MULTICRITERIA COMPARISON OF THREE TECHNOLOGIES FOR THE TREATMENT OF 42 PFAS IN DRINKING WATER USING A COMPREHENSIVE EXPERIMENTAL APPROACH

suez

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Agenda

1. Context & treatment challenge for DW production
2. Methods
3. Relevant results on GAC, PAC, membranes & IEX for PFAS
4. Multicriteria comparison of technologies: Case study
5. Conclusion & perspectives

1. Context

- PFAS : **Man-made chemicals (more than 14 000 compounds)** widely used **since the 1940s thanks to exceptional properties** *(stability of polarized C-F bonds)*

- **Worldwide** massive **contamination** by PFAS more and more quantified and mediatized
  Ex In Europe (Le Monde, Feb 2023) : more than 17,000 sites > 10 ppt - more than 2,100 clusters > 100 ppt
  No clear picture of the spreading : issue for wastewater and leachate discharge - Sludge disposal - Resources & Drinking water management

- **Priority on DW** driven by sanitary risks and drastic current and evolving regulations
  USA : focused on **6** PFAS
  Europe : linked to sum of **20** & total compounds

Regulation less stringent than EU regulation

Canada	**PFOA :** 200 ng/L **PFOS** : 600 ng/L
WHO	**PFOA :** 100 ng/L **PFOS** : 100 ng/L **Sum of PFAS** : 500 ng/L
EU	**Total PFAS : 500** ng/L **Sum 20 PFAS** : 100 ng/L
Australia	**PFOA :** 560 ng/L **Sum PFOS and PFHxS** : 70 ng/L
Germany	**Sum 20 PFOAS** : 100 ng/L **Sum of PFAS 4** : 20 ng/L
Japan	**Sum PFOA and PFOS** : 50 ng/L
Netherlands	**Sum of 4 PFAS :** 4.4 ng/L
Belgium & Sweden	**Sum of 4 PFAS :** 4 ng/L
USA	**PFOA:** 4 ng/L **PFOS:** 4 ng/L **PFHxS:** 10 ng/l **PFNA:** 10 ng/l **GenX:** 10 ng/l **Danger index** for a sum of PFNA, PFHxS, PFBS, Gen X : 1
Denmark	**Sum of 4 PFAS :** 2 ng/L

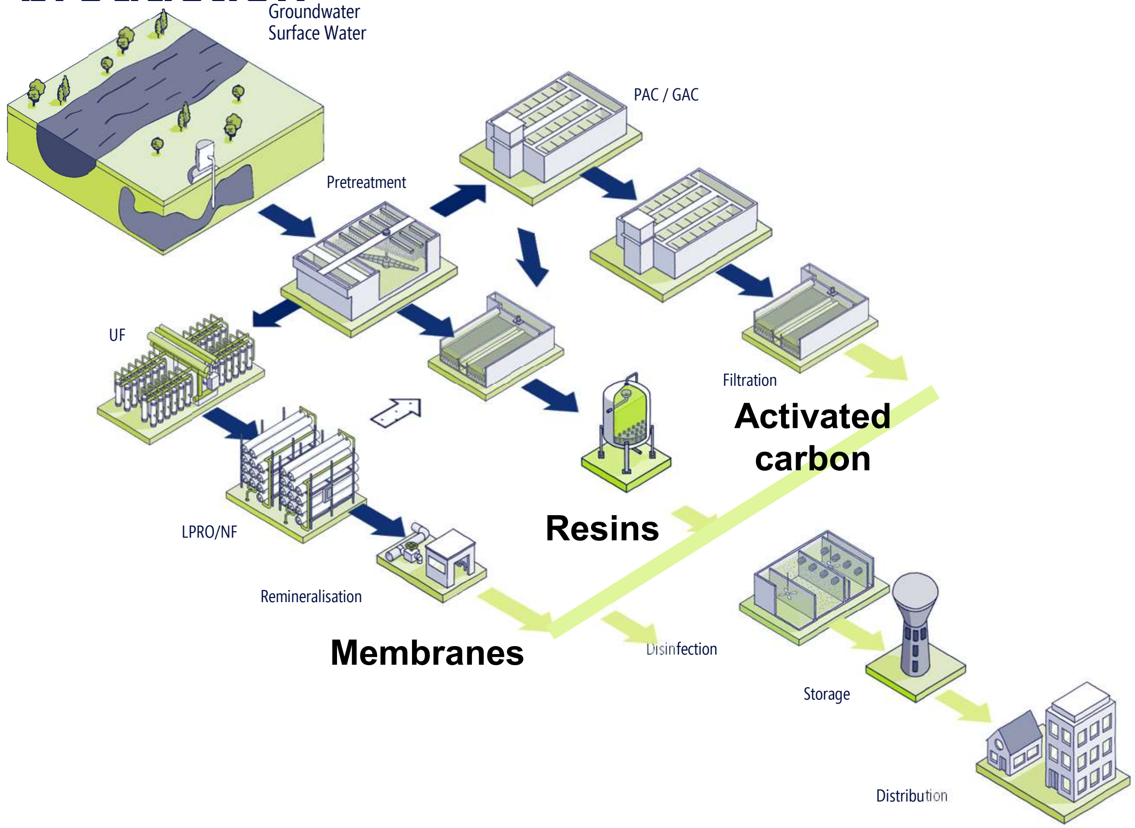
Regulation more stringent than EU regulation

