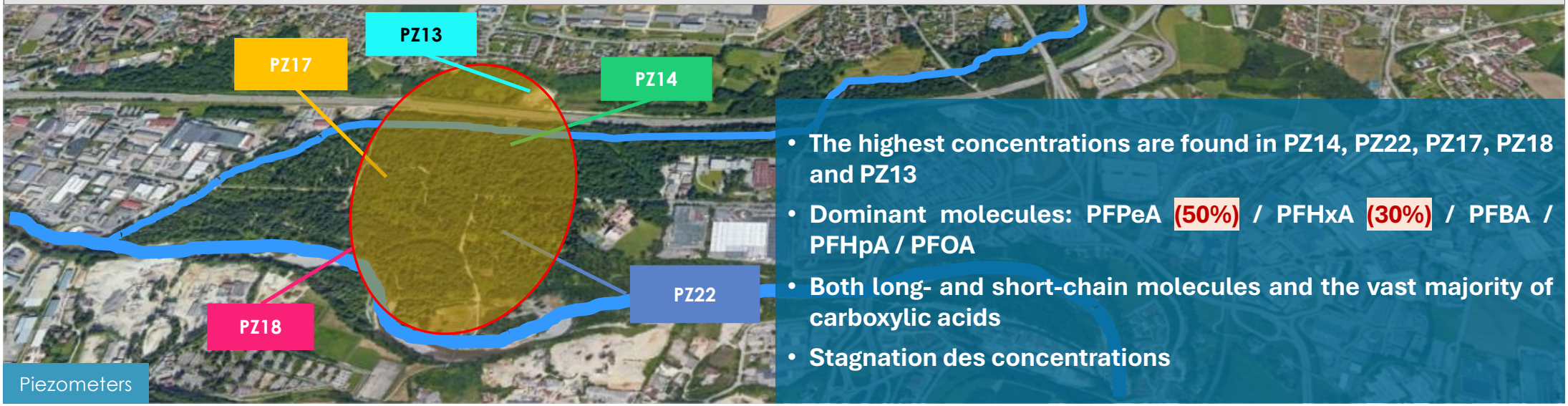
Wells in operation (currently shut down)



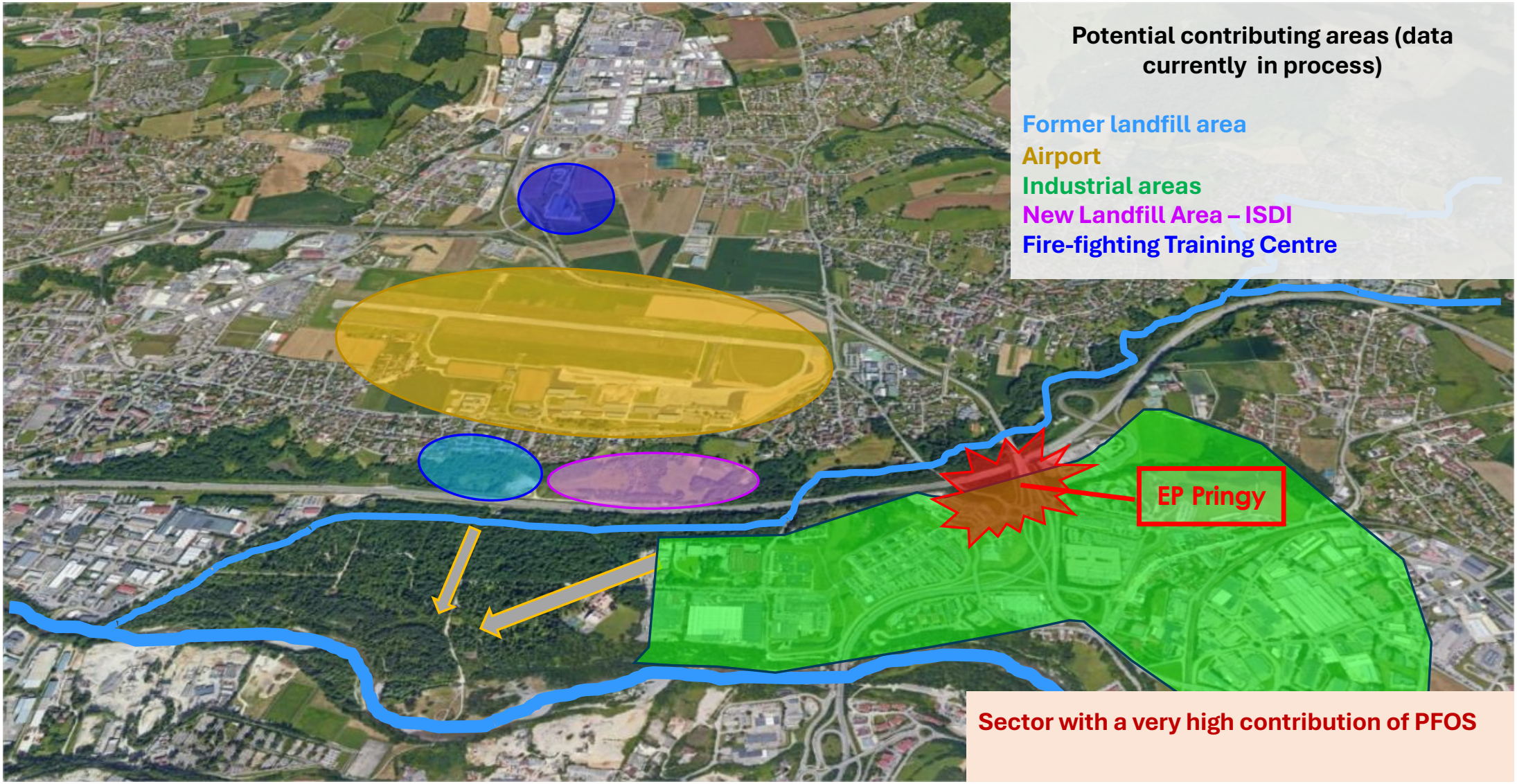
- **The highest concentrations are found at the level of the F2 well**
- **Dominant molecules: PFPeA (45%) / PFHxA (30%) / PFBA / PFHpA / PFOA**
- **Both long- and short-chain molecules and the vast majority of carboxylic acids**
- **Except for F2, concentration stagnation**

Σ PFAS concentration (ng/L) in the piezometers from Aug 23 till April 25



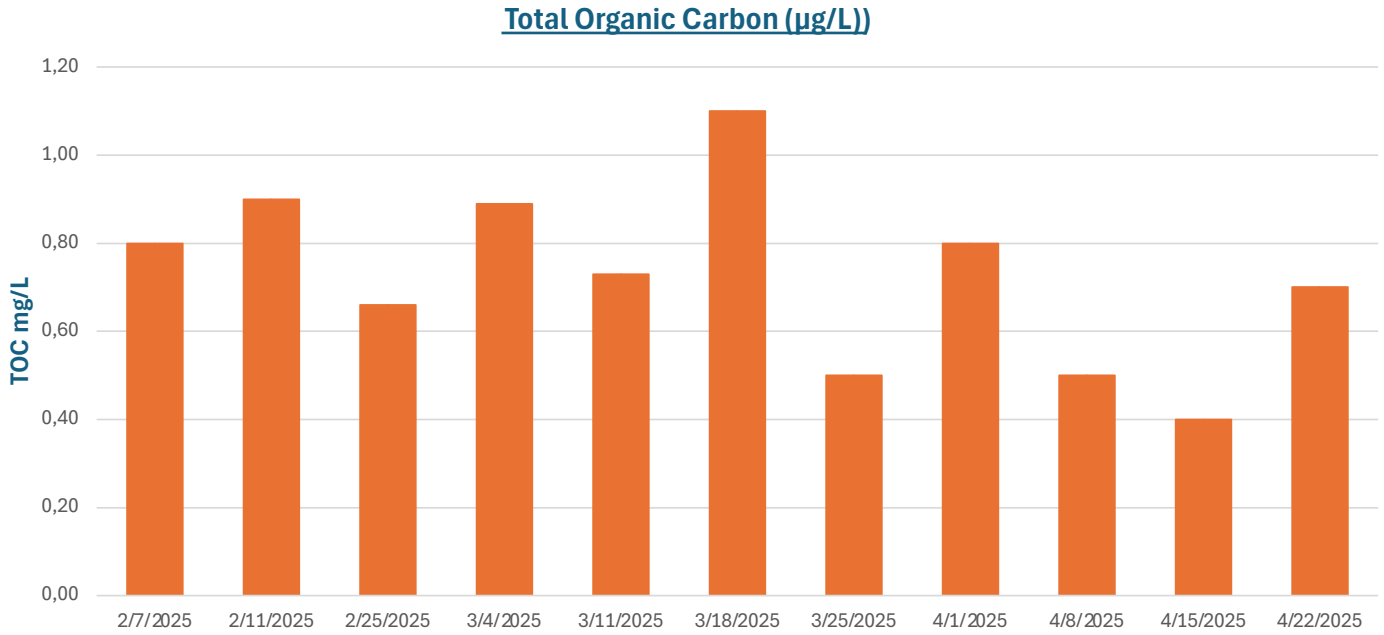


- The highest concentrations are found in PZ14, PZ22, PZ17, PZ18 and PZ13
- Dominant molecules: PFPeA (50%) / PFHxA (30%) / PFBA / PFHpA / PFOA
- Both long- and short-chain molecules and the vast majority of carboxylic acids
- Stagnation des concentrations

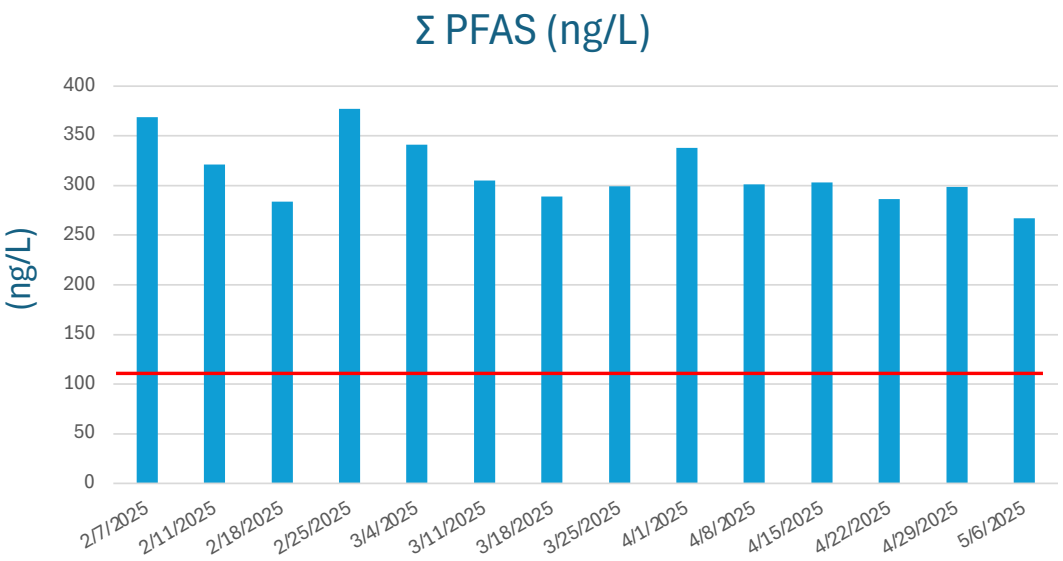

Potential contributing areas (data currently in process)
Former landfill area
Airport
Industrial areas
New Landfill Area – ISDI
Fire-fighting Training Centre
EP Pringy
Sector with a very high contribution of PFOS

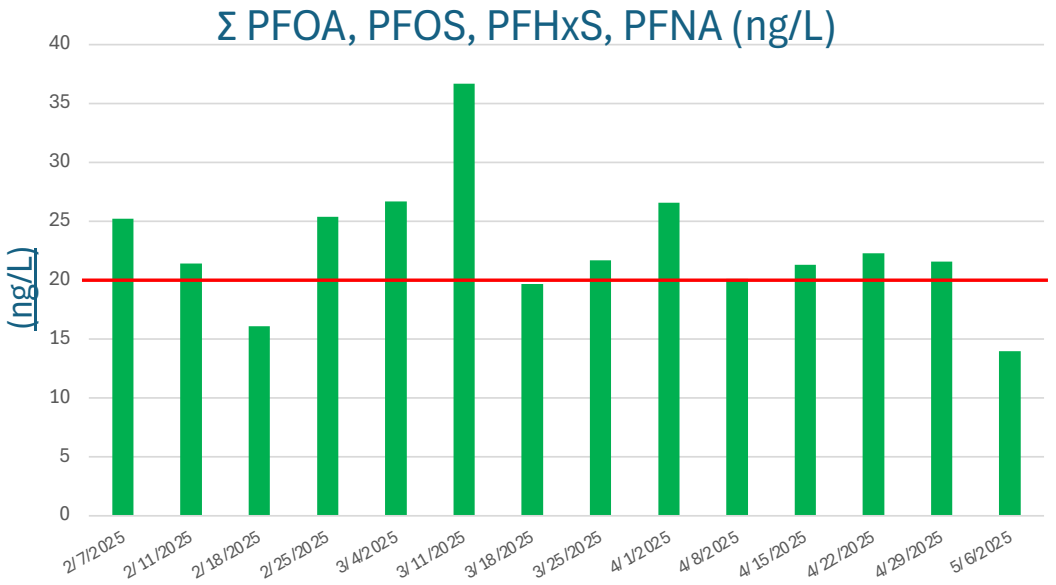
Groundwater quality

Groundwater free of suspended solids, slightly basic (pH 7.5), high hardness (38°f), conductivity around 700 µS/cm

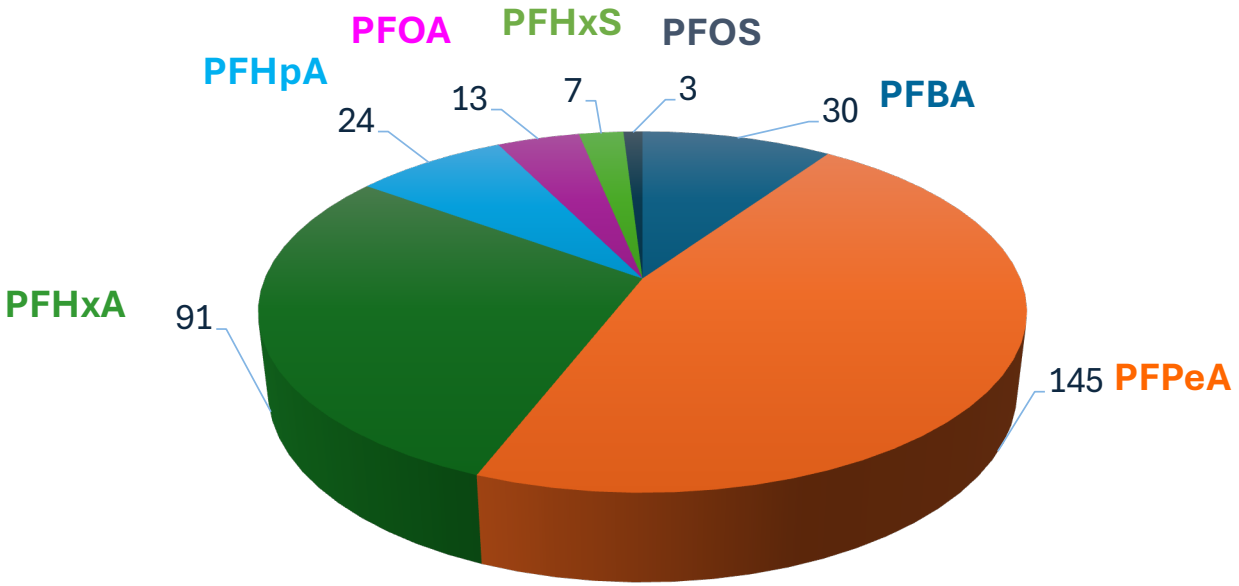


Groundwater quality





Groundwater quality



Technologies for PFAS retention

	Activated Carbon (AC)	Ion exchange resins (IEX)	Nano-filtration (NF)	Reverse Osmosis (RO)
Organic pollutants	++	+	+++	+++
PFAS Long Chains	++	+++	++	+++
PFAS Short Chains	-	+	-	+++

