13th IWA Specialized Conference on Small Water and Wastewater Systems

APPLICATION OF PAC FOR MEMBRANE FOULING CONTROL IN A PILOT-SCALE MBR SYSTEM

A.I. Zouboulis[1], *P.K. Gkotsis*[1], *D.X. Zamboulis*[1] *M.M. Mitrakas*[2]

[1]School of Chemistry, A.U.Th., [2]School of Chemical Engineering, A.U.Th.

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

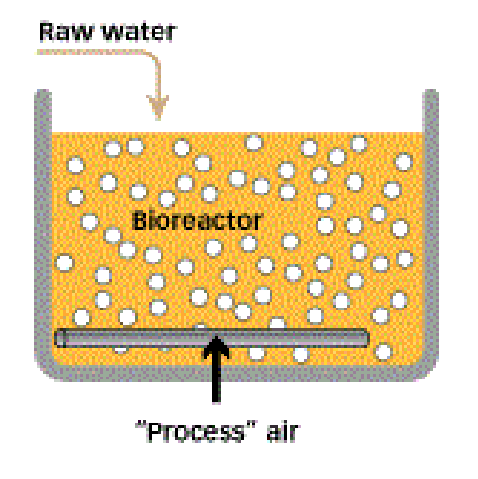
COMPETITIVENESS AND ENTREPRENEURSHIP OPC II
regions at the centre of development

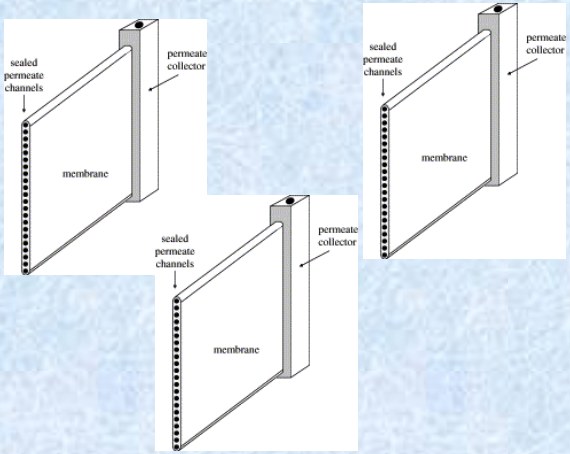
NSRF 2007-2013
programme for development

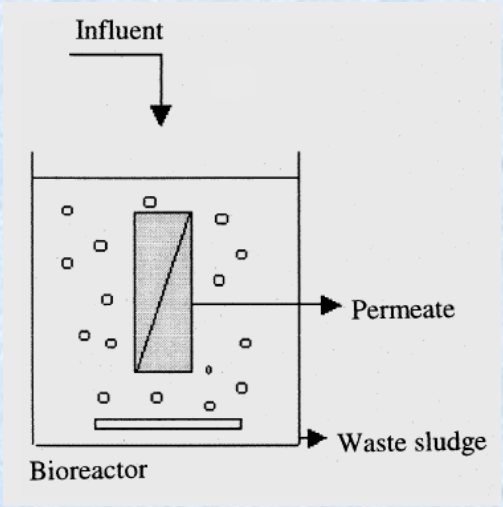
Ministry of Education and Religious Affairs, Culture & Sports
GSRT - Management and Implementation Agency for RTD and Innovation Activities

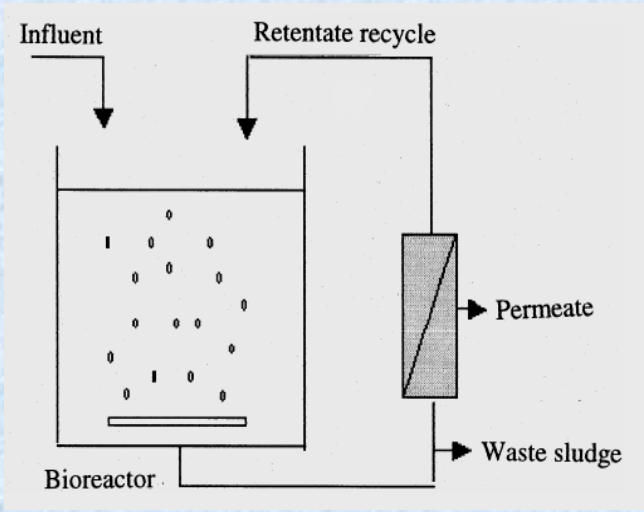
O.P. Competitiveness and Entrepreneurship (EPAN II), ROP Macedonia - Thrace, ROP Crete and Aegean Islands, ROP Thessaly - Mainland Greece - Epirus, ROP Attica

Wastewater treatment & water reclamation through the integration of biological wastewater treatment with membrane technology









Submerged/Immersed MBR

Side-stream/External MBR

Membrane fouling

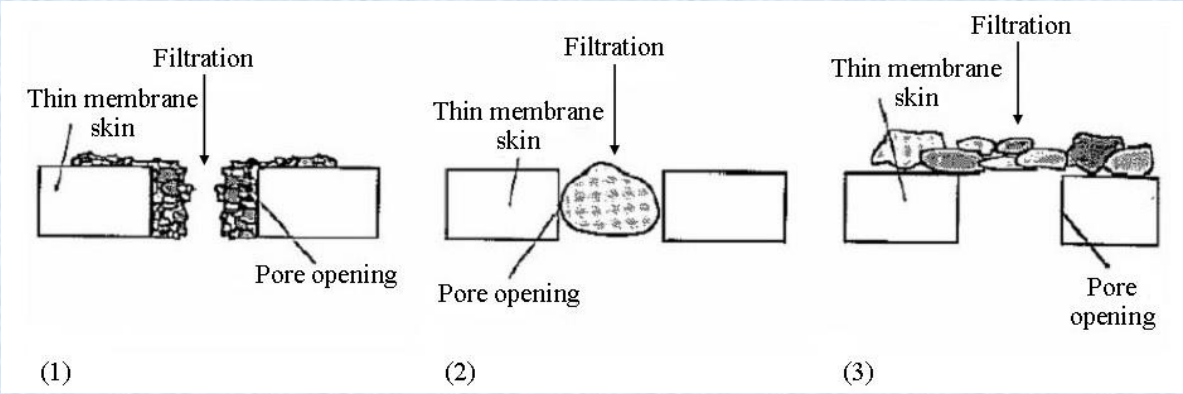
FOULING

A process by which a variety of species present in the water increase the membrane resistance by:

(1) adsorption onto the pore surfaces within the bulk membrane material (pore restriction)

(2) complete pore-blocking

(3) deposition onto its surface



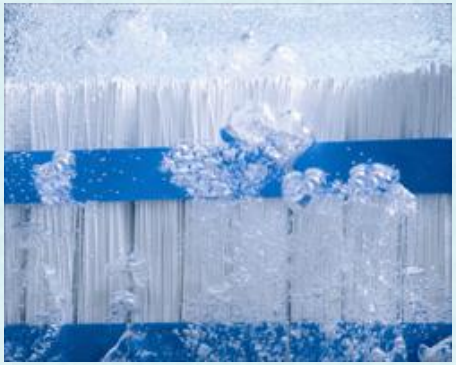
Common methods applied for fouling mitigation

A. Optimal operation of MBR process

1. **Permeate flux reduction**
2. **Aeration increase**

- Gas/liquid flow to achieve shear stress at the surface

- Partly intermittent & coupled with filtration breaks



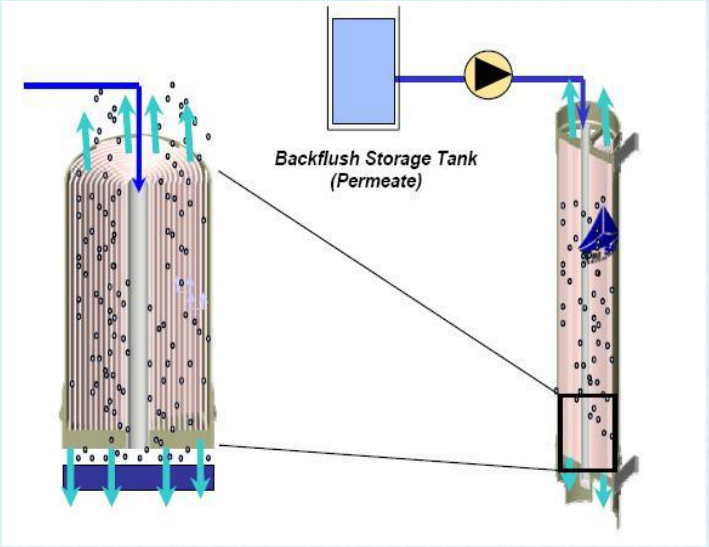
B. Physical cleaning

1.Filtration breaks

Periodical discontinuity of filtration (e.g. every 10 min for 1 min)

2. Backflushing

Periodically with permeate (e.g. every 3-10 min for 15-60 s)



C. Chemical cleaning

(NaClO, $C_6H_8O_7$ etc)

Innovative methods applied for fouling mitigation

A. Adsorbent agents

activated carbon, zeolite e.t.c.

(reduced cake resistance)

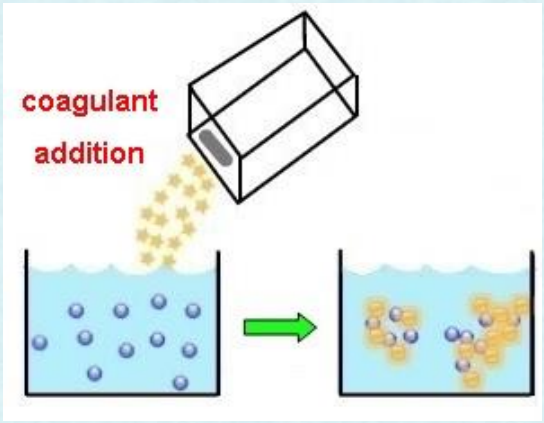
Conner et al. (2011)

B. Coagulant addition

$FeCl_3$, $Al_2(SO_4)_3$, PACl,

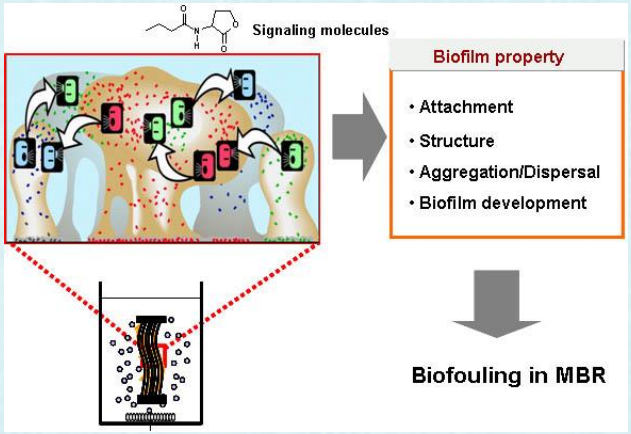
cationic organic polymers e.t.c.

(larger aggregates of the biological flocs)



C. Quorum quenching (QQ)

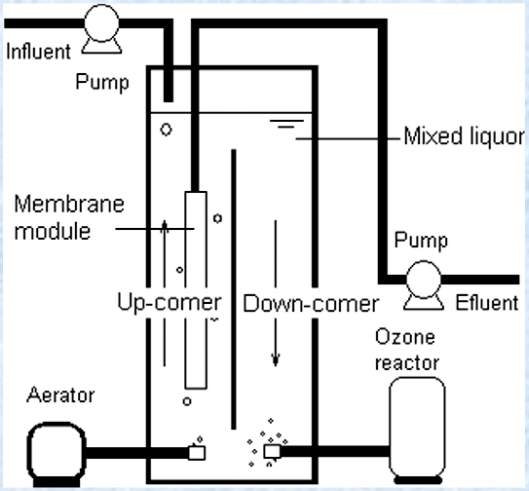
- ***Communication by signaling molecules (autoinducers) & regulation of gene expression***
- ***Controlling bacteria (inhibition of QQ) by interfering with their signalling systems***



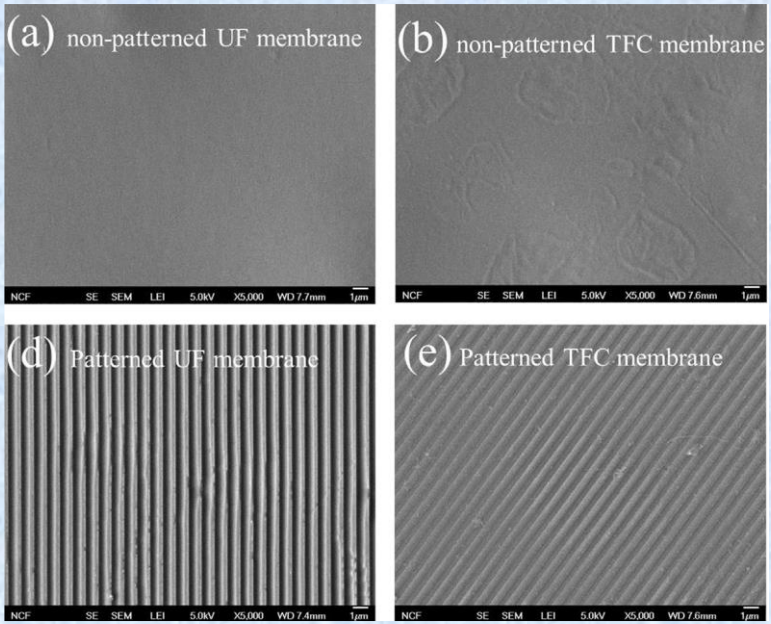
D. Application of ultrasound, electric field and ozone

E. Membrane surface modification

1. **Physical coating/adsorption on the membrane surface**
   - (i) Coating via filtration
   - (ii) Coating via adsorption
   - (iii) Coating via casting
2. **Grafting methods on the membrane surface**
3. **Patterned membranes**
4. **Plasma treatment of polymer membranes**
5. **Chemical reactions on the membrane surface**
6. **Surface modifications with nanoparticles**
   - (i) Membrane modification with deposited nanoparticles
   - (ii) Phase inversion method



Hu et al. (2010)



Maruf et al. (2014)

PRIMARY OBJECTIVE

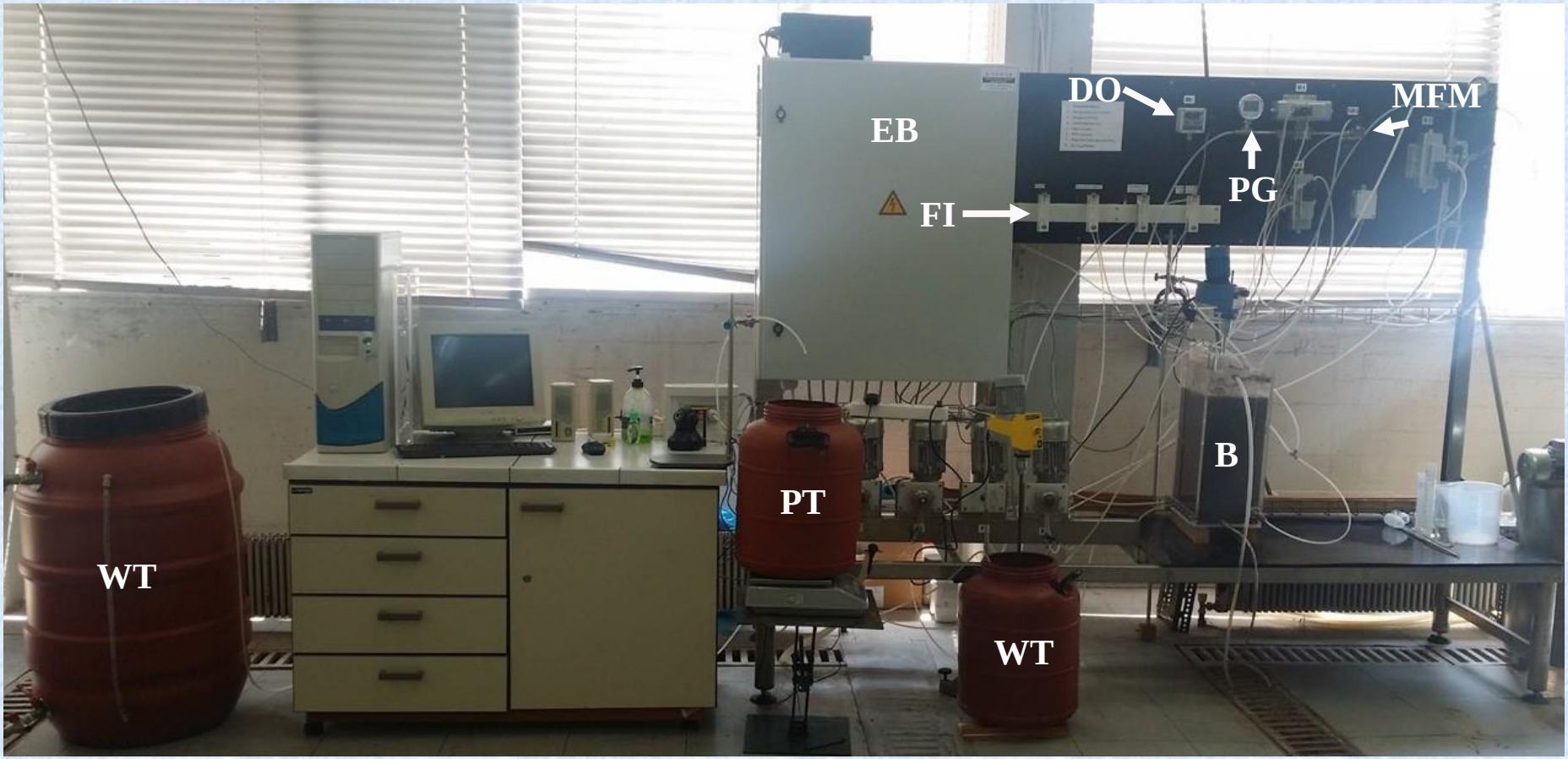
The development of an integrated methodology for fouling control in MBRs

by the:

Addition of **powdered activated carbon (PAC)** that will improve sludge filterability and promote the removal (adsorption) of organics which are responsible for fouling

!

Pilot-scale MBR system



WT: Wastewater Tanks

EB: Electronic Board

B: Bioreactor

FI: Flow Indicators

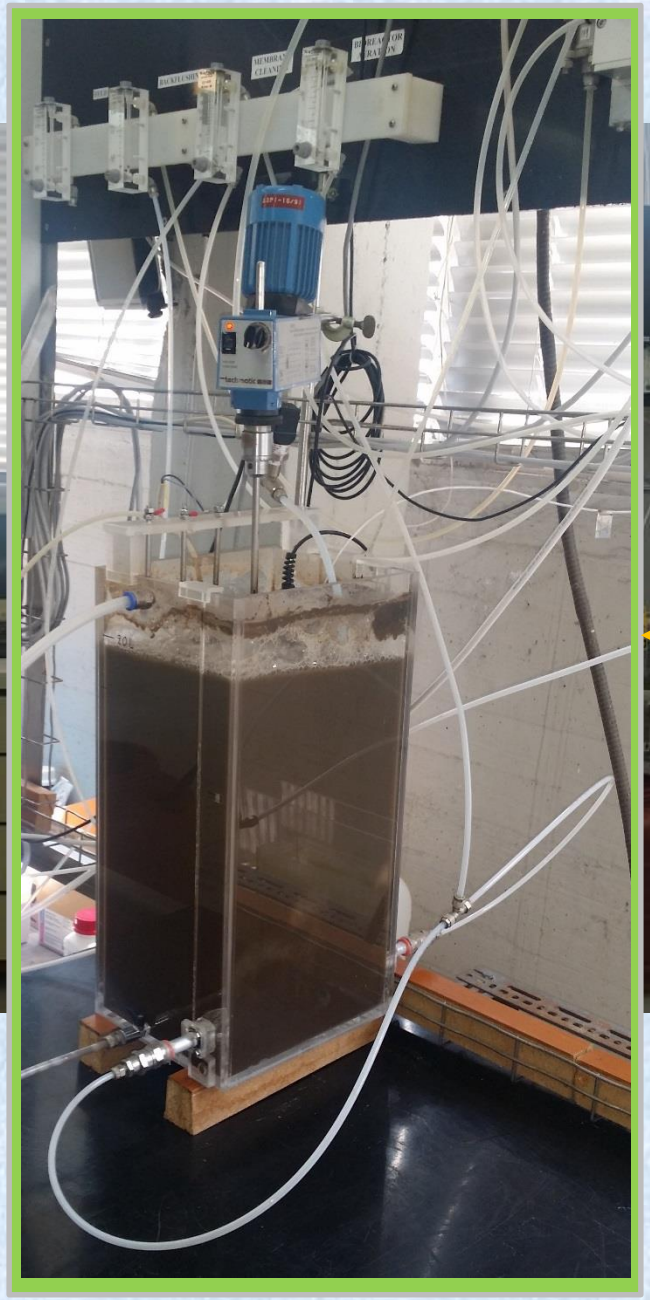
PT: Permeate Tank

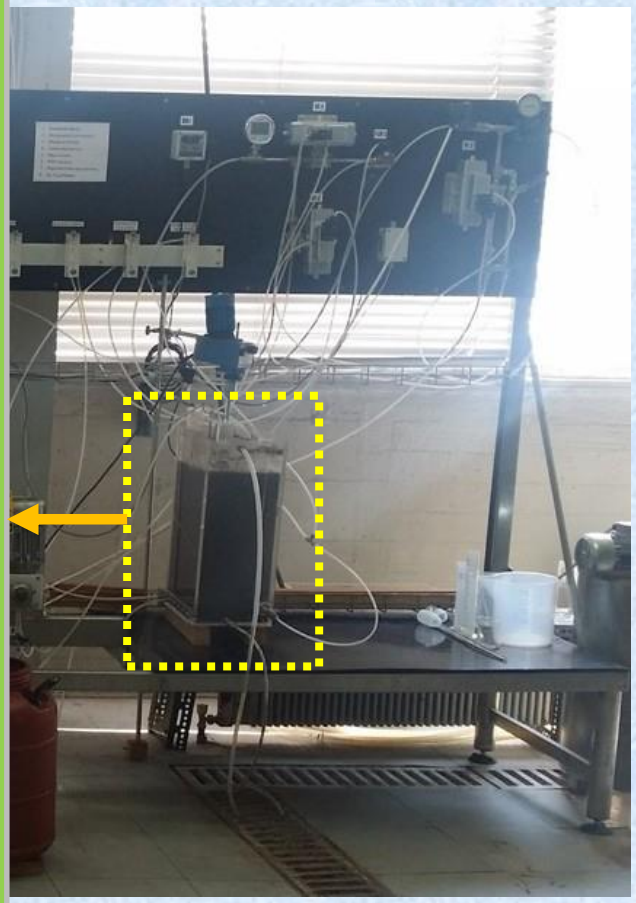
PG: Pressure Gauge

DO: Dissolved Oxygen meter

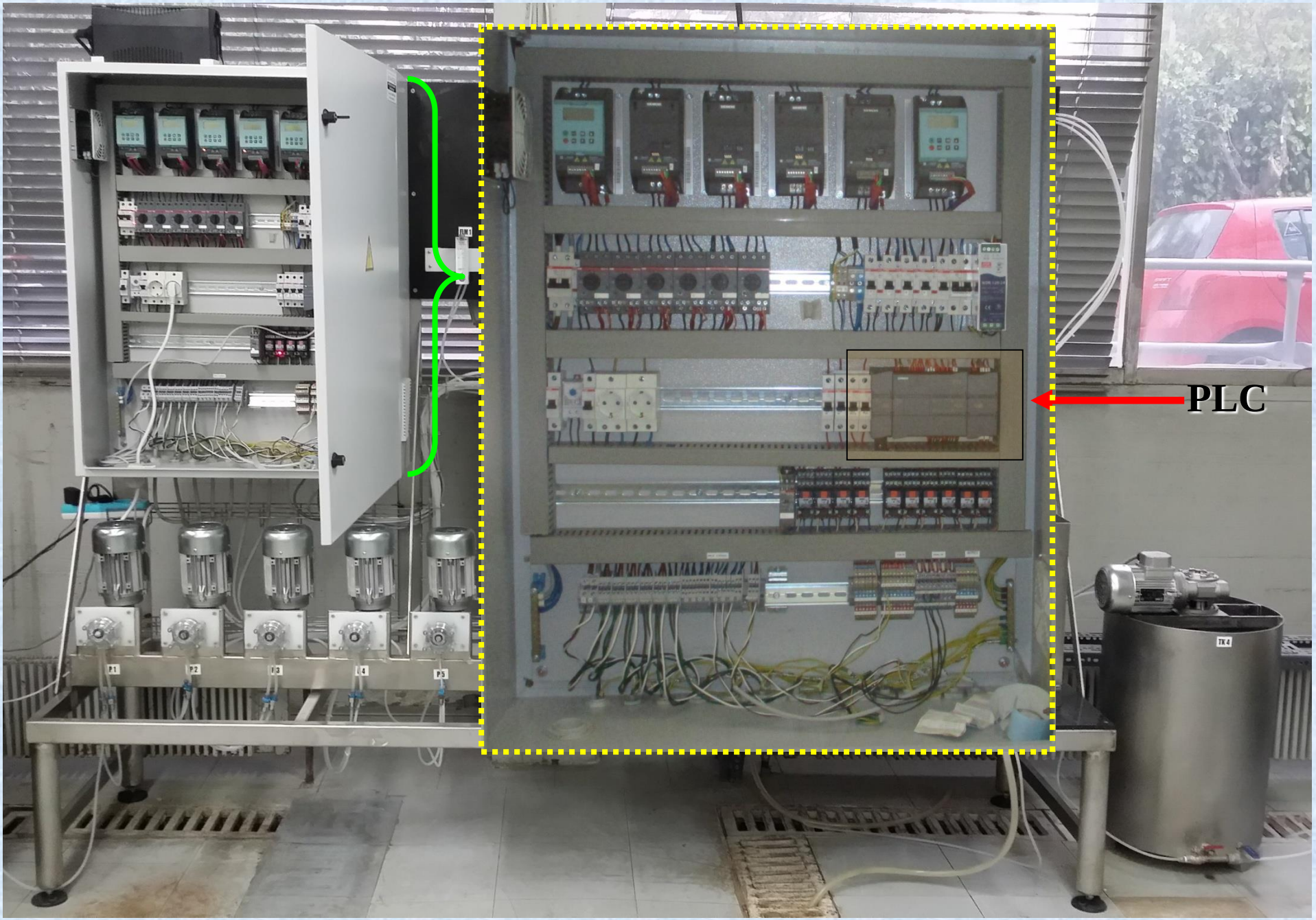
MFM: Mass Flow Meter

Pilot-scale MBR system





Pilot-scale MBR system



Synthetic wastewater composition

Substance	Concentration (g/L)
Peptone water	1.60
Meat extract	1.10
Urea	0.30
K_2HPO_4	0.28
NaCl	0.07
$CaCl_2 \cdot 2H_2O$	0.04
$MgSO_4 \cdot 7H_2O$	0.02

Synthetic wastewater characterization

- *BOD = 1036 ± 58 mg/L*
- *COD = 1987 ± 73 mg/L*
- *SS = 0 mg/L*
- *pH = 7.3*

	Low strength	Medium strength	High strength
COD, mg/L	250	500	1000
BOD, mg/L	110	220	400

(Tchobanoglous, 1991)

Membrane characteristics & pilot-scale MBR operation

Kubota FS membrane, H-203

Membrane specifications	
Model	H-203
Configuration	Flat Sheet
Material	Chlorinated Polyethylene
Pore size	0.4 μm
Surface area	0.11 m^2
Maximum TMP	20 kPa (0.2 bar)
Chemical cleaning	Citric or oxalic acid

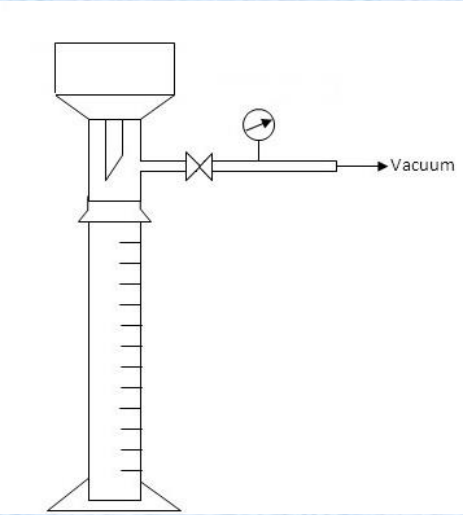
Operating parameters

- Filtration time: 9 min
- Backwashing time: 1 min
- DO: 2-3 mg/L
- Flux: 17 LMH
- F/M: 0.2 mg BOD / (mg MLVSS·d)
- HRT: 13 h
- SRT: 10 d

Ability to test a wide range of PAC concentrations (0.5 - 5.0 g/L)

A. Filterability tests (reversible fouling)

Time to filter (TTF) test method (APHA 1992)



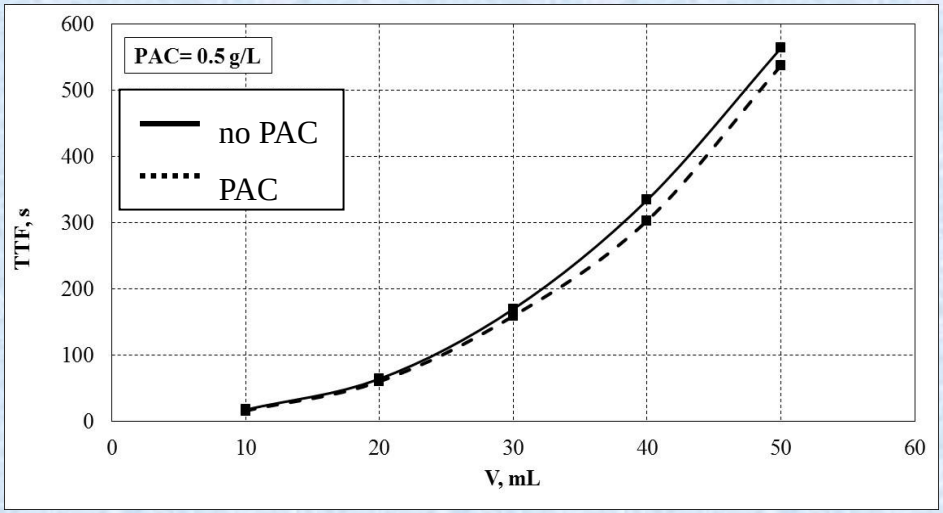
P = 510 mbar
V_{filt} = 50 mL

B. SMP (sEPS) concentration measurements (irreversible fouling)

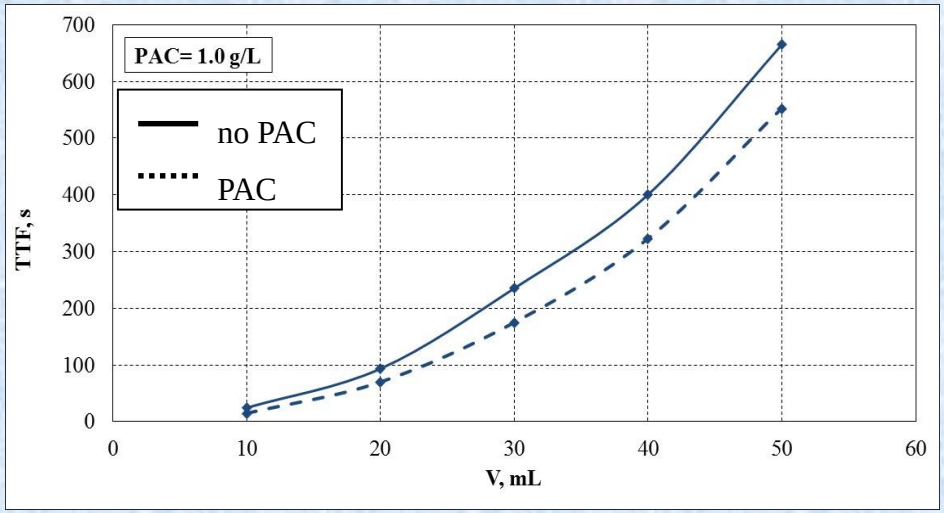
Phenol-Sulphuric (colorimetric) Acid Method

(carbohydrate concentration determination)

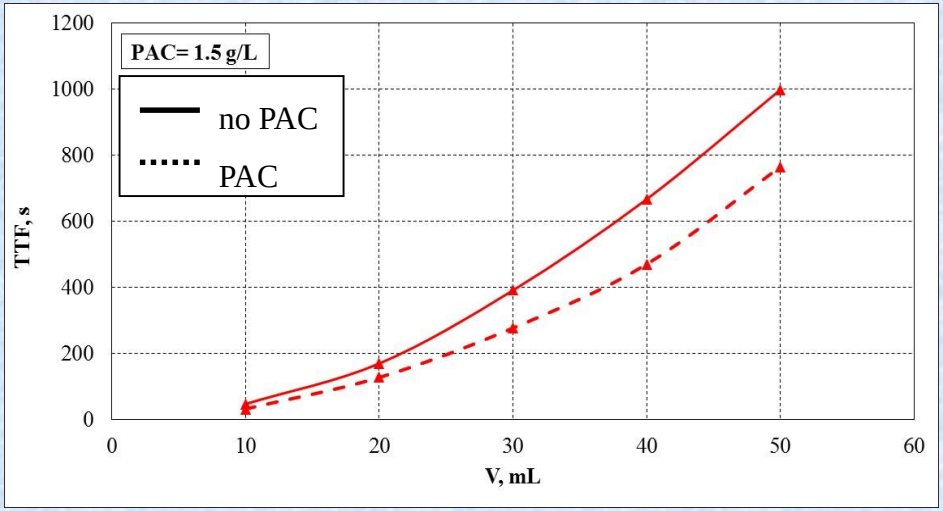
Results - Effect on reversible fouling



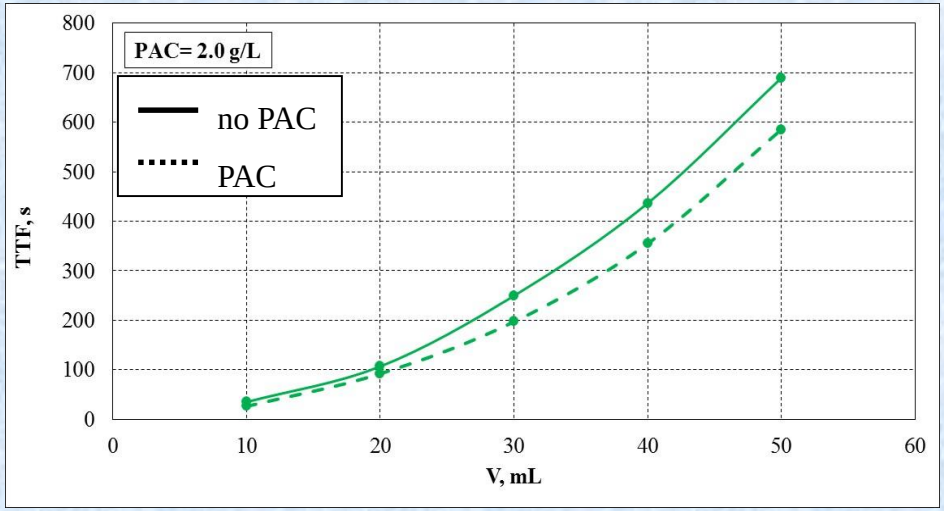
Addition of PAC at 0.5 g/L



Addition of PAC at 1.0 g/L

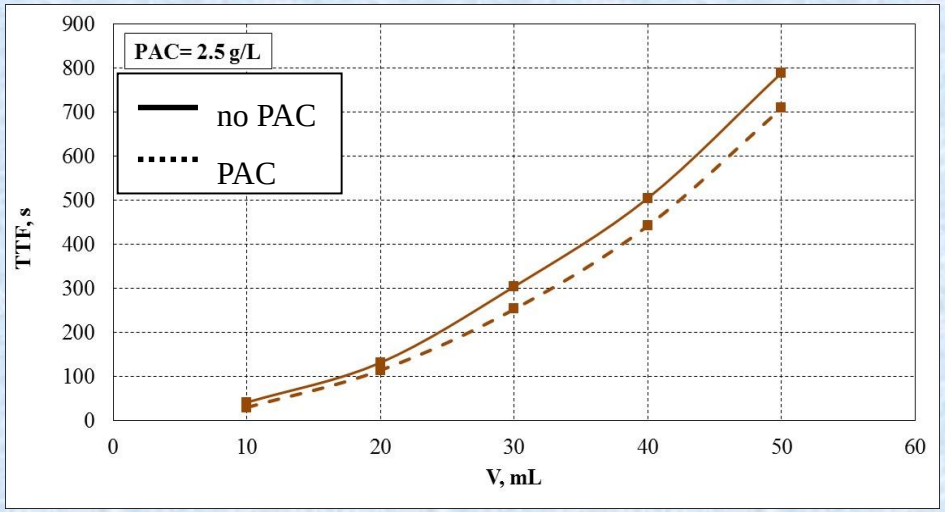


Addition of PAC at 1.5 g/L

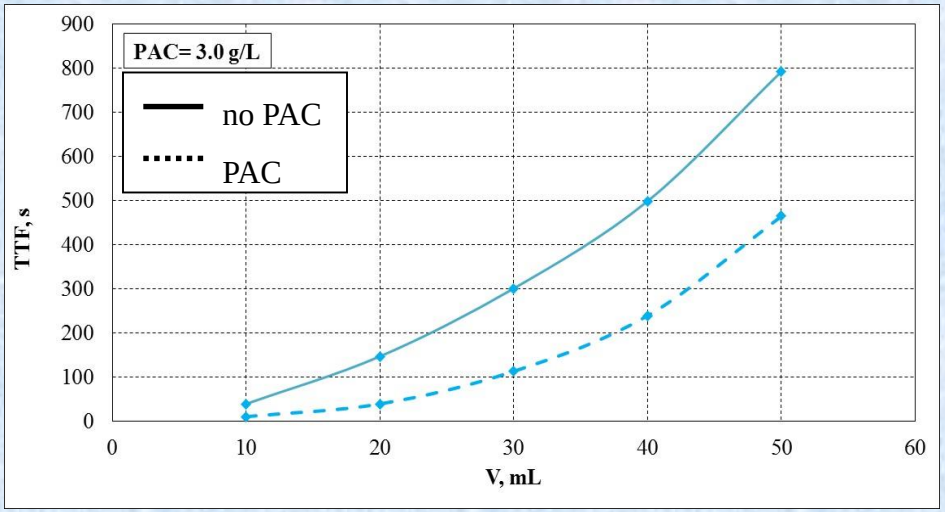


Addition of PAC at 2.0 g/L

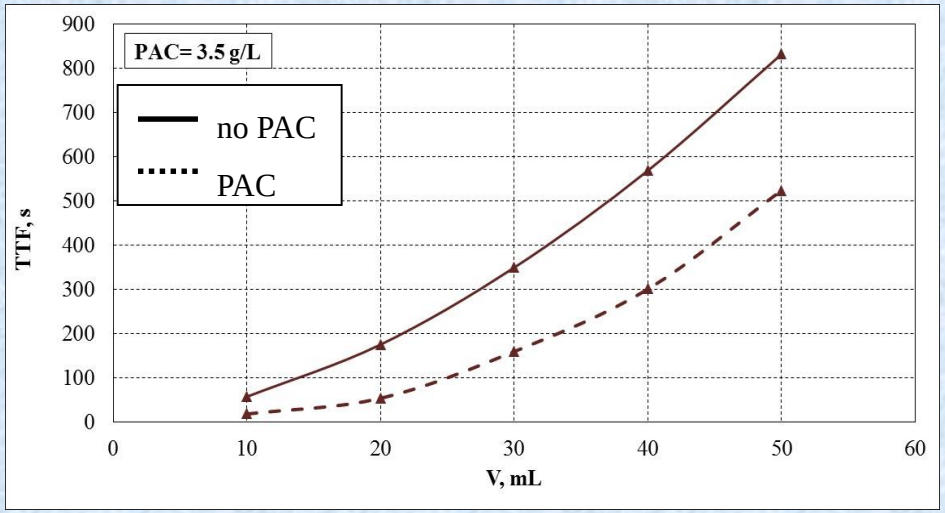
Results - Effect on reversible fouling



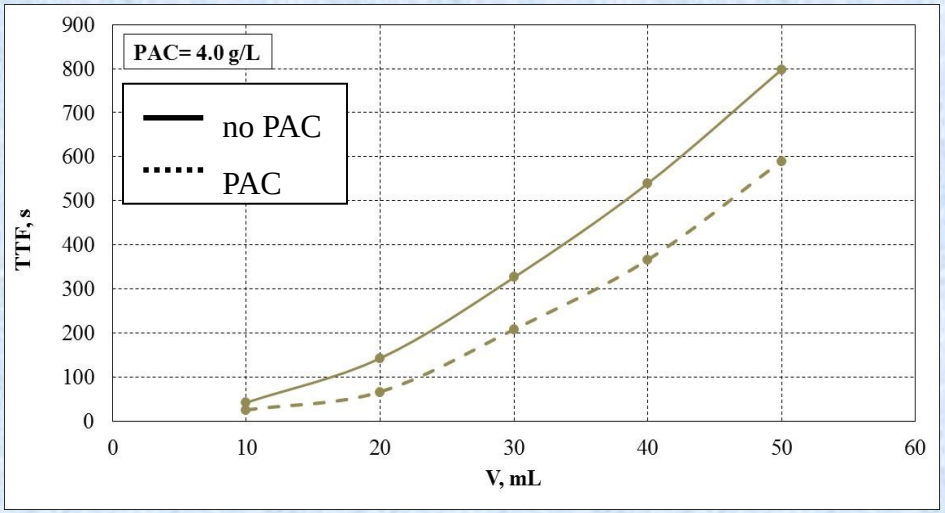
Addition of PAC at 2.5 g/L



Addition of PAC at 3.0 g/L

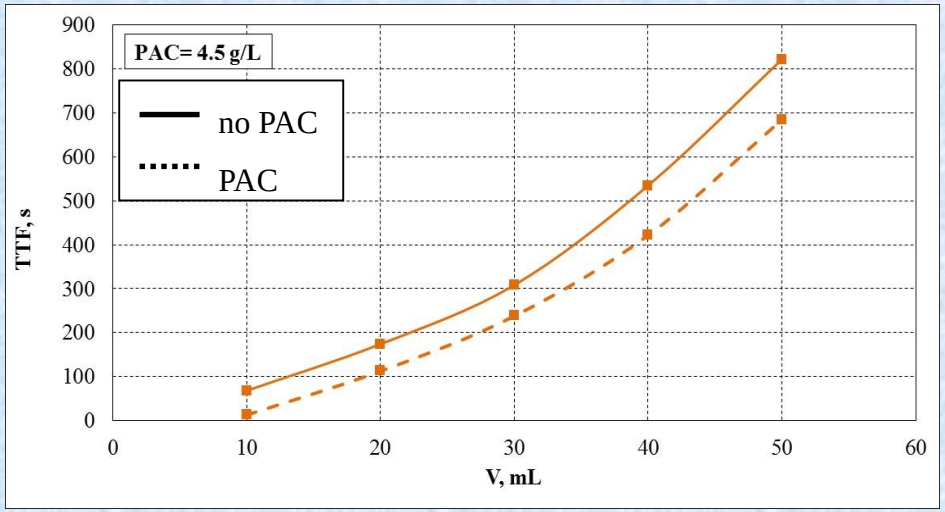


Addition of PAC at 3.5 g/L

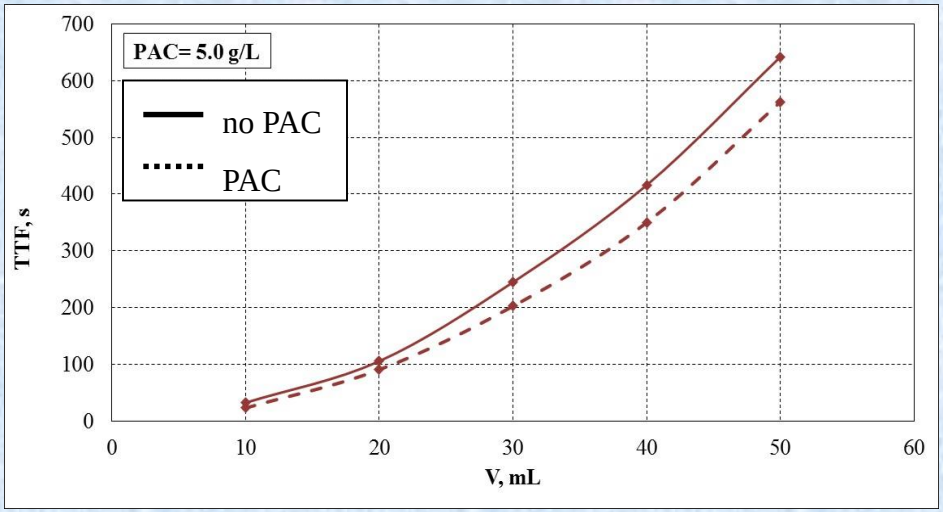


Addition of PAC at 4.0 g/L

Results - Effect on reversible fouling

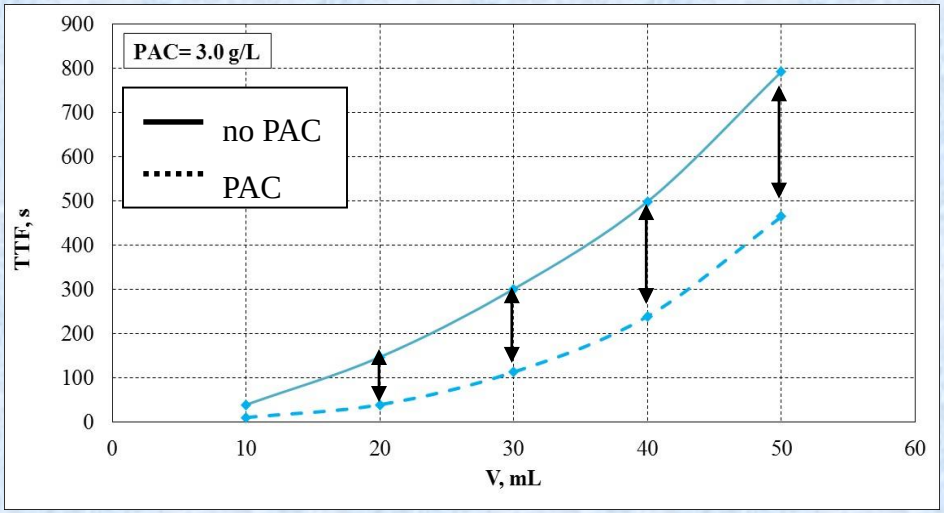


Addition of PAC at 4.5 g/L

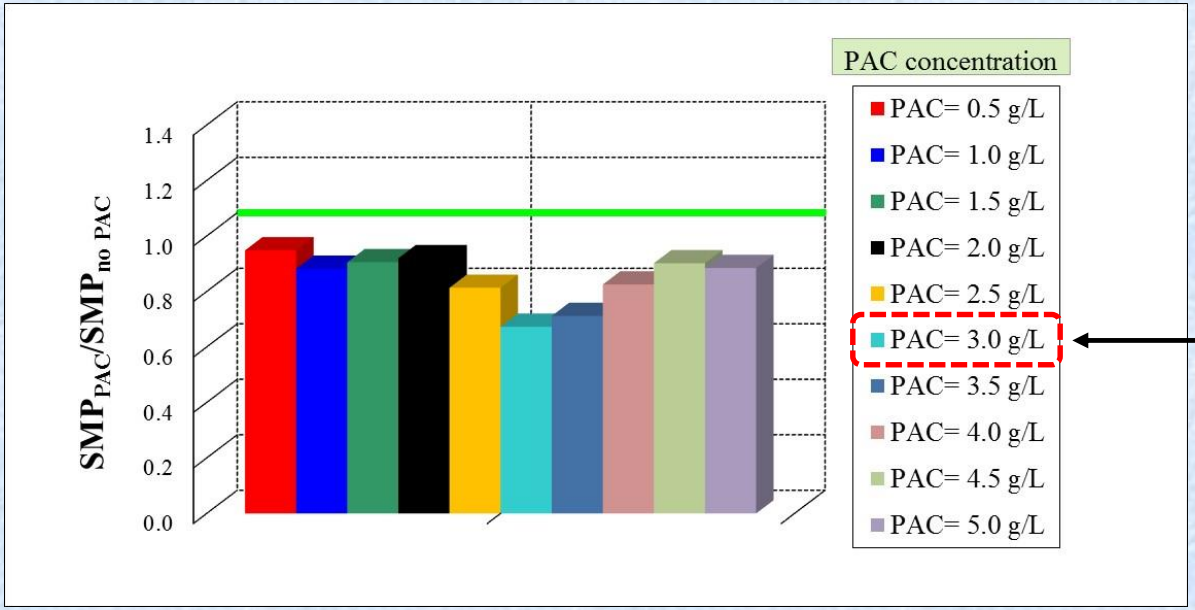


Addition of PAC at 5.0 g/L

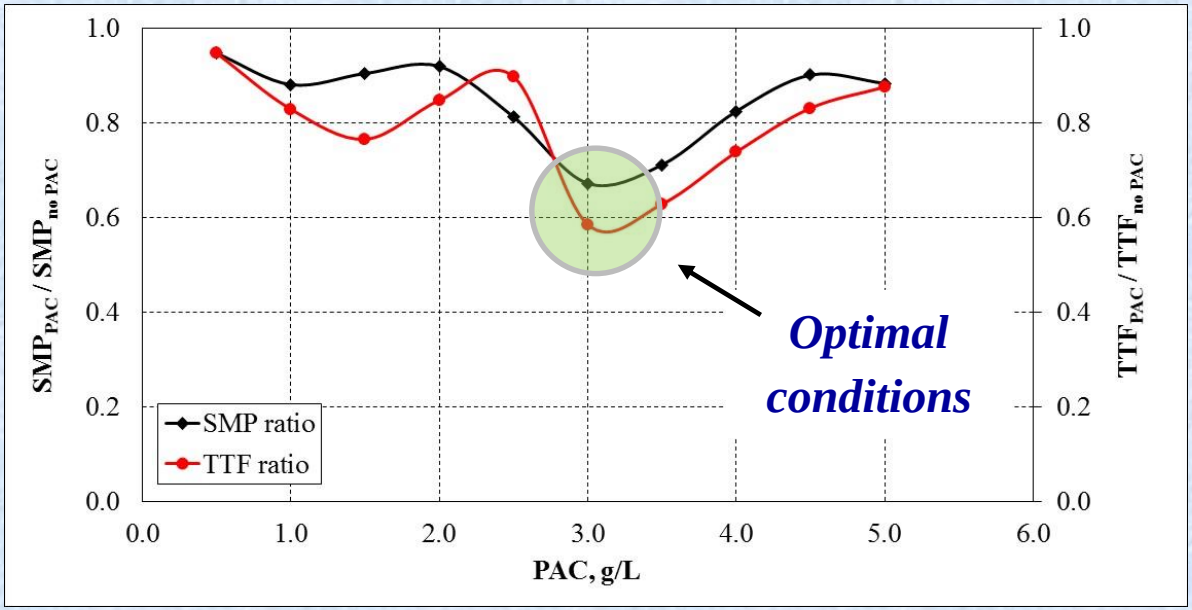
- The addition of PAC **enhanced sludge filterability** at all concentrations
- Optimal concentration in the mixed liquor: **3.0 g/L**



Results - Effect on irreversible fouling & comparison

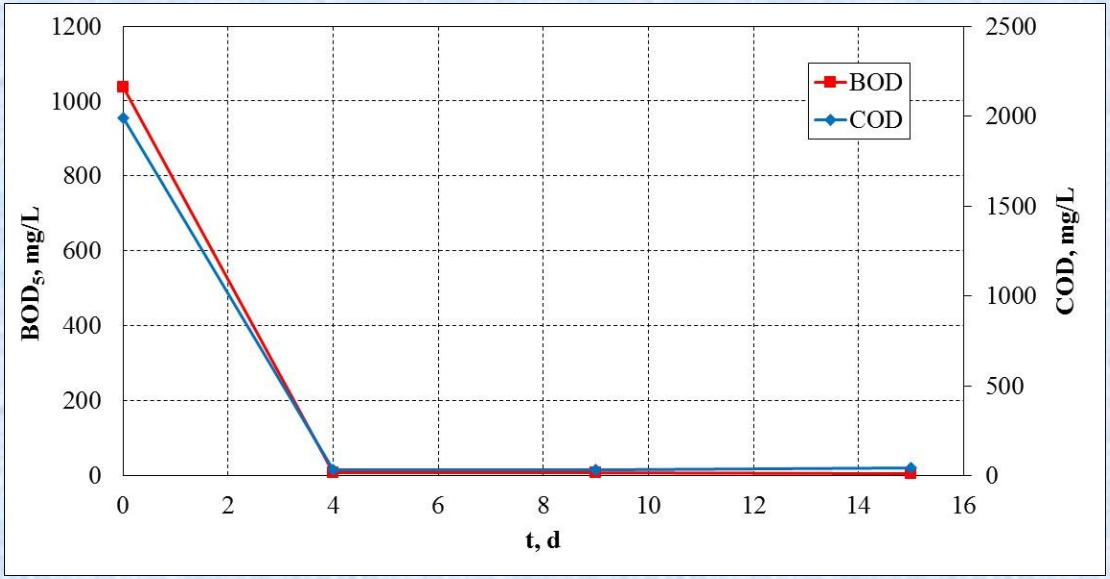


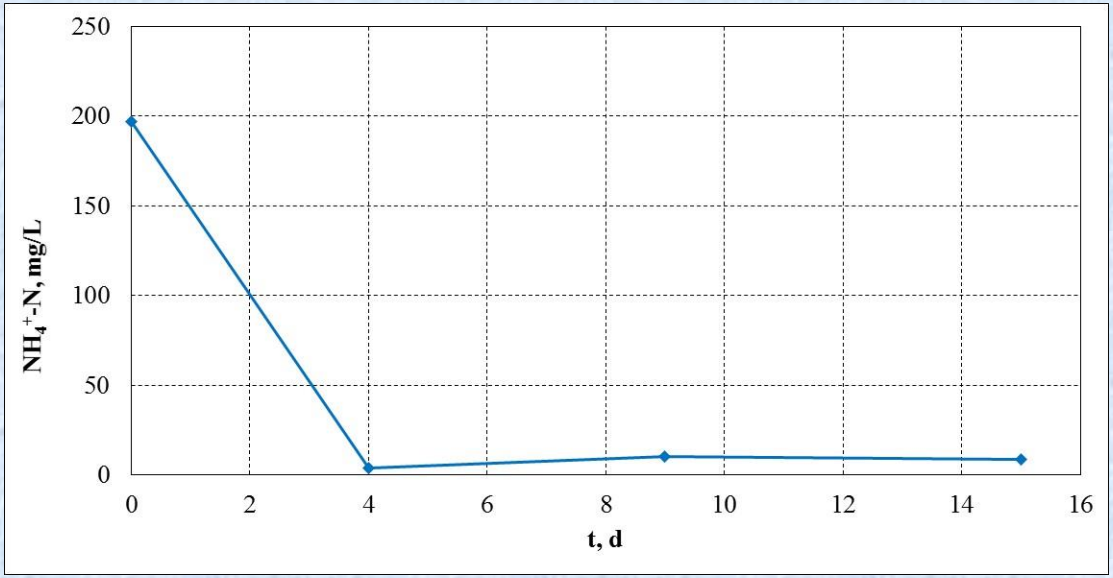
Optimal concentration



Optimal conditions

Results - MBR operation and removal efficiency





A) Membrane fouling assessment

- The addition of PAC **enhanced sludge filterability** at all concentrations (0.5 - 5.0 g/L)
- Optimal concentration in the mixed liquor regarding both reversible and irreversible fouling mitigation: **3.0 g/L**
- Strong indication that PAC **might act as a foulant** at high concentrations (> 5 g/L)

B) MBR operation & removal efficiency

- The pilot-scale MBR operated successfully with a challengingly **high strength** synthetic municipal wastewater
- Remarkable behaviour was observed in terms of **organic removal** (> 95%).

13th IWA Specialized Conference on Small Water and Wastewater Systems

THANK YOU VERY MUCH

Acknowledgements

The financial support through the co-financing by: a) The European Union and the Greek State Program EPAN-II (OPCII)/ ESPA (NSRF): 'SYNERGASIA II', Project (FOULMEM) "New processes for fouling control in membrane bioreactors" (11SYN 8-1084) and b) The European Union and the Greek State Program PAVET, Project (PhoReSE): ''Recovery of Phosphorus from the Secondary Effluent of Municipal Wastewater Treatment'' and the active participation of ''Aktor'' S.A. company, are gratefully appreciated. The latter was supported also by