Main concerned 6 PFAS :
PFBS – PFOS – PFOA – PFHxS – PFNA – GenX

PFAS : challenges for water professionals to qualify/quantify contamination & to adapt treatment for risks control

1. Treatment challenge for DW production

- What are the treatment performances for various types of polluted resources ?
- How to combine them?
- How to integrate them in existing assets?
- How to select the best (technical + economical + environmental) solution for each specific case to comply with local regulation ?



What is the best treatment strategy for each specific case ?

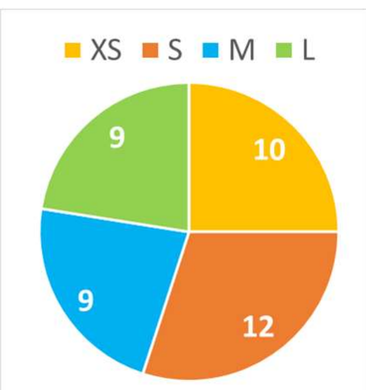
2. Methods

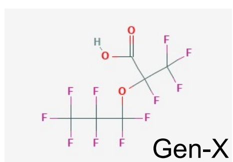
42 **PFAS**
Regulation, occurrence, properties

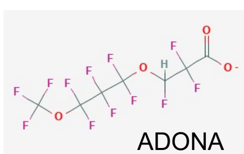
LQ
1 - 5 ng/L

Excepted 20 ng/L for PFPrA

UHPLC MS MS (WATERS)







5 **Activated Carbon**
2 GAC
3 PAC

4 **Membranes**
2 LPRO
2 NF

3 **IEX resins**

2 **2 water matrices**
Clarified surface water (DOC ≈ 2 mg/L)
Groundwater (DOC ≈ 1 mg/L)

Step 1: Lab Scale (9 months)
Treatment efficiency in controlled conditions

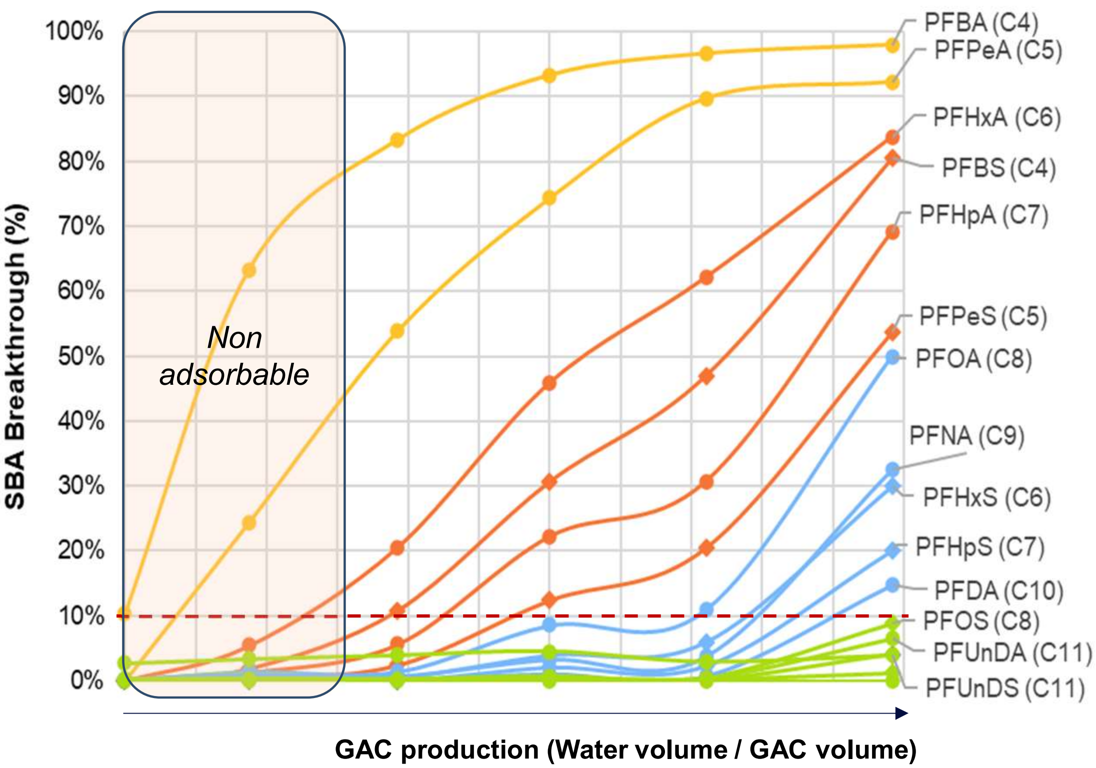
Step 2: Mini pilot & Pilot scale (6 months)
Transpose laboratory results to industrial scale

≈ 200 samples ≈ 20 000 analysis

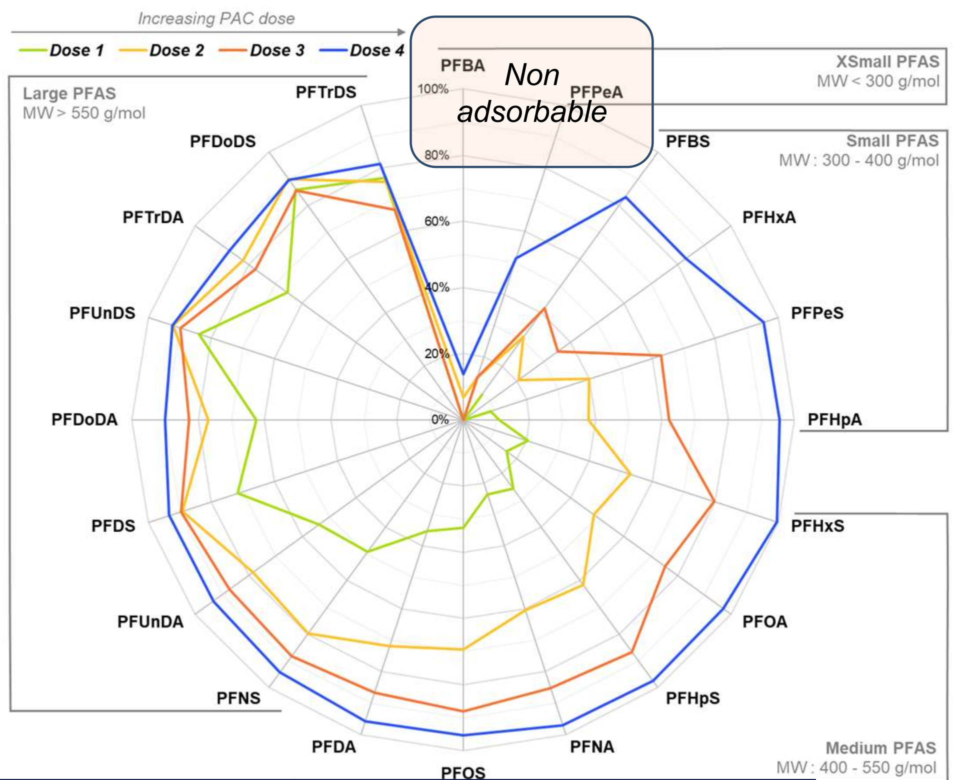
3. Relevant results on GAC & PAC for PFAS (20-DW)

Ex. for groundwater - DOC=1 mg/L

Ex. PFAS **GAC** breakthrough @ 10% - CT = 15’



Ex. PFAS removal @ different **PAC** doses - CT = 30’

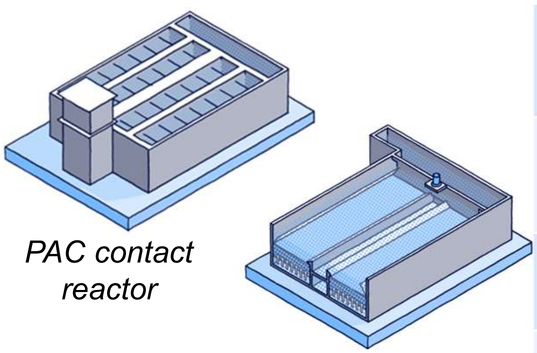


XS-S PFAS : very low adsorbable compounds needing high, not realistic, GAC renewal or PAC doses

3. Relevant results on GAC & PAC for PFAS (20-DW)

- **Adsorption efficiency**
  - ↗ With the PFAS MW
  - ↗ Depending on functional group of PFAS: sulfonic acid (-S) > carboxylic acid (-A) - Neutral > anionic > cationic
  - ↘ With the OM in the water matrix
  - = No impact of pH
  - ↗ With the GAC-PAC type *(agglomerated media, high surface specific, high Iodin index)*
  - ↗ With increased contact time
- **Operational recommendations**

Ex : Groundwater
DOC = 1 mg/L



PAC contact reactor

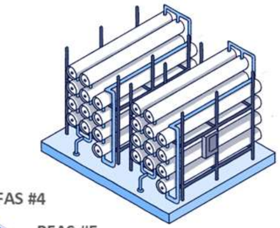
GAC filter

PFAS size	PFAS (20-DW)	20 other PFAS	% removal for PAC @ 50 ppm - CT = 30’	GAC breakthrough @ 10 % - CT = 12’
XSmall PFAS (MW < 300 g/mol)	PFBA, PFPeA	PFPrA, TFMS, PFEtS, PFMPA, PFMBA, 3:3 FTCA, FBSA	15 - 70 %	< 3 500 VV
Small PFAS (MW : 300-400)	PFHxA, PFHpA **PFBS**, PFPeS	**GenX,** ADONA, 5:3 FTCA, 4:2 FTS, 6:2 FTS FBSE, N-Me-FBSE	60 - 95 %	< 10 000 VV
Medium PFAS (MW : 400-550)	**PFOA , PFNA** → PFDA **PFHxS → PFOS**	FOSA, N-Me-FOSE, 9Cl-PF3ONS	80 - 99 %	< 20 000 VV
Large PFAS (MW > 550 g/mol)	PFUnDA → PFTrDA PFNS → PFTrDS	PFTeDA PFHxDS	90 - 99 %	> 20 000 VV

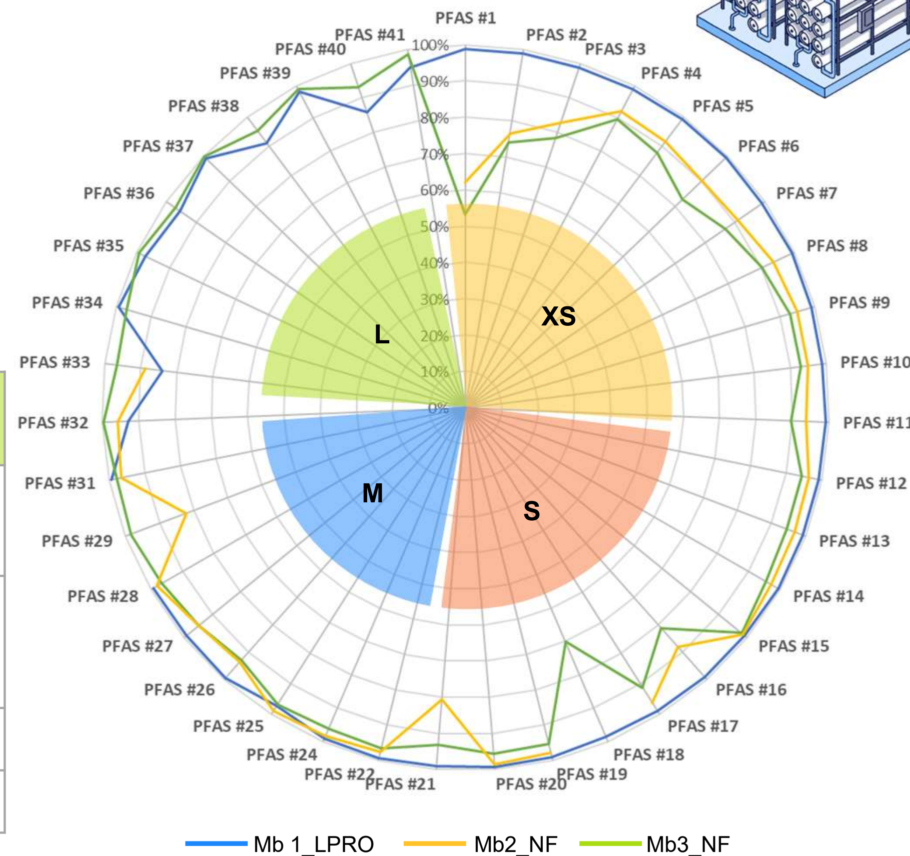
- **AC can be a solution to treat PFAS pollution depending on the type of PFAS, concentration & matrix**
- **Challenge for S and XS PFAS : Non / low adsorbable compounds**

3. Relevant results on membranes

Trials simulating a **3-stages** plant operating at **85% recovery**



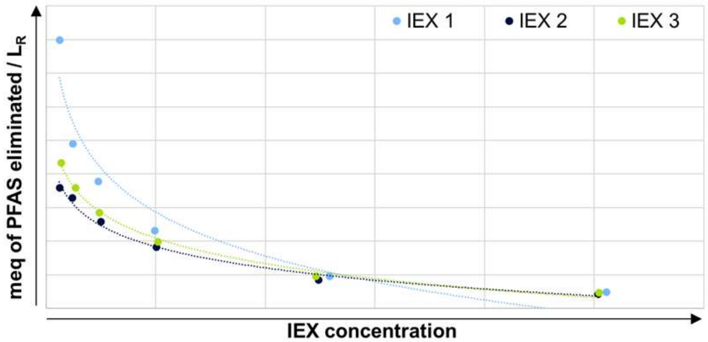
	Very small PFAS (MW<300g/mol)	**Small PFAS** (300-400 g/mol)	**Medium PFAS** (400-550 g/mol)	**Large PFAS** (MW > 550 g/mol)
Ex from EU DW reg	PFBA, PFPeA	PFHxA, PFHpA **PFBS**, PFPeS	**PFOA** **PFNA** → PFDA **PFHxS** → **PFOS**	PFUnDA → PFTrDA PFNS → PFTrDS
Other	PFPrA, TFMS, PFEtS, PFMPA, PFMBA, 3:3 FTCA, FBSA	**GenX,** ADONA, 5:3 FTCA, 4:2 FTS, 6:2 FTS FBSE, N-Me-FBSE	FOSA, N-Me-FOSE, 9Cl-PF3ONS	PFTeDA PFHxDS
NF	**50 – 80%**	**80 – 90%**	**> 90%**	**> 90%**
LPRO	**> 90%**	**> 90%**	**> 90%**	**> 90%**

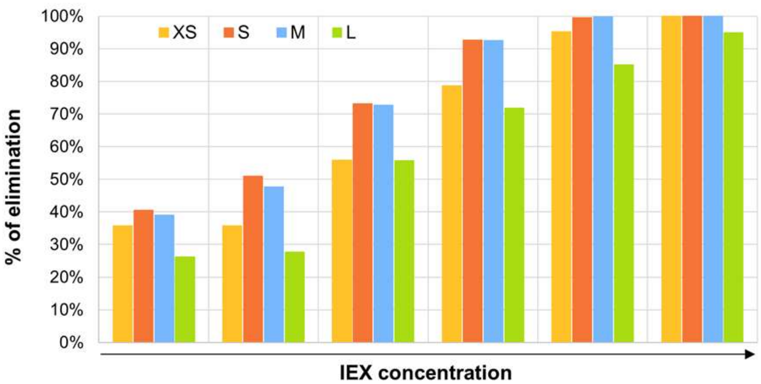


- XS & S compounds: LPRO very efficient (>90%) / nanofiltration partial rejection (50 – 90%)
- Medium & Large PFAS: LPRO and NF efficient (> 90%)

3 – Relevant results on Ion Exchange resins (IEX)

IEX batch test – groundwater (DOC = 1 mg/L)





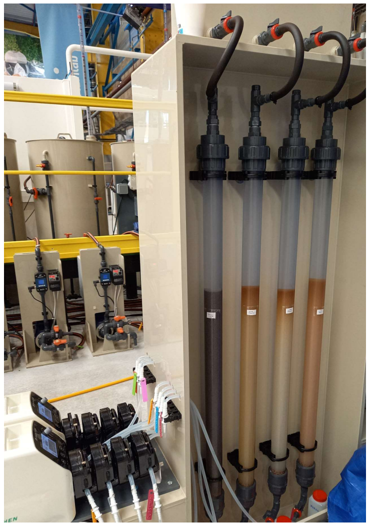
Resins efficiency

→ No significant difference between the 3 tested resins

→ No significant difference between XS & S compounds : advantage on Activated Carbon treatment

→ No impact of NOM level *(for DOC < 2 mg/L)*

→ Pilot test & economic and technical comparison to Activated Carbon on-going



❑ **Resin can be a technical solution to treat PFAs pollution - Adapted to treat S and XS compounds**
❑ **Costs & environmental approach to be managed**

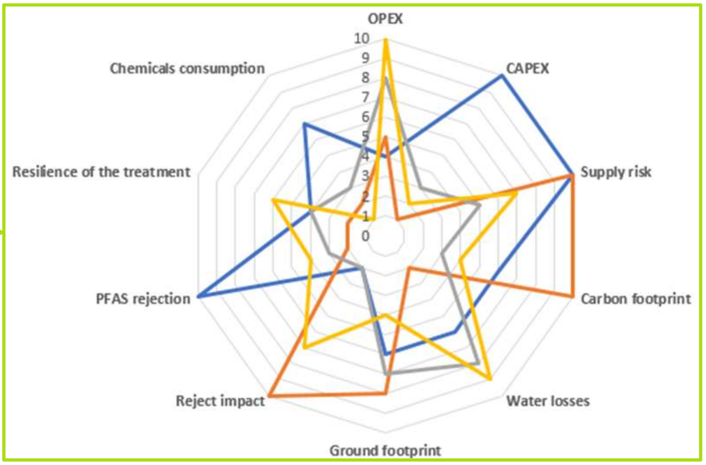
4. Multicriteria comparison of technologies

Type of water
- Organic matter
- PFAS pollution: mix and quantification
- Other pollution: pesticides, metabolites…

Process lines combining treatments
- Adsorption
- Membranes solutions
- IEX

Site specific constraints

COSTS
OPEX
CAPEX
Supply risk
ENVIRONMENT
Carbon footprint
Water losses
Ground footprint
Discharge management
Operational performances
PFAS rejection
Resilience of the treatment
Chemicals consumption



CASE STUDY HYPOTHESES → **SUEZ DATABASE** → **BEST TREATMENT SOLUTION**

4. Case study

Context

- ❑ French groundwater treatment plant (11 000 m^3/d)
- ❑ Existing treatment = **GAC**

- ❑ **Industrial pollution 6:2 FTSA**

9 PFAS detected including 6:2 FTSA **degraded in by-products**

- **PFHxA (C6)**
- **PFBA (C4)**
- **PFPeA (C5)**

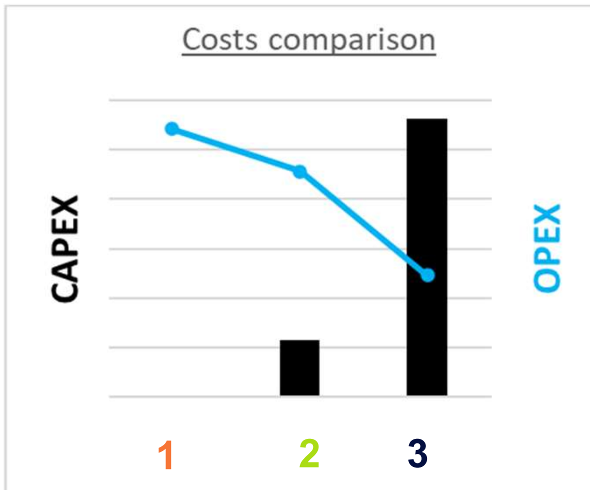
Inlet	→	Target
∑20 PFAS		∑20 PFAS
0,14 - 0,31 µg/l		**0,1 µg/l**

- ❑ DWTP **refurbishment** project

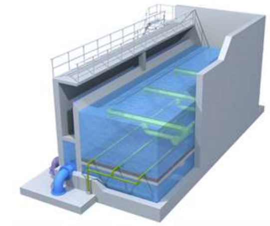
Results

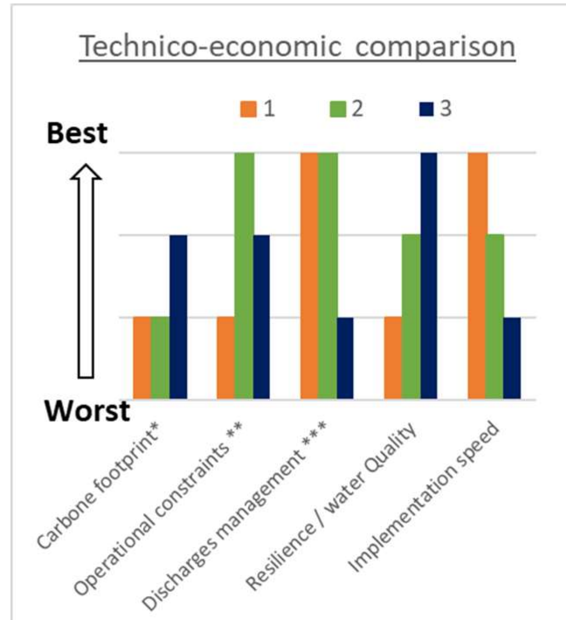
- ❑ 3 proposed treatment lines:

1. **Increase GAC regeneration**
2. **GAC with continuous replacement**
3. **Mix GAC / LPRO**



Carbazur-Up ®





** GAC regenerated, energy for mb only, excl CIP and antiscalant*
*** GAC charge regeneration, chemical, membrane washing*
**** quantity, pollutant loads, diversity of discharges*

Option 2 is the most adapted to the local constraints (discharges, manpower). It allows to optimize existing assets.

5. Conclusion and perspectives

Priority 1 → drinking water production

1. Refurbishment / strengthening to optimize existing assets

2. New DWTP design

→ **Need of precise knowledge about efficiency of each process**

- Large panel of PFAS
- Analytical complexity
- Complex lab and pilot trials
- Numerous impacting factors

→ **Considering each site-specific context**

Priority 2 → Destruction

But, when removed from the water cycle, …
don't put back into the resource !

- ❑ Destruction treatments needed
- ❑ Many key players in the US, China...
- ❑ Existing solutions must be studied in terms of efficiency but also economic and environmental performance
- ❑ And demonstrations are required !

THANK YOU FOR YOUR ATTENTION