- The most suitable and used technologies to date for the production of drinking water from groundwater
- Doubt about the effectiveness of activated carbon on short chains
- Potentially better on resins but not approved?
- NF/RO – Good performance but high CAPEX/OPEX (high flow rate)

Methods

- **20 PFAS** + 8 PFAS (1) and AOF (2)
- 21 Pesticide metabolites (3) and nickel (4)

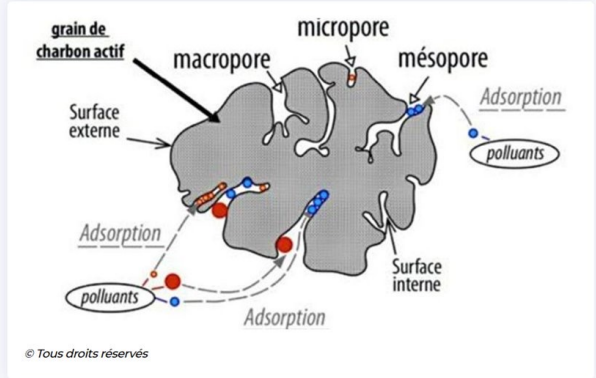
- Preliminary laboratory tests:
  - Activated Carbon adsorption (AC)
  - Ion Exchange resins (IEX) at 2 pH (8 and 6.5)
  - Membrane solutions : nanofiltration (NF) ans Reverse Osmosis (RO)

- In situ trials on selected processes

Results not presented:
(1) 8 PFAS precursors not quantified in raw water nor after treatment (LQ = 10 ng/L; 20 and 50 µg/L for 6:2 and 8:2 FTOH)
(2) AOF not quantified in raw water or after treatment (LQ = 2 µg/L)
(3) Relevant and non-relevant pesticide metabolites in drinking water (Source ANSES – April 29. 2024) not quantified in raw water
(4) Since the beginning of 2025, nickel has sometimes been quantified (0.3 to 1.6 µg/L; LQ = 0.2 µg/L) in raw water (drinking water quality limit: 20 µg/L)

Laboratory trials – Activated Carbon adsorption

- Findings of the literature reviews
  - Longer carbon adsorption time for PFAS → **Improved efficiency of micro-granular and powder carbons**
  - **Improved adsorption of short-chain PFAS on mesoporous or microporous carbons**
- Consultation with 4 activated carbon suppliers
- 4 coals retained: 1 granular, 2 micro-granular and 1 powder

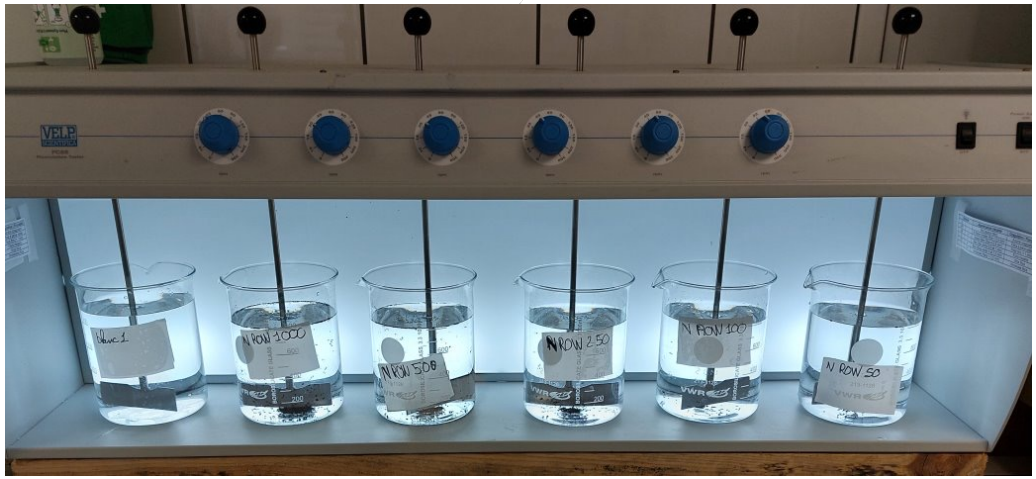


Material reference	Nature	Particle size	Pore size
1	**Plant-based (wood)**	**Granular** - Extruded pellet to 0.8 mm	**micro/mesoporous**
2	Coal	**Micro-granular – 0.4-1 mm**	mesoporous
3	Coal	**Micro-granular – 0.4-0.8 mm**	mesoporous
4	Recovered by-product of a thermal process	**Powder < 50 µm**	**micro/mesoporous**

Laboratory trials – Ion Exchange resins

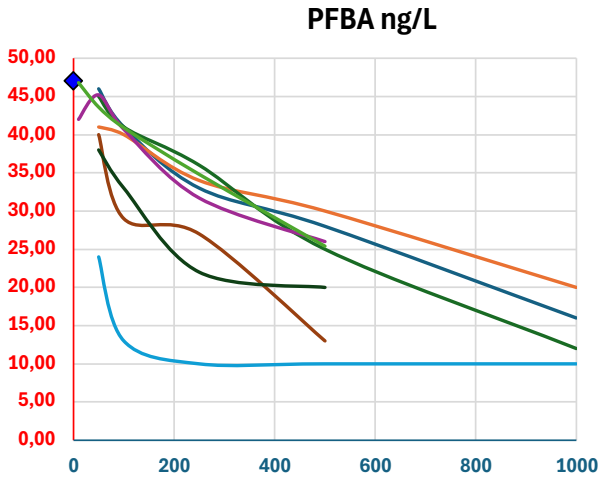
Selection of 2 resins (n°5 and 6) for which the application for drinking water approval was in progress

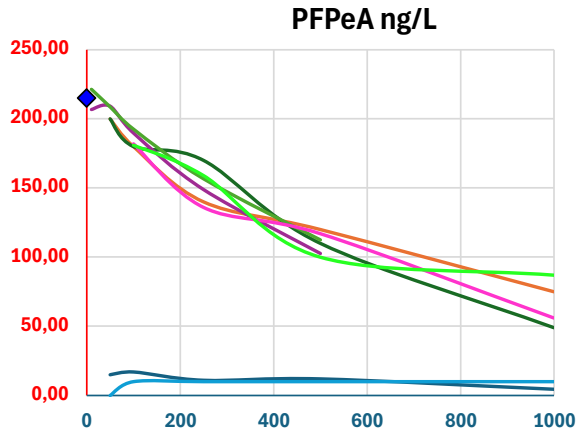
Non-regenerative resins

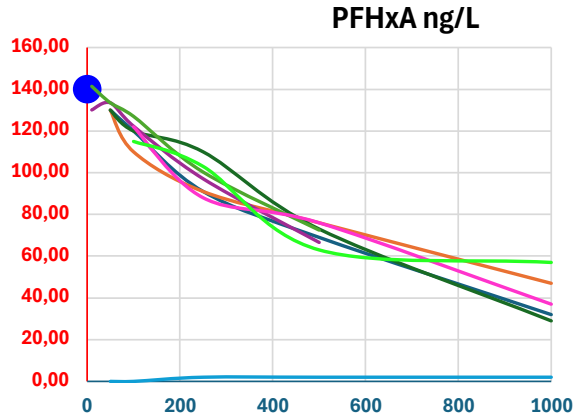


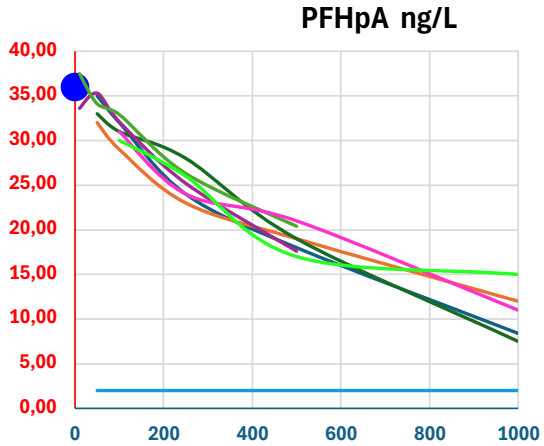
Jar test (1 blank and 5 dosages)
Time = 2h

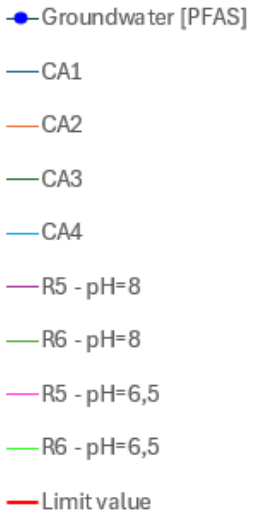
Laboratory trials – RESULTS AC/Resins



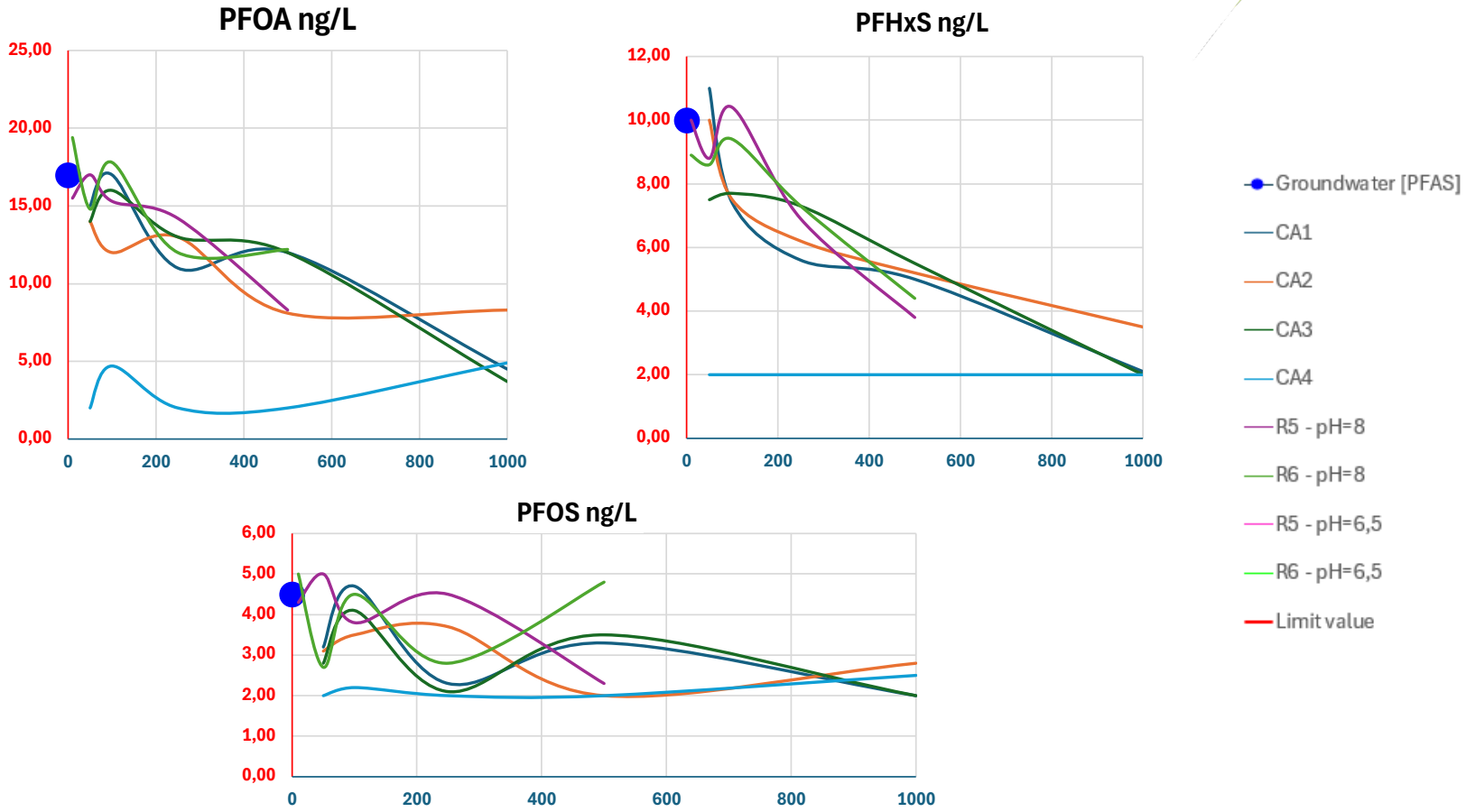






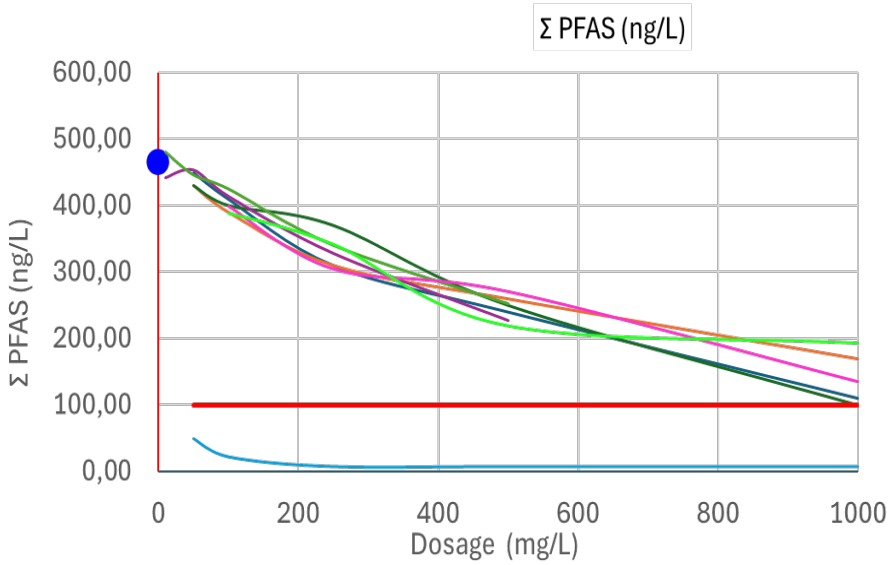


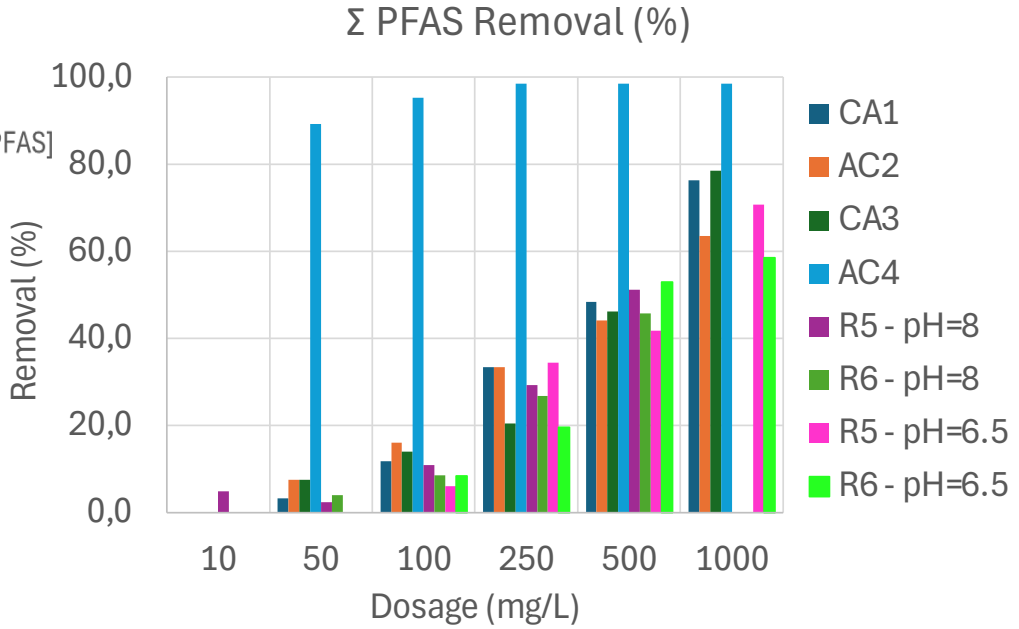
Laboratory trials – RESULTS AC/Resins



Laboratory trials – RESULTS AC/Resins

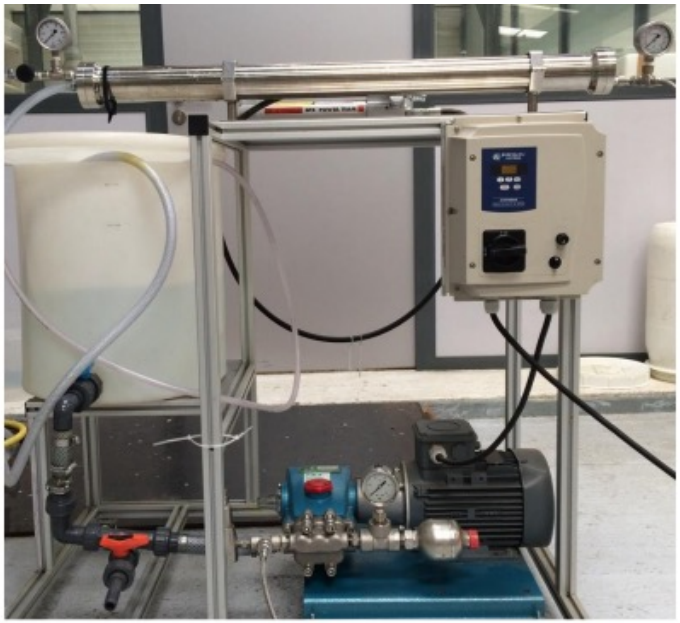
- Powdered activated carbon (AC 4) effective even at low dosages
- For resins, tests conducted at pH 6.5 do not lead to better results than at pH 8
- Similar efficiency between granular, micro-granular activated carbons and resins (at equivalent dosage)





Laboratory trials - NF/RO Membranes

- NF and RO membranes: spiral membranes (2.5 inch diameter) equivalent to 8 inch membranes with drinking water approval
- Pilot operation in concentration mode
- Step 1: Raw water trial with each membrane
- Step 2: Trial of 2nd RO concentration on the RO concentrate

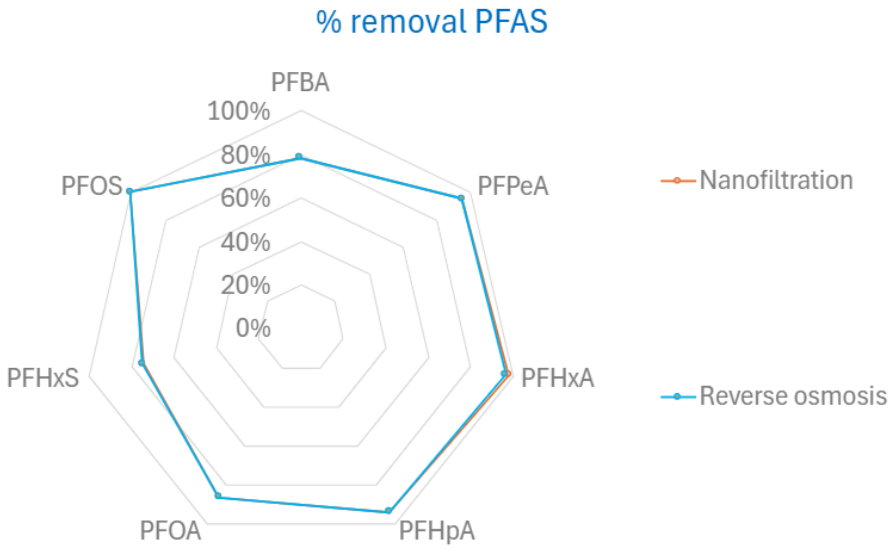


Laboratory trials - RESULTS NF/RO

Step 1 – Groundwater treatment

	Permeate flow (L/h.m²)	Medium pressure	Permeability (L/h.m².bar)	Recovery	Antifouling addition (ppm)	Delta of flow with water (%)
Reverse osmosis	32,8	4,0	8,2	80 %	3	-4,3
Nanofiltration	31,5	5,7	5,5	80 %	3	-8,0

In fact, the NF membrane is very closed



No PFAS quantified in NF and RO permeates:

- PFBA et PFPeA < 10 ng/L
- The others < 2 ng/L

(% removal calculated with LQ)

Sample Designation	Unit	Osmosis concentrate	Permeate of 2nd concentration	2nd concentrate
Conductivity (25°C)	µS/cm	/	110,0	4900
Full Alkali Strength (TAC)	°F		3,3	186,0
Alkali Strength (TA)	°F		<0.5	<0.5
Total Hardness (TH)	°F		2,7	203,0
Calcium (Ca)	mg/L	*631*	10,0	590,0
Magnesium (Mg)	mg/L	*60*	<0.5	130,0
Nickel (Ni)	µg/l		<0.2	3,7
AOF (adsorbable organic fluorine)	µg/l E/L		***<2***	***2,9***
Σ 20 PFAS	**ng/l E/L**	***2 300***	**4,5**	**5000**
Perfluorohexanoic acid (PFHxA)	**ng/l E/L**	***700***	**4,5**	**1500**
Perfluoropentanoic acid (PFPeA)	**ng/l E/L**	*1050*	< 10	2300
Perfluoroheptanoic acid (PFHpA)	**ng/l E/L**	*175*	<2.0	410
Perfluorooctanoic acid (PFOA)	**ng/l E/L**	*75*	<2.0	170
Perfluorobutanoic acid (PFBA)	**ng/l E/L**	*230*	< 10	500
Perfluorohexane sulfonic acid (PFHxS)	**ng/l E/L**	*39*	<2.0	87
Perfluorobutanesulfonic acid (PFBS)	**ng/l E/L**		< 10	19
Perfluoropentanesulfonic acid (PFPeS)	**ng/l E/L**		<10	11
Perfluorooctane sulfonic acid (PFOS)	**ng/l E/L**		<2.0	23

