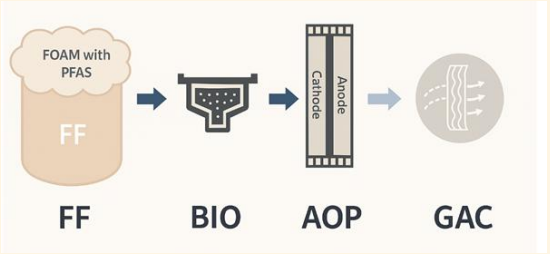
COMPARISON BETWEEN CONVENTIONAL ACTIVATED SLUDGE AND MEMBRANE BIOREACTOR FOR THE REMOVAL OF COD FROM PFAS POLLUTED WASTEWATER

E. Brivio Sforza, M. Mantovani, V. Tatangelo, A. Franzetti, **V. Mezzanotte**

Università di Milano Bicocca, Italy

Foreword

The LIFE CAPTURE project aims at developing a treatment train to remove PFAS from the foam resulting from the foam fractionation of contaminated soils (to extract ~ 90% of PFAS) including biological treatment, advanced oxidation and adsorption on activated carbon



but also....

According to the new EU Directive (UWWTD, 2024)

LAB scale

WWTP receiving wastewater from 150,000 PE or more will have to adopt quaternary treatments to remove at least 80% of at least 6 pollutants, among the ones listed in Category 1 and in Category 2

AND

The performance of quaternary treatments is strictly dependent on the performance of the secondary, biological treatment which removes most of the possible substances limiting the efficiency of the following processes and partially contributes to the removal of micropollutants

Category 1 (substances which can be very easily removed):

i) amisulpride (CAS n. 71675-85-9);
ii) carbamazepine (CAS n. 298-46-4);
iii) citalopram (CAS n. 59729-33-8);
iv) clarithromycin (CAS n. 81103-11-9);
v) diclofenac (CAS n.15307-86-5);
vi) hydrochlorothiazide (CAS n. 58-93-5);
vii) metoprolol (CAS n.37350-58-6);
viii) venlafaxine (CAS n.93413-69-5).

LAB scale

CAPTURE

Category 2 (substances which can be easily removed):

LAB scale

i) benzotriazole (CAS n.95-14-7);

ii) candesartan (CAS n.139481-59-7);

iii) irbesartan (CAS n.138402-11-6);

iv) Mixtures of 4-methyl benzotriazole (CAS n.29878-31-7) and 5-methylbenzotriazole (CAS n.136-85-6).

2024 UWWTD does not set limits for PFAS, but says that:

- ...In most instances, poor understanding and poor knowledge of such pollution, which can lead to a **deterioration in the functioning of the treatment process** and contribute to the pollution of the receiving waters, while also preventing the recovery of sludge and the reuse of treated wastewater. Member States should therefore regularly monitor and report on such non-domestic pollution that enters urban wastewater treatment plants and is discharged into water bodies ….
- …Recent data shows that PFAS are found in urban wastewater, sometimes at high concentrations. ….. It is therefore essential to better understand the pathways of PFAS into the environment and to monitor them in the inlet and outlet of the urban wastewater treatment plants. This monitoring should start in the first instance where the discharges reach catchment areas used for the abstraction of drinking water…
- …The Commission shall adopt implementing acts in order to establish a methodology for measuring 'PFAS Total' and 'Sum of PFAS' in urban wastewater by 2 January 2027….
- …By 31 December 2033 and by 31 December 2040, the Commission shall carry out an evaluation containing, among others, an analysis of the feasibility and appropriateness of the development of an extended producer responsibility system for products generating PFAS and microplastics in urban wastewater based in particular on the monitoring data in the inlets and outlets of the urban wastewater treatment plants;

CAPTURE

Scope and protocol of the research

Assessing the performance of biological treatment in the presence of PFAS

- Initial lab-scale experiments aimed to optimize biological treatment conditions for PFAS-contaminated wastewater, prior to pilot-scale application.
- PFAS may inhibit bacterial activity, affecting key biological processes.
- A commercial AFFF (Aqueous Film Forming Foam) was added to a real wastewater to simulate PFAS contamination, as AFFF is a common PFAS source in fire-fighting wastewater and in contaminated soils.

PFAS in the AFFF used to spike PFAS in wastewater

Compound	Concentration (mg/kg)
4:2 - Fluorotelomer sulfonate (4:2-FTS)	0.013
6:2 - Fluorotelomer sulfonate(6:2-FTS)	8.274
Perfluorobuthanoic acid (PFBA)	0.046
Perfluoropenthanoic acid (PFPeA)	0.011
Perfluorohexanoic acid (PFHxA)	0.132

CAPTURE

PRELIMINARY ASSESSMENT OF THE POTENTIAL TOXICITY OF AFFF PFAS ON ACTIVATED SLUDGE

- Preliminary testing with a pre-existing adapted lab scale plant to verify the proper functioning of the system and define operational parameters.
- Aqueous film-forming foams (AFFFs) were chosen for spiking urban sewage as they are one of the most important sources of PFAS pollution in soils and waters within Life CAPTURE project

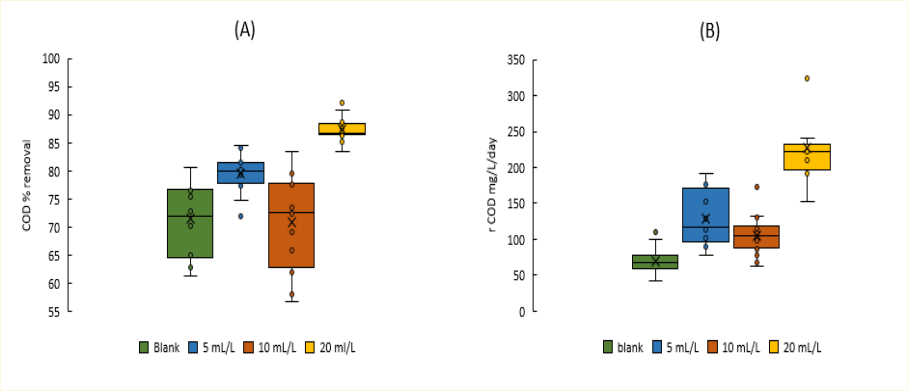
LAB-SCALE TESTING FOR AS/MBR COMPARISON

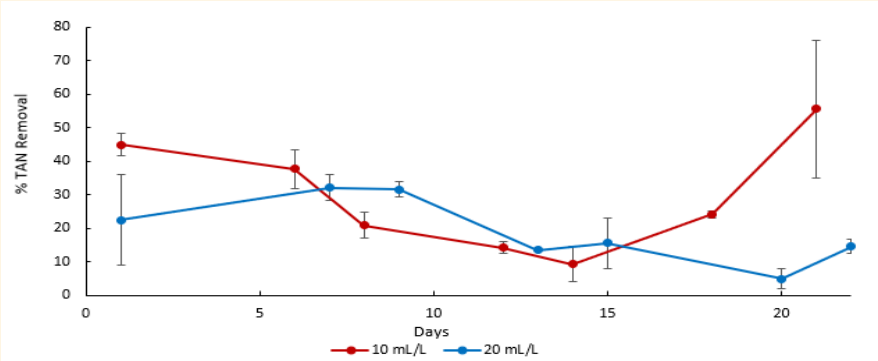
Plants fed on primary clarified municipal wastewater as such (blank) and spiked with increasing doses of PFAS-containing AFFFs. Inlet and outlet effluent sampling to evaluate:

- COD removal and nitrification efficiency
- Composition and variation of the microbial community by metagenomic analysis

Results

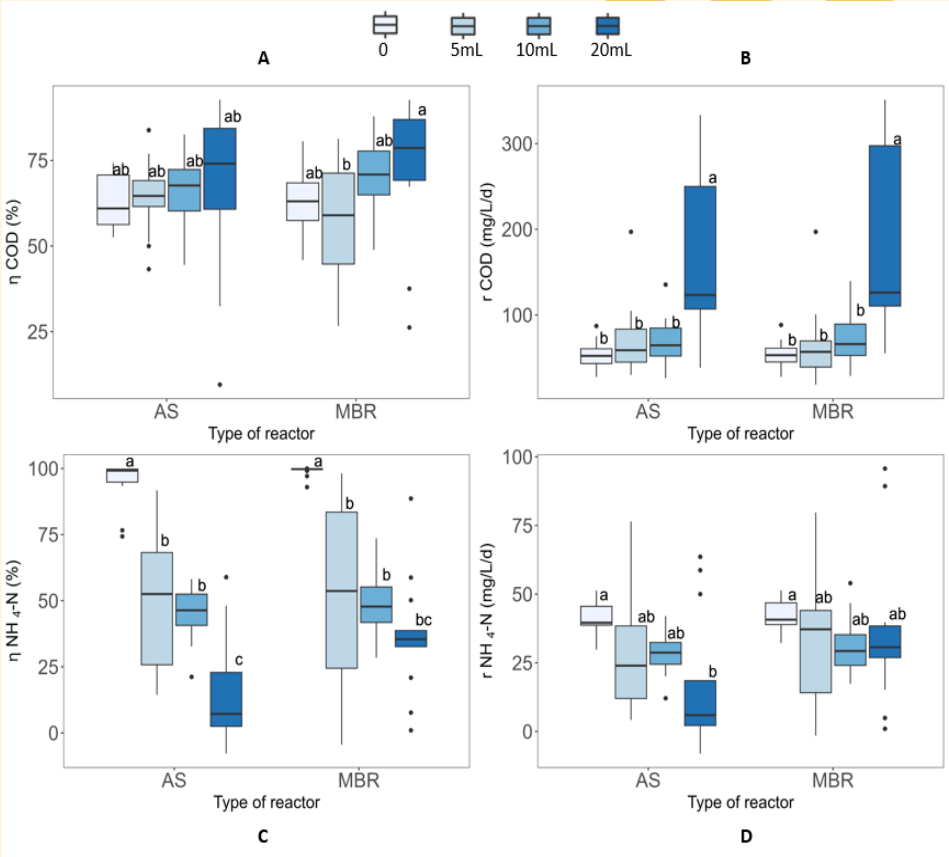
PRELIMINARY ASSESSMENT





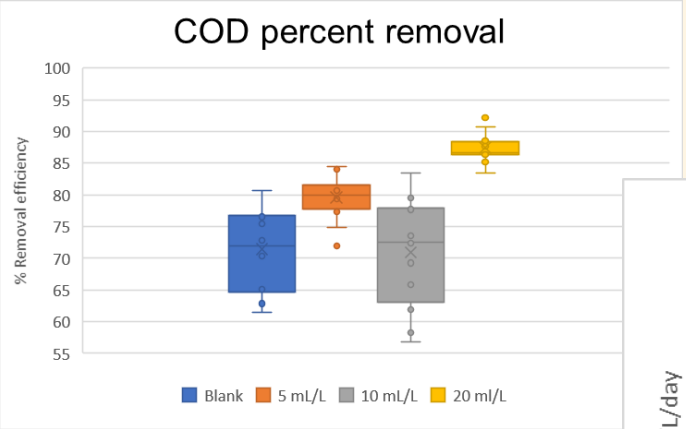
HRT: 18 H

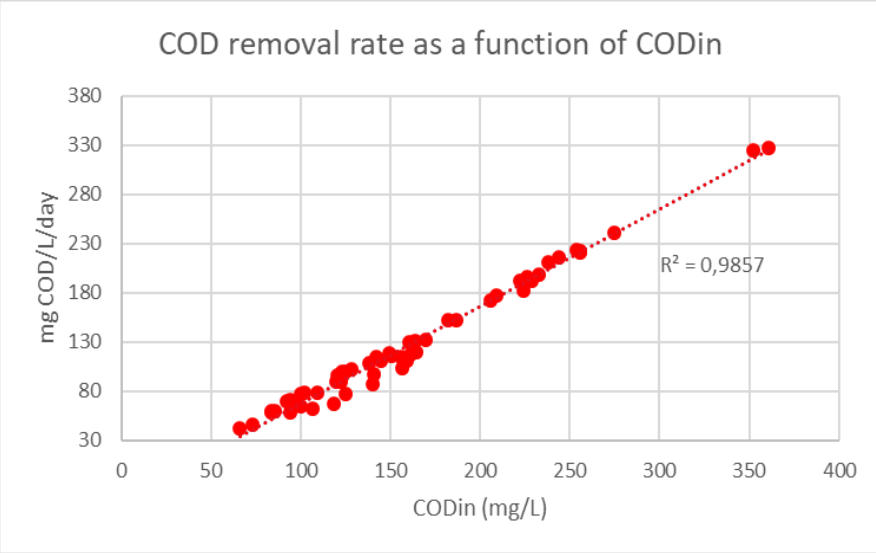
AS/MBR COMPARISON

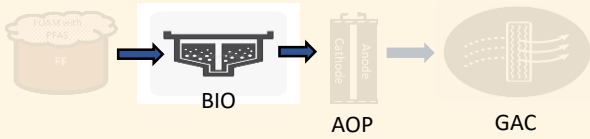


HRT: 8 H

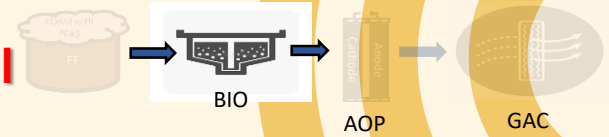
RESULTS

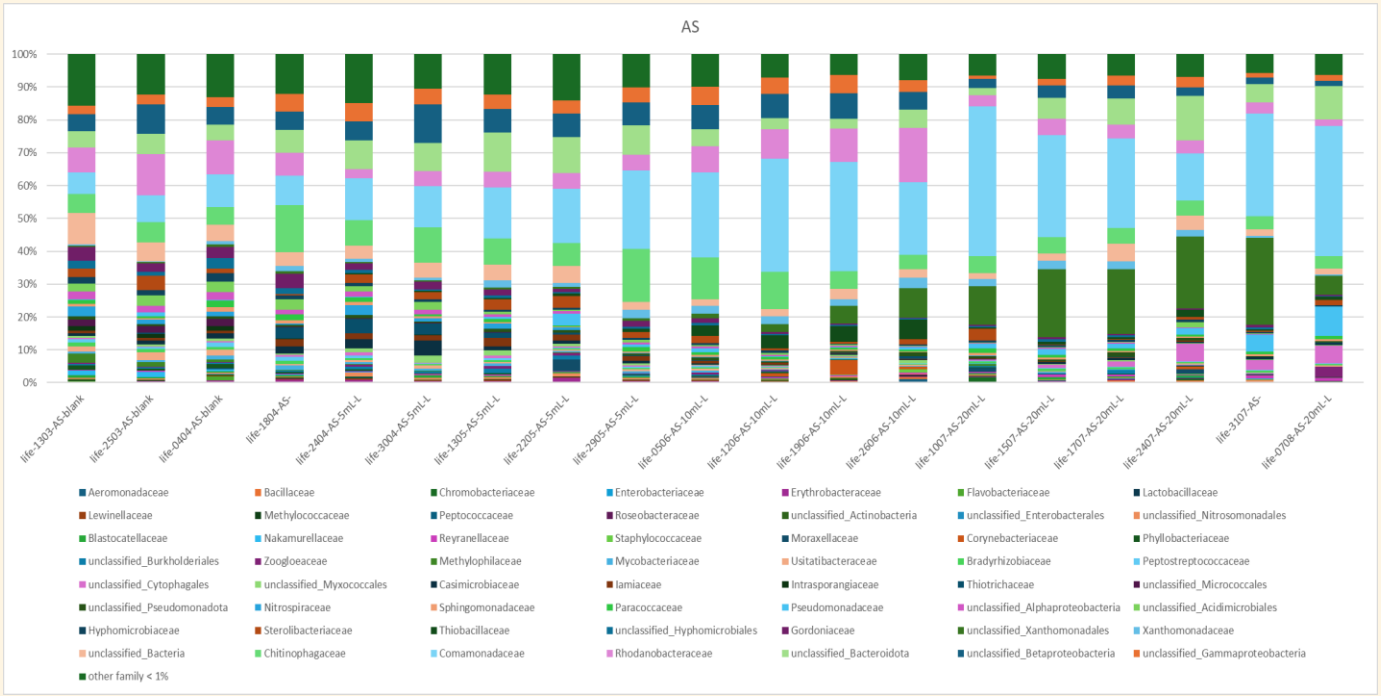

COD percent removal
% Removal efficiency
100
95
90
85
80
75
70
65
60
55
Blank
5 mL/L
10 mL/L
20 ml/L


COD removal rate as a function of CODin
mg COD/L/day
380
330
280
230
180
130
80
30
0
50
100
150
200
250
300
350
400
CODin (mg/L)
R² = 0,9857


BIO
AOP
GAC

Characterization of activated sludge microbial community in the Conventional Activated Sludge System (AS)



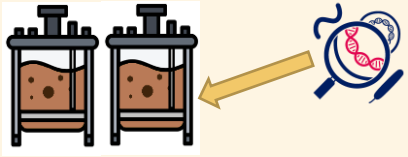


- *Comamonadaceae* and *Xanthomonadales* increased significantly with higher AFFF doses.

- Rhodanobacteraceae and Chitinophagaceae showed a decline in relative abundance

↓

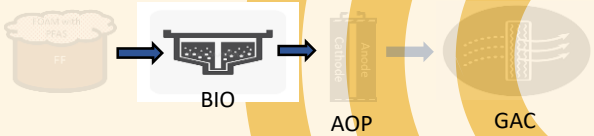
sensitivity to PFAS.

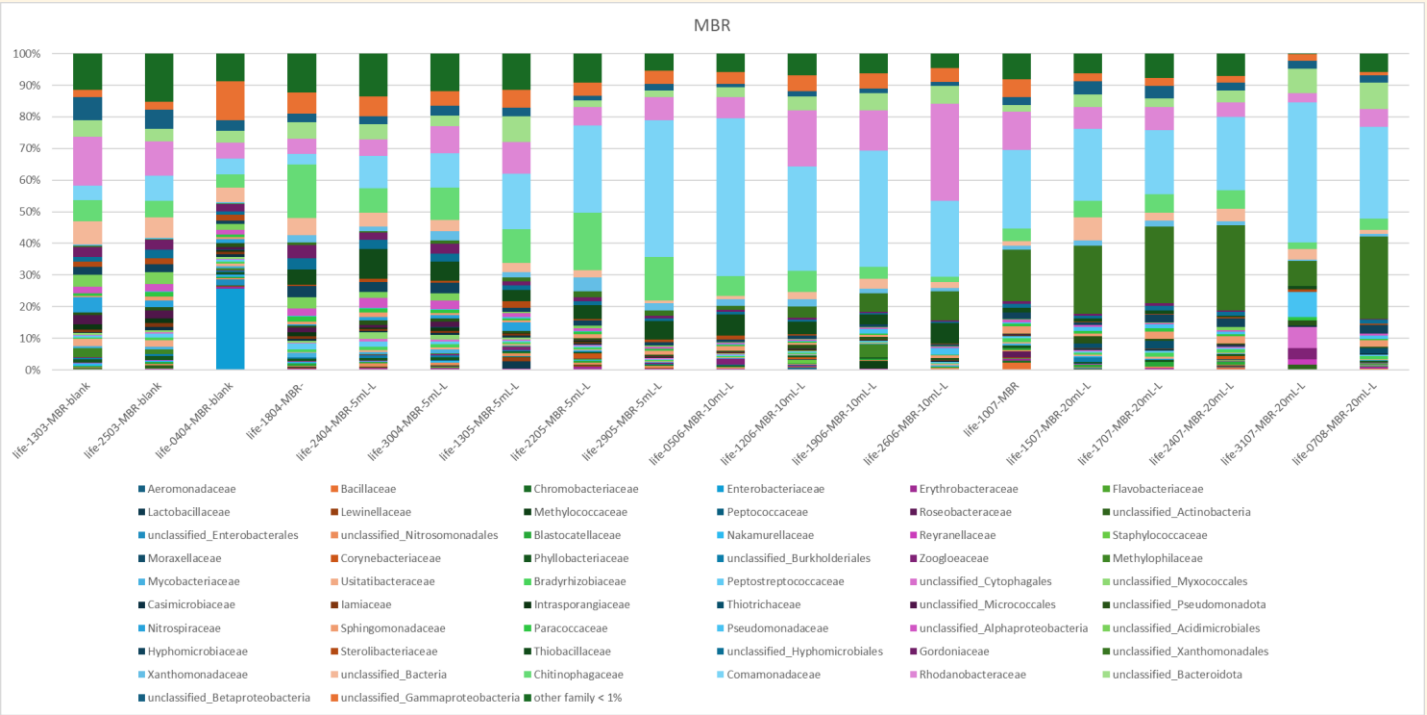


CAPTURE

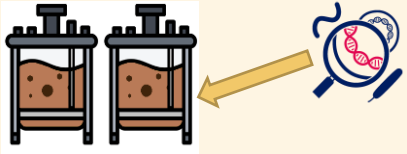
Life

Characterization of activated sludge microbial community of the Membrane Bioreactor (MBR)





- The trend was similar to that observed in the other reactor, with an increase in *Comamonadaceae* and *Xanthomonadales*, along with a rise also in *Gammaproteobacteria* and Pseudomonadaceae.



Final considerations (1)

- No inhibition by AFFF was observed on COD removal in the lab-scale biological processes fed on primary clarified municipal sewage
- The microbial community changed but the bacteria maintained or improved their initial activity level for COD removal
- Nitrification was inhibited at the higher AFFF doses in the AS but not in the MBR system. Expected NH_4-N concentration in foams from SFF are very low and would not affect the performance of any further treatment, but the inhibition of nitrification could be aprblem in wastewater treatment

CAPTURE

Final considerations (2)

- MBR was slightly more efficient for COD and N removal at higher AFFF concentrations. This could lead to address towards MBR technology for liquids with high PFAS concentrations, but MBRs present different management issues correlated with the formation of foam, due to the strong aeration needed to avoid the membrane clogging.
- The absence of negative effects is particularly important both in the perspective of LIFE Project and in view of the application of the recent European UWWTD. Of course, a good performance of biological process is a key issue for a good performance of quaternary treatments.

CAPTURE

THANK YOU FOR YOUR ATTENTION

emilio.briviosforza@unimib.it
valeria.mezzanotte@unimib.it
andrea.franzetti@unimib.it
valeria.tatangelo@unimib.it

www.life-capture-pfas.com | life@abo-group.eu

Life

SLU iFLUX ABO CONSULTANCY POLITECNICO MILANO 1863 GREENSOIL Group Sustainable Soil Remediation VIACQUA SGS UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA