Emerging micropollutant removal from wastewater using membrane technologies

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I+D+i

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Index

1. Introduction
2. Technologies
3. Results Trace organics removal
   - MBR
   - MBBR
   - IFAS-MBR
   - Reverse osmosis
   - Flux-enhancer addition
4. Conclusions

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Introduction TrOCs removal

- Legislation still pending→ Which removal do we want to achieve?
- LCA studies reveal that a higher removal does not mean lower environmental impact: ecotoxicity is diminished but higher energy consumption
- We should provide an adequate removal depending on receiving water
- Range of technologies available with different removal rates:
  - High removal:
    - AC → regeneration cost, negative LCA
    - Reverse osmosis, AOP → high energy costs
  - Low removal:
    - Simple technologies can be adequate in some cases
    - Any improvement in the WWTP will be benefitial for the AWTP (advanced water treatment plant)

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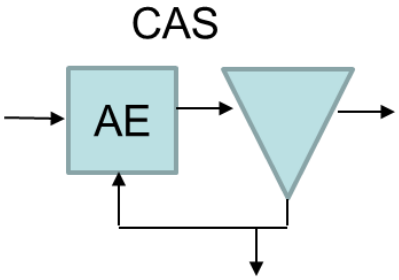
Introduction: Technologies

Broad spectrum of technologies with different removal rates:

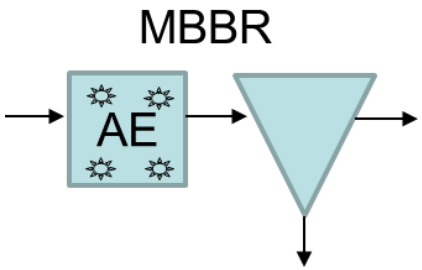
- MBR
- MBMBR
- IFAS-MBR
- AS with cationic polymer addition
- Reverse osmosis

Introduction: Biofilm-MBR

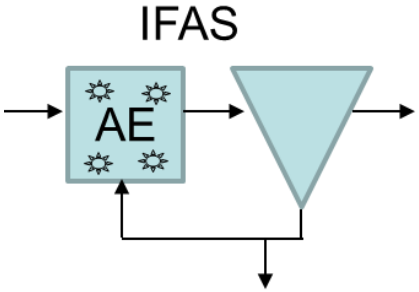
- Activated sludge systems



- MBBR =Moving bed bioreactor



- IFAS =Integrated Fixed-film activated sludge



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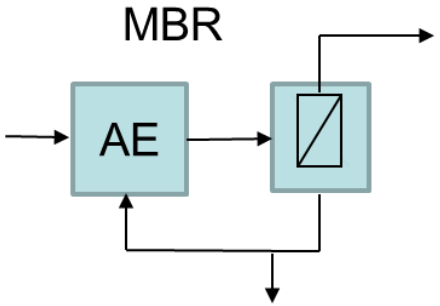
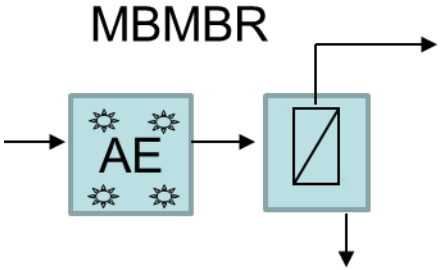
Introduction: Biofilm-MBR

- MBR= Membrane bioreactor

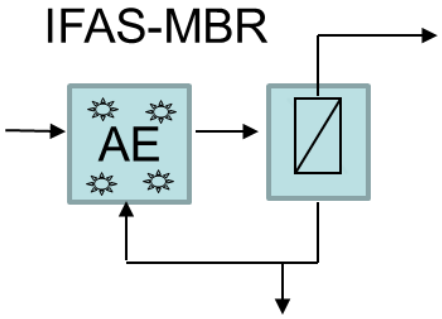


- MBMBR =Moving bed membrane bioreactor

Carriers



- IFAS-MBR =Integrated Fixed-film membrane bioreactor



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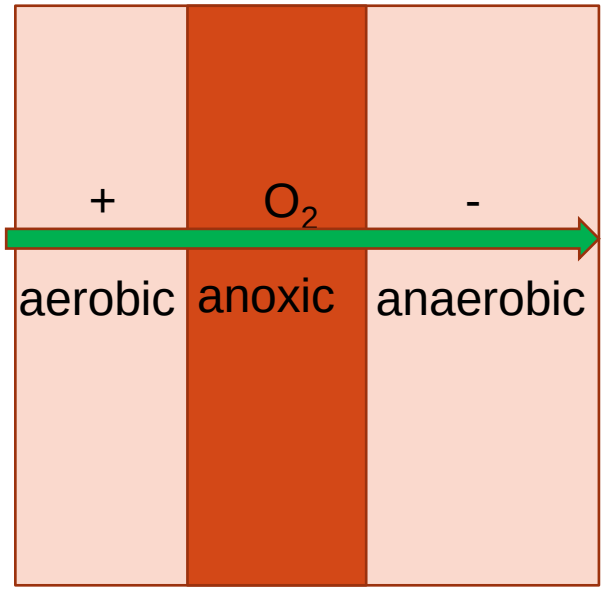
Introduction: Biofilm-MBR

- Different conditions
- Different biology
- High sludge residence time (SRT)

→Improved trace organics removal?



Biofilm

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Pilot plant

MBR/RO reclamation pilot plant in Almuñécar (South of Spain)

- Urban wastewater (WWTP Almuñécar)
- High and stable temperature
- 29 months of operation
- Composite samples, 3/week

MBR

5 m^3/h treated

RO

800 L/h treated

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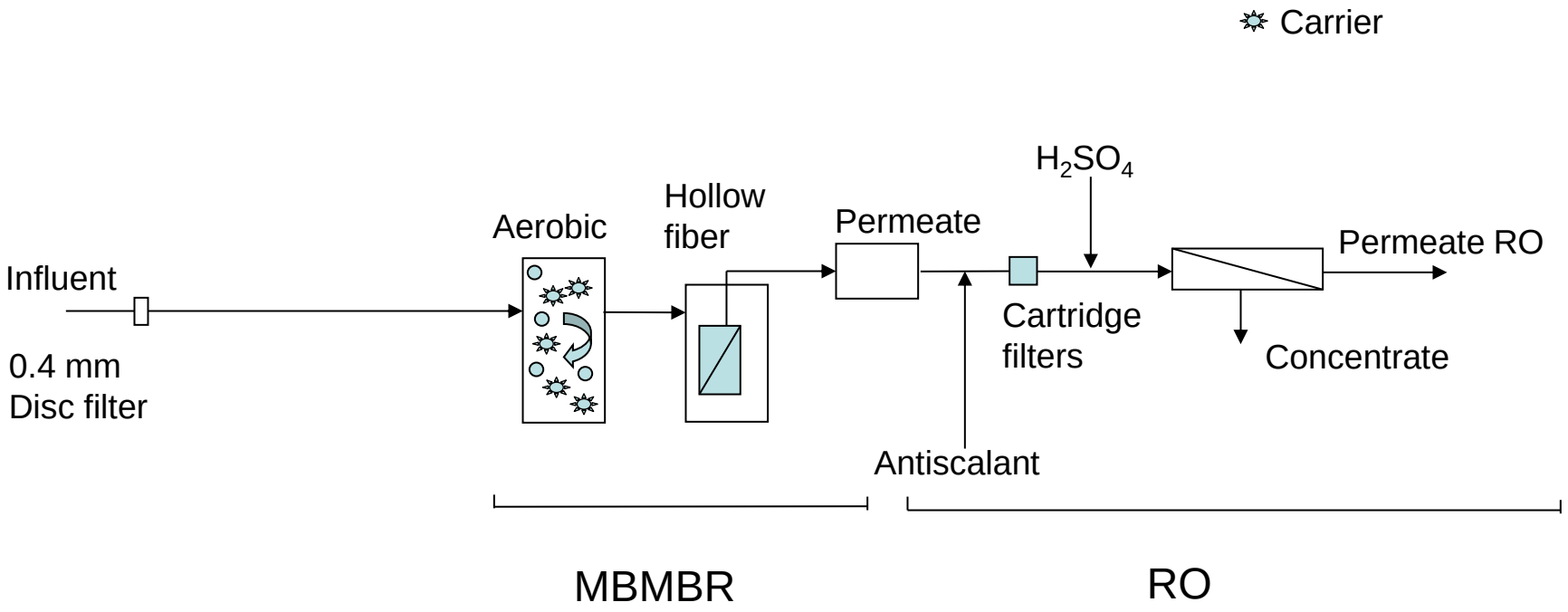
Pilot plant - MBMBR/RO



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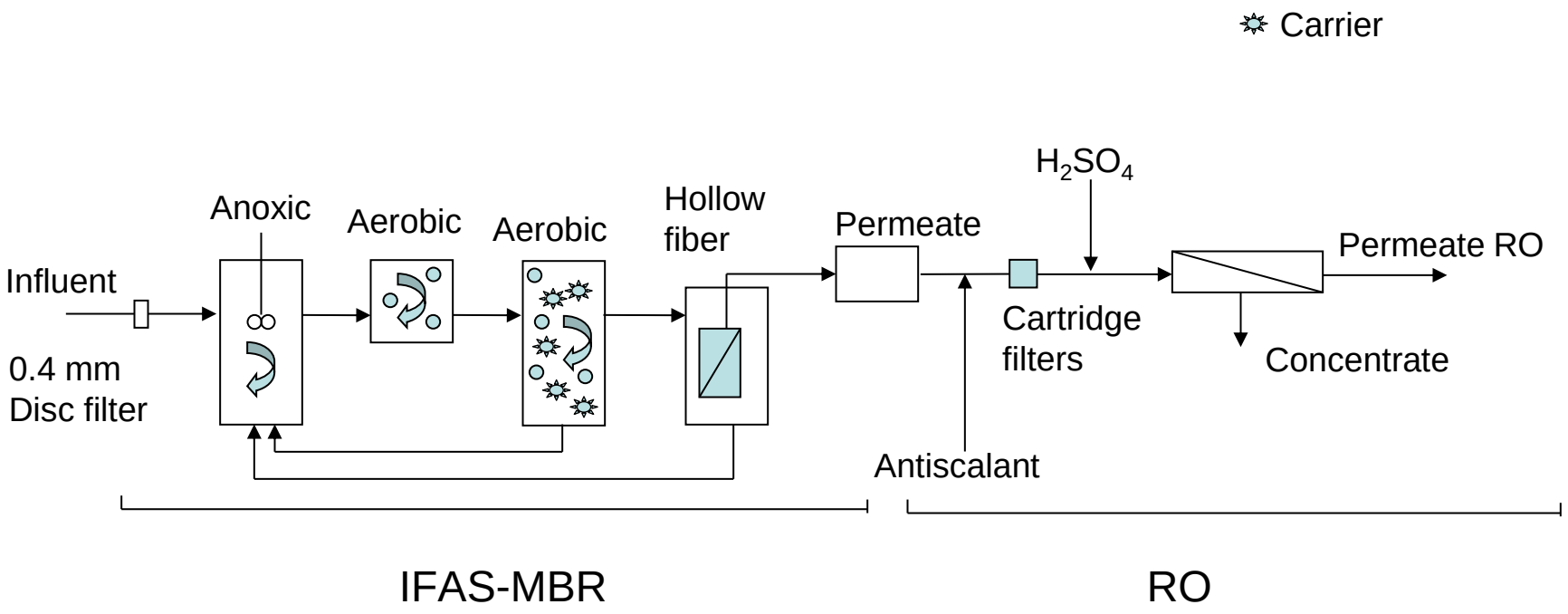
Pilot plant- IFAS-MBR/RO



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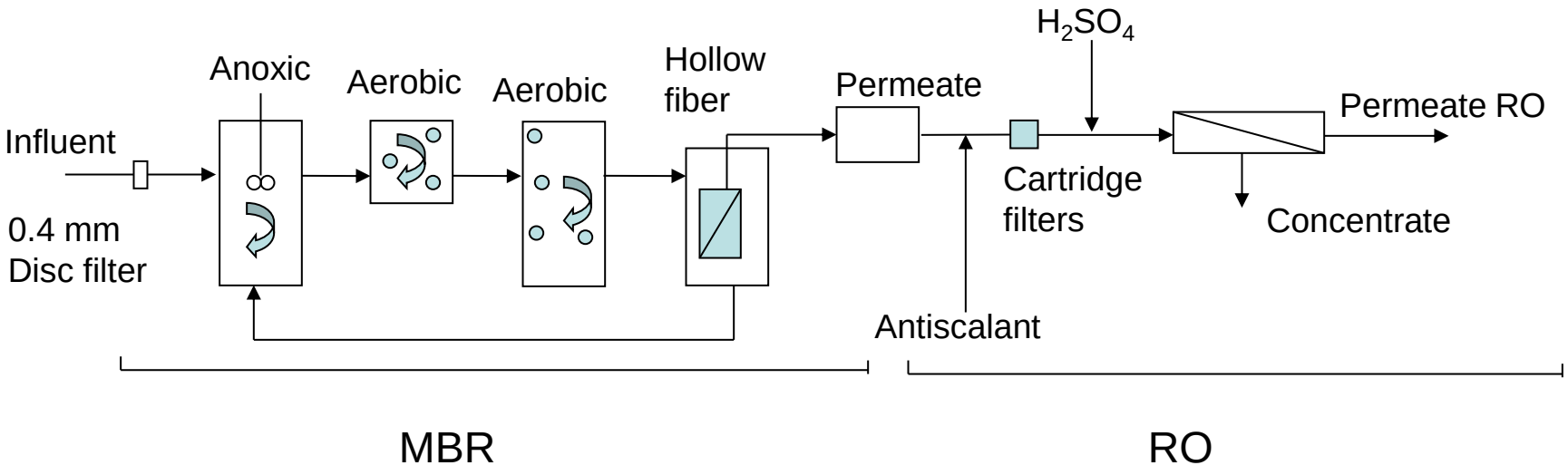
Pilot plant - MBR/RO



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Pilot plant – Operational data

	SRT	MLSS aerobic tank	MLSS membrane tank	HRT	T	Total COD	COD filtered
	d	g/L	g/L	h	ºC	mg/L	mg/L
IFAS-MBR 10	10	2.5	7.3	13	18-27	3138	168
IFAS-MBR 20	20	5.3	8.0	13	16-20	1022	56
MBMBR	-	0.3	9.7	6	13-23	1147	66
MBR	20	7.4	10.6	13	12-30	1233	176

MBR	Supplier	Pore size
Type		µm
Hollow fiber (HF)	Koch Membranes	0.05

RO	
Membrane	Material
TRISEP 4040-X201-TSA	Aromatic Polyamide-urea

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Trace organics

Method: HPLC with MS

Studied Pharmaceutical Active Compounds (PhACs)

Antibiotics	**Sulfamethoxazole** **Trimethoprim**	**Lipid regulators**	**Clofibric acid** **Gemfibrozil**
 **Anti-inflamatory drugs**	**Acetaminophen** **Diclofenac** **Ibuprofen** **Naproxen** **Salycilic acid** **Ketoprofen** 	**β-blockers**	**Propanolol**
		Anticonvulsant	**Carbamazepine**
		Stimulant	**Caffeine** 
		Estrogens	**17α-ethinylestradiol** **17b-estradiol** **Estriol** **Estrone**

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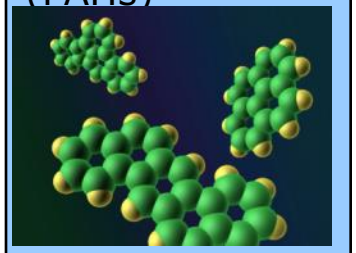
Trace organics

Studied PAHs, DEHP, LAS y Nonylphenols

Method PAHs: HPLC with simultaneous UV detection and fluorescence
Method DEHP, LAS and NPs: HPLC and MS

Polycyclic aromatic hydrocarbons (PAHs) 	Naphthalene Phenanthrene Fluoranthene Pyrene Anthracene Benz[a]anthracene Chrysene Benz[b]fluoranthene Benzo[k]fluoranthene Benz[a]pyrene Dibenz[ah]anthracene Benz [ghi]perylene	Di-(2-ethylhexyl) phalate	DEHP
		Linear alkylbenzene sulfonates (LAS)	C10, C11, C12, C13
		Nonylphenols 	Nonylphenol (NP) Nonylphenols mono and diethoxylate (NP1EO and NP2EO)

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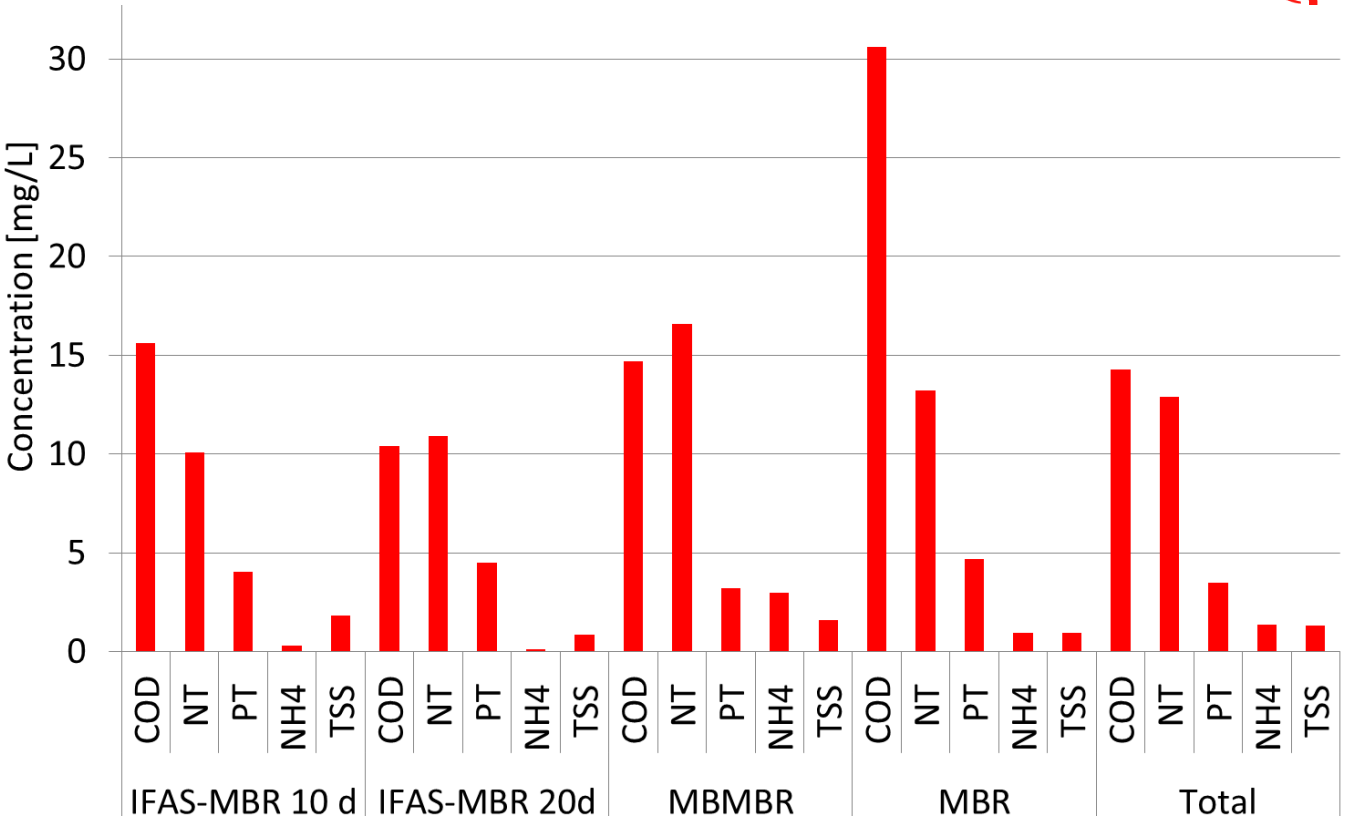
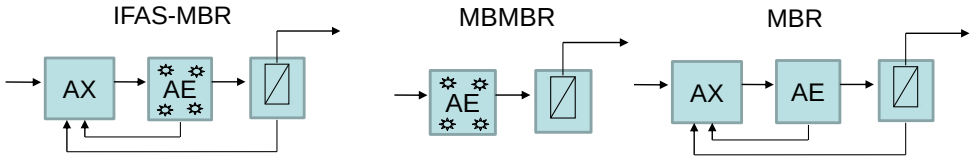
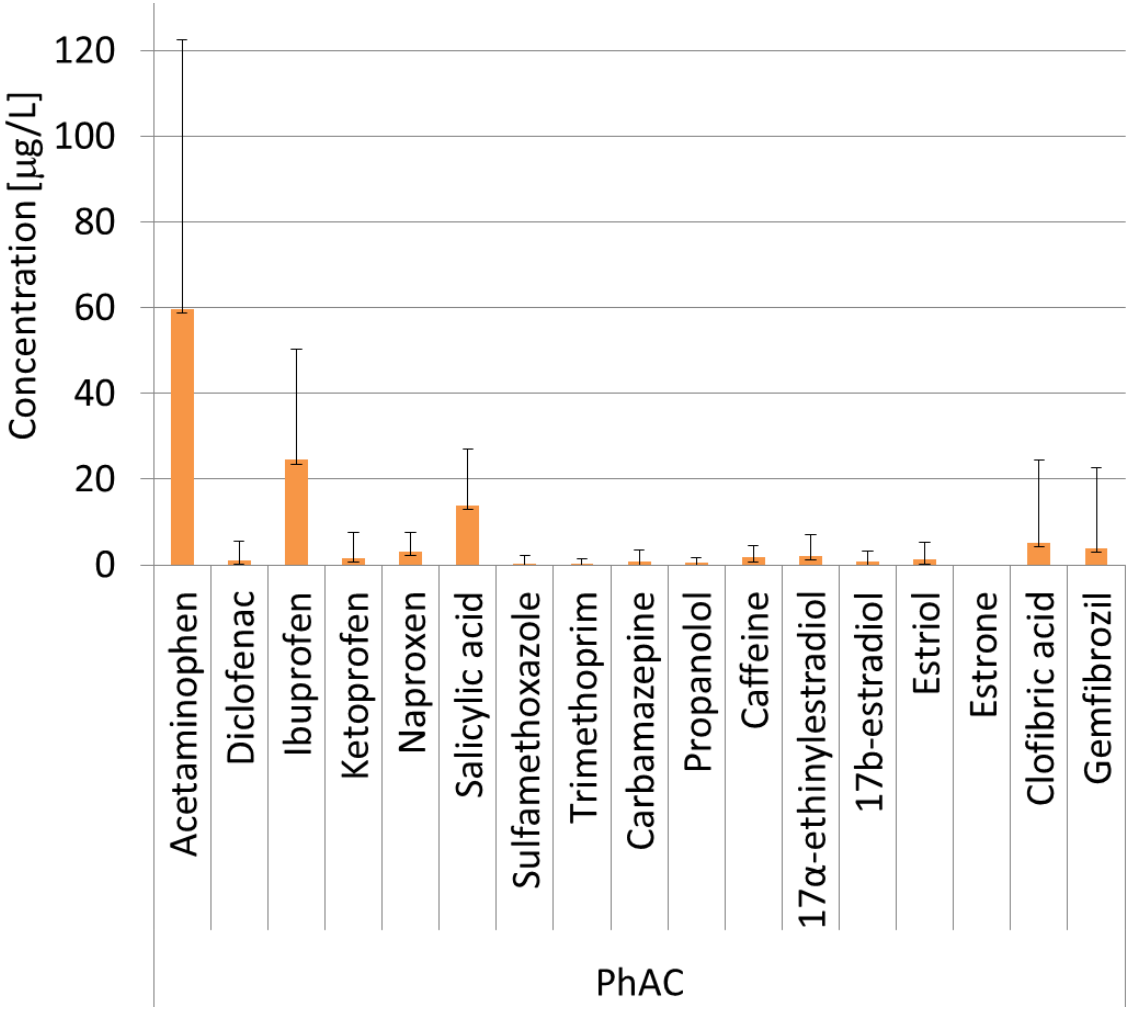
Results – Effluent quality





- High water quality for reuse
- IFAS-MBR assures high nitrification

Influent concentrations: PhACs



- High concentrations of antiinflamatory drugs
- All studied compounds detected except estrone

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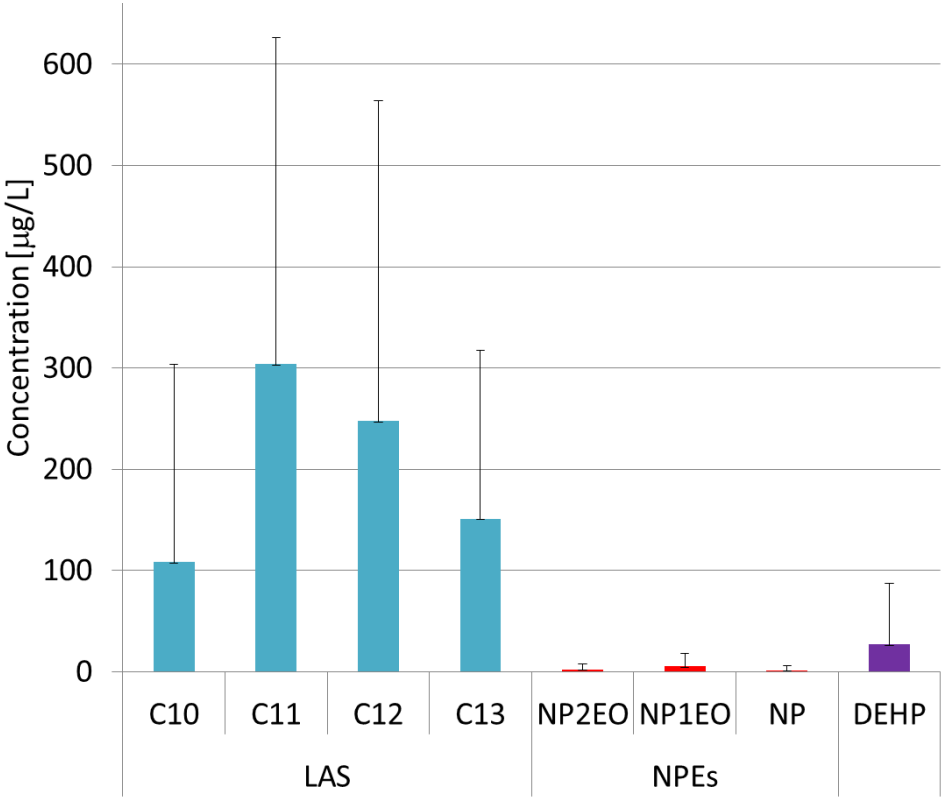
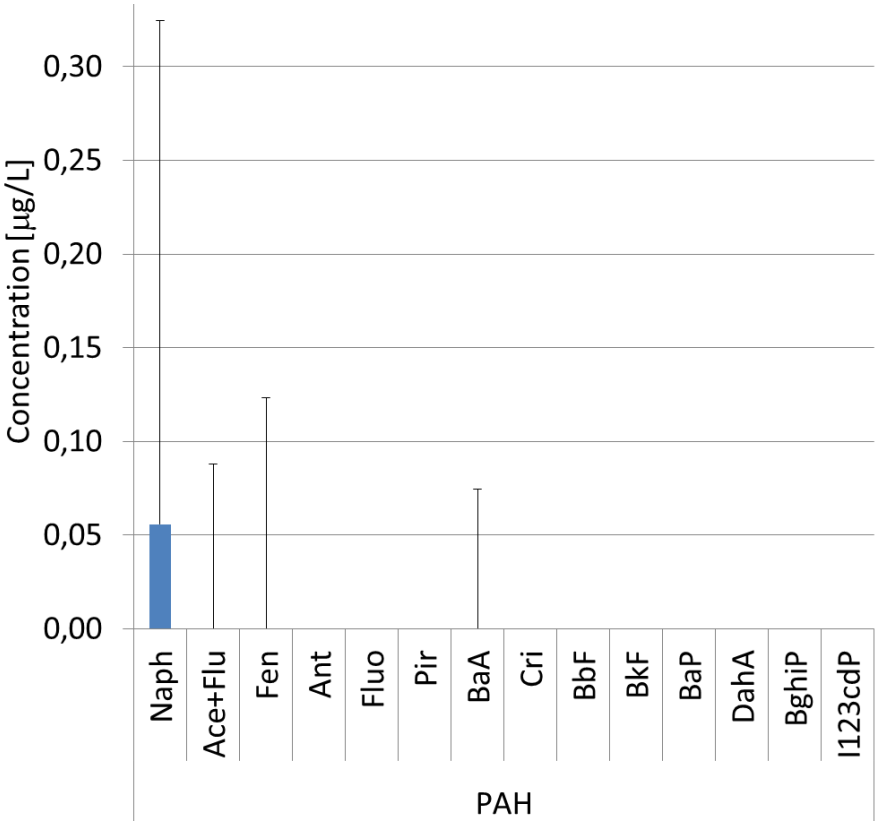
Influent concentrations: LAS, NP, DEHP and PAH





- LAS and DEHP: High influent concentration
- PAH mainly not detected

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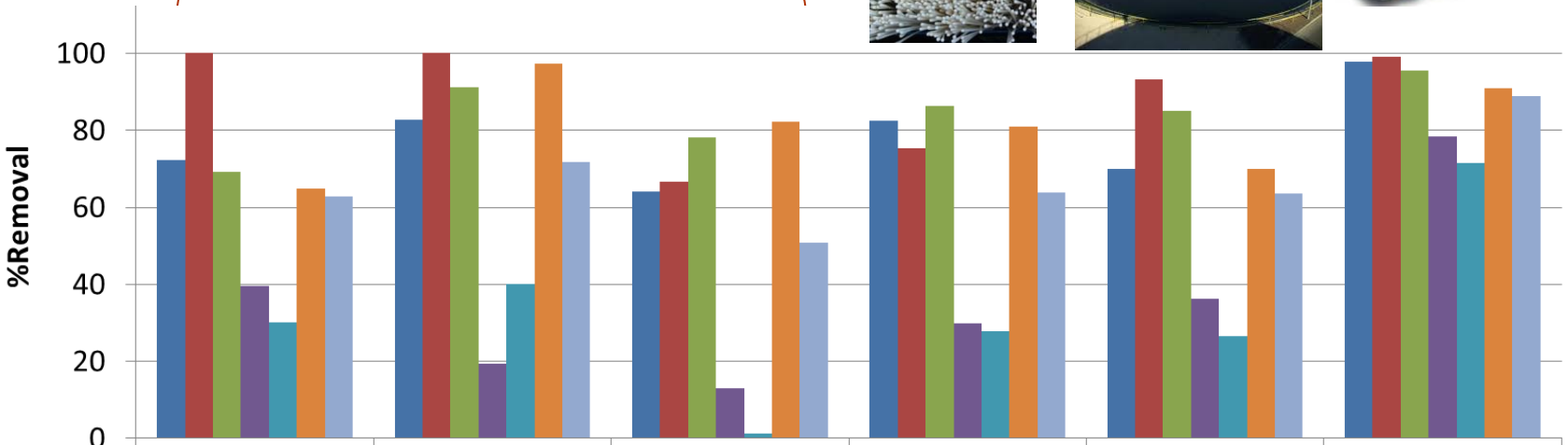
Comparison of Technologies



	IFAS-MBR10	IFAS-MBR20	MBMBR	MBR	CAS	RO
PhACs	72,3	82,8	64,2	82,4	69,9	97,8
Hormones	100	100	66,7	75,4	93,3	99
LAS	69,3	91,1	78,2	86,4	85,1	95,5
NPEs	39,5	19,4	13	29,8	36,3	78,4
DEHP	30	40,2	1,2	27,8	26,5	71,5
PAHs	64,9	97,4	82,2	81	70,1	90,8
Global	62,7	71,8	50,9	63,8	63,5	88,8

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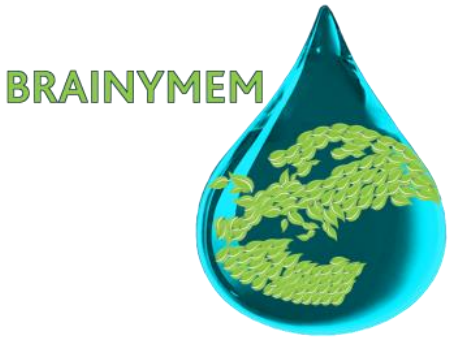
De la Torre et al., Water Sci Tech 71 (5) (2015), 761-768

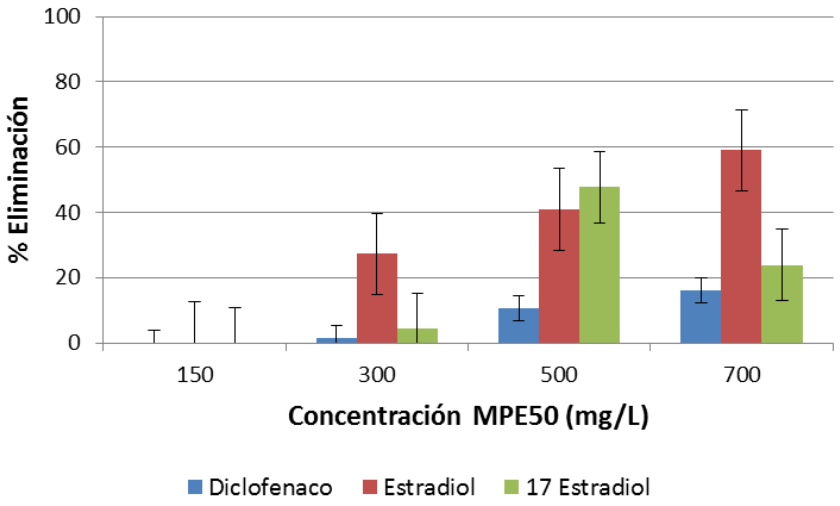
Cationic polymer addition

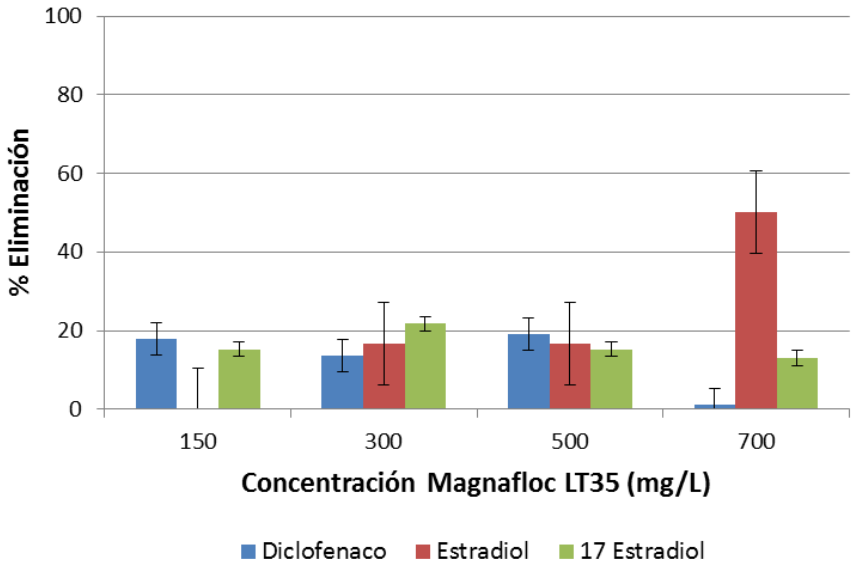
- BRAINYMEM Project: evaluation of “flux-enhancers”: cationic polymers added to the activated sludge to improve filterability→ **associated MP removal?**
- References for treated wastewater (Matamoros and Salvadó, 2013) and influent wastewater (Carballa et al., 2005; Zhou, 2011) indicate poor removal rates, very variable depending on the compound (0-70%)



Cationic polymer addition

- Jar test with aerated sludge samples and added micropollutants
- Cationic polymers added to activated sludge: Nalco (MPE50) and BASF (Magnafloc LT35)
- 20-60% increased removal of hormones for MPE50 for the highest concentration





Conclusions

- IFAS-MBR showed the highest removal rates (72%) and removed hormones below the detection limit
- Operating conditions are highly relevant (SRT, MLSS, HRT)
- MBMBR showed the worst performance (low HRT and biomass conc.)
- All compounds effectively removed except for NPs and DEHP → potential problem with the WFD
- For higher removal rates, RO is necessary (but also advanced oxidation and active carbon)
- Addition of flocculants improved hormone removal up to 60%

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  - Jorge Ignacio Pérez
  - Silvia Ruiz
  - María del Mar González
  - Jose Luis González

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Thank you for your attention

Questions?

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