Laboratory trials - RESULTS NF/RO

Step 2 – RO concentrate treatment (by RO)

- Concentration factor limited by a significant turbidity in the concentrate. Total Recovery 91%.
- High concentration of PFAS in the 2nd concentrate can lead to the passage of PFAS into the permeate: PFHxA
- 2nd concentrate: quantification of PFBS, PFPeS and PFOS; not quantified in the raw water nor in the concentrate.
- The same for Nickel (initial recalculated concentration: 0.34 µg/L) and AOF

	Permeate flow (L/h.m²)	Medium pressure	Permeability (L/h.m².bar)	Recovery	Antifouling addition (ppm)	Delta of flow with water (%)
Reverse osmosis	22,0	3,6	6,1	58 %	3	+0,1

Comparison of the different processes (drinking water production)

	Granular activated carbon	Micro-granular activated carbon	Powdered activated carbon	Resin	Membrane
PFAS Selectivity		**Weak**		**High**	**Weak**
Treatment efficiency	Average		**High**	Average	**High**
Contact time		10 to 30 min		< 5 min	
Implementation	Classic filter	Fluidized bed	Decanter or Fluidized Bed	Classic filter	Low-pressure filtration
Drinking water Approval	Yes	Yes	Yes	**Ongoing (2025)**	Yes
Cost of the consumable	Moderate (standard quality) **to high (selective PFAS)**	Moderate	Moderate	**High**	***(High)***
Energy cost	**Weak**		Medium		**High**
Waste	**Can be reactivated**	**Can be reactivated**	Can't be reactivated (incineration)	Non-regenerative (incineration)	Concentrate (2^{nd} concentration before incineration)
Disadvantages			**Reagent consumption (coag/floc)**	**Reagent consumption (acid/base)**	**Chemicals consumption (sequestrant/washing)**

Pilot tests – Material & method

- Pump immersed in the F2 well to supply the 2 pilot lines:
  - Flow rate: between 100 L/h and 2,000 L/h
  - HMT 30m
- **GAC**
  - Features and operating parameters:

D (m)	S (m2)	H (m)	V (L)	Contact time (min)	Feed rate (L/h)	Speed (m/h)
0,29	0,066	1,000	66	**20**	200	3

  - Line equipped with rotameters, control valve, pressure sensor, flowmeter, alarm
  - **24-hour operation with a contact time of 20 minutes**

Pilot tests – Material & Method

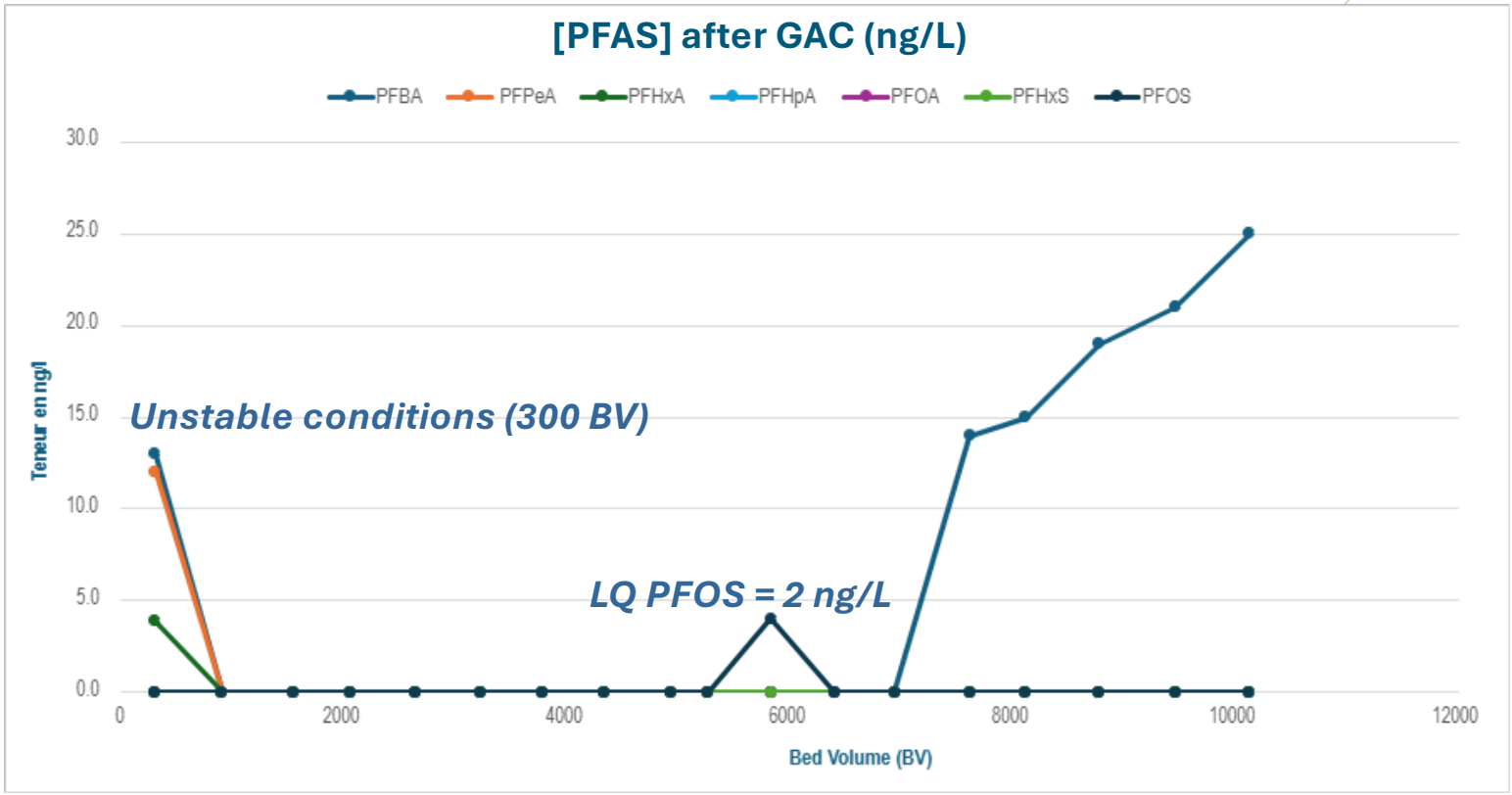
PAC

- PAC preparation:
  - 100 L stirring tank; Dosage: 20 to 50 g/L
  - Diaphragm metering pump: 0.1 to 2.5 L/h
- 3 reactors stirred in series:
  - 160 L unit tank
  - Transfer pump at the outlet of tank n°3
- Sand filter
- Bag filter (1 µm)
- Line equipped with rotameter, control valve, pressure sensor, flowmeter, alarm
- **24-hour or batch operation**
- **Variation in contact time (30 – 60 min) and PAC dosage (10 to 100 mg/L)**

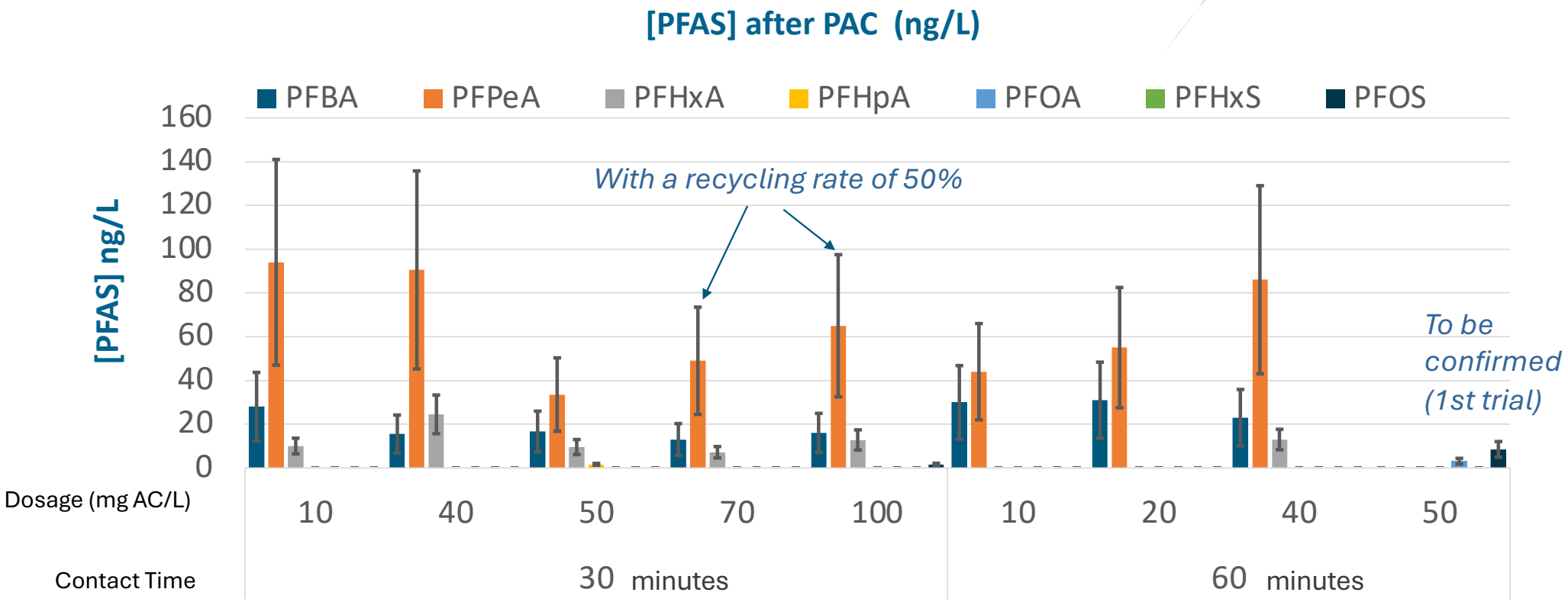
Pilot tests - Material & Method

- Pilot installation and commissioning
  - Blank test
    - Borehole water supply
    - No significant difference in PFAS input/output
- Pilot Unit Tracking
  - 1 weekly visit
    - Checking that it is working properly (pumps, agitators, etc.)
    - Verifying/adjusting operating parameters
    - Sensor reading
    - Sample collection
    - On-site measurements: pH, temperature, conductivity
    - Analysis: TOC, 28 PFAS, AOF index

Pilot tests - RESULTS GAC

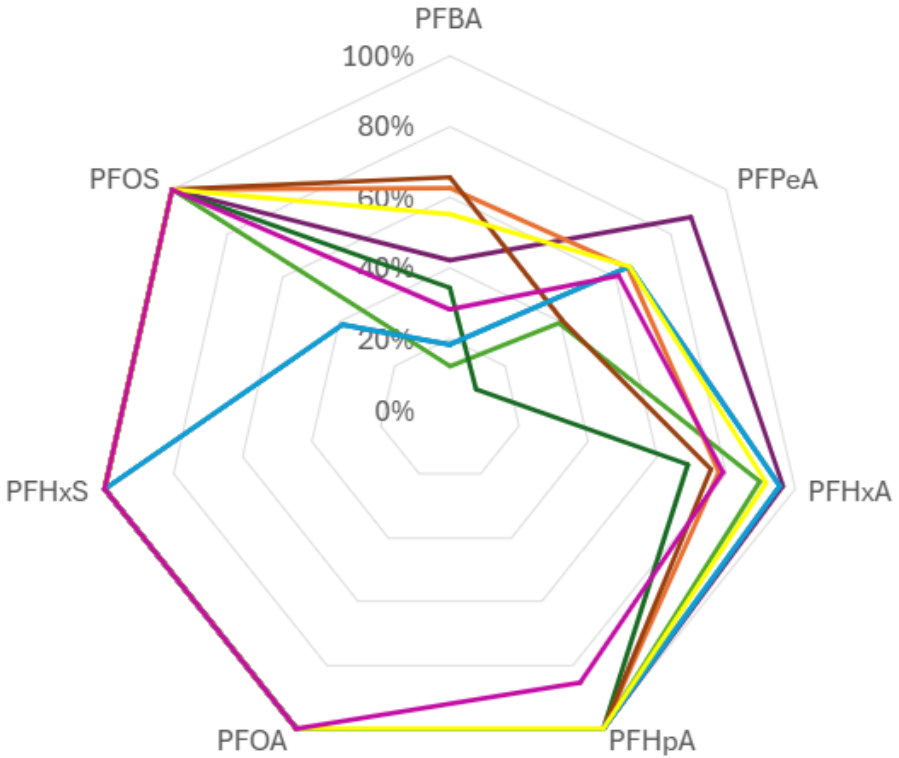


Pilot tests - RESULTS PAC

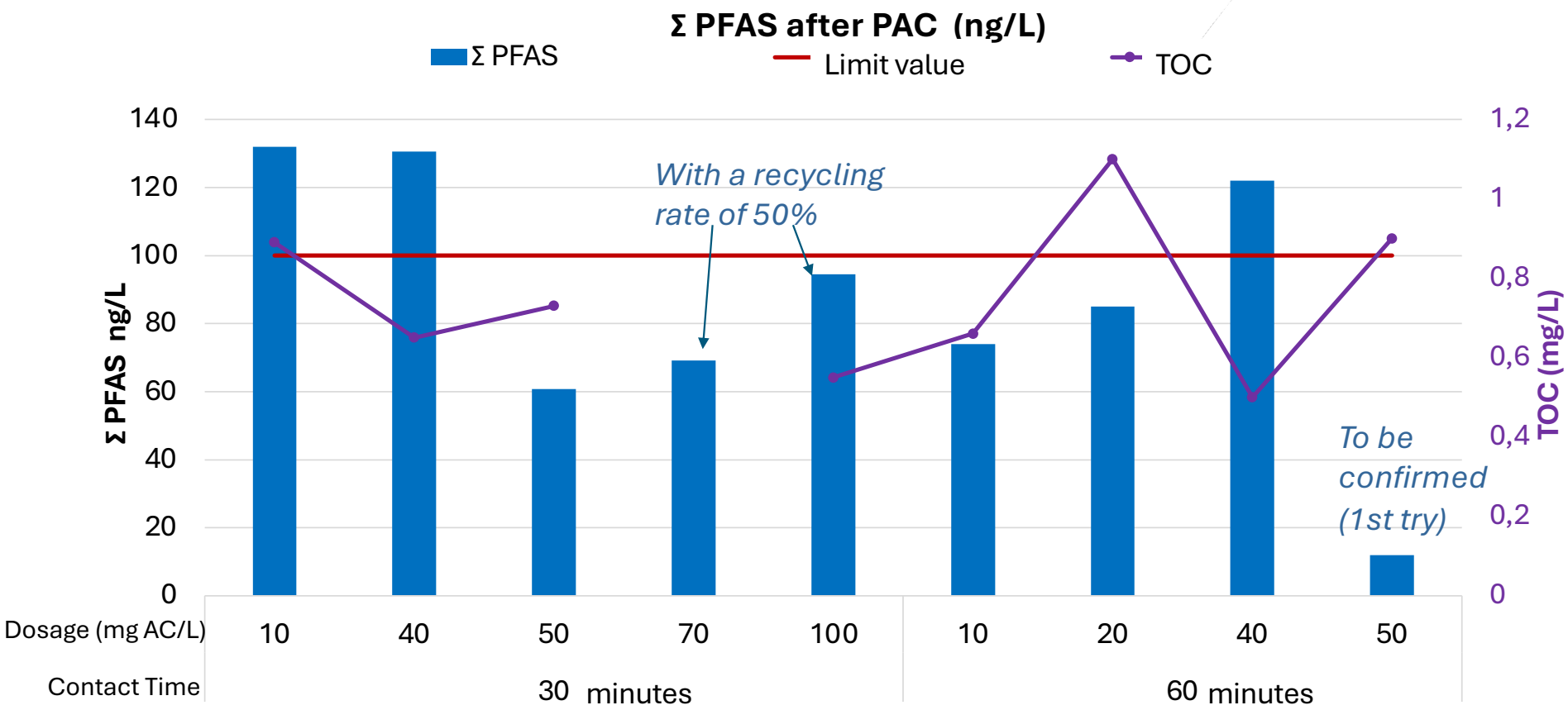


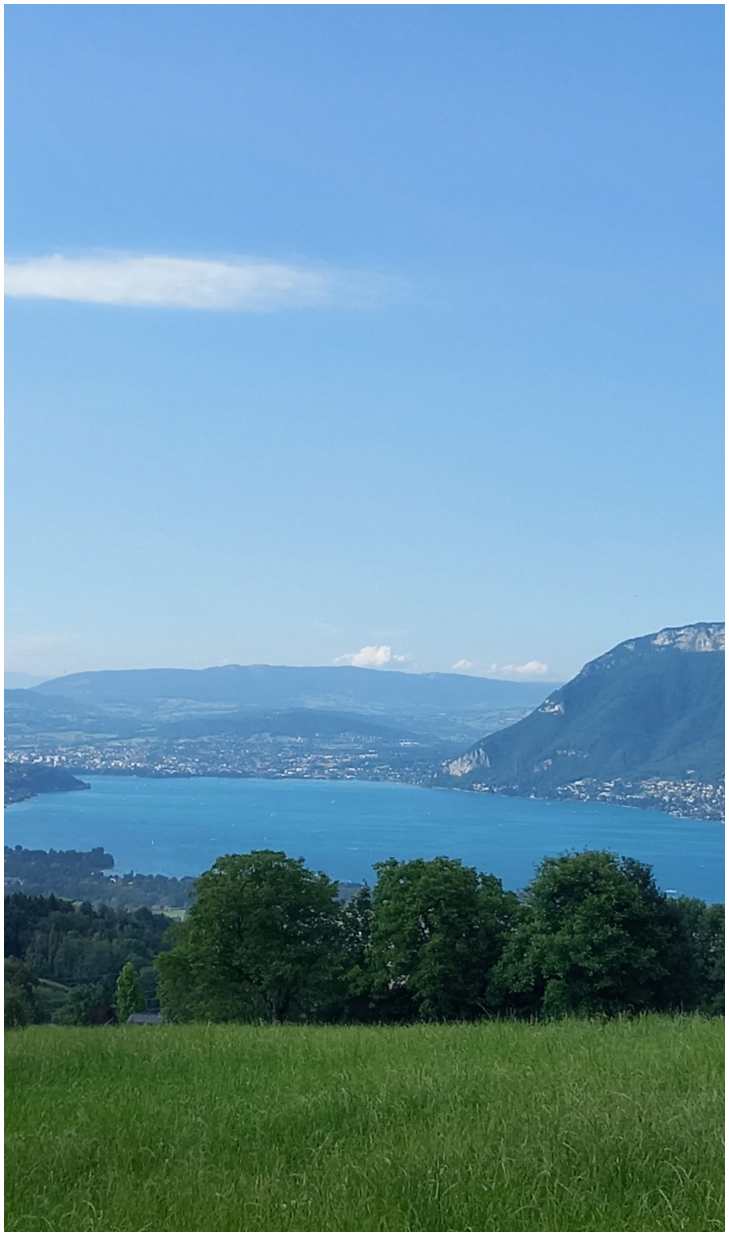
Pilot tests - RESULTS PAC

% removal with PAC at different active carbon dosage



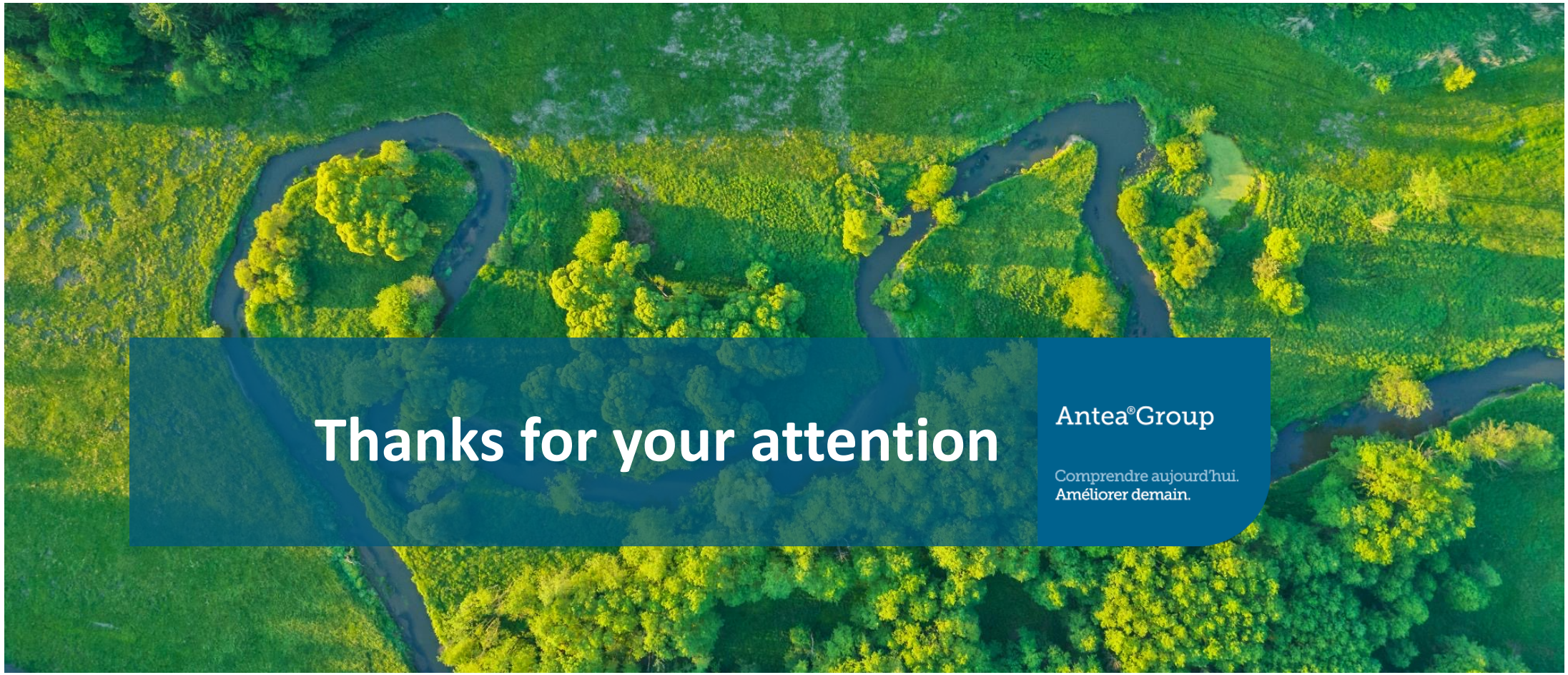
Pilot tests - RESULTS PAC





What's next...

- Continuation of GAC and PAC trials
- Comparative analysis of treatment systems
- Analysis of constraints (land, water supply network, discharge, waste, etc.)
- Pre-dimensioning of treatment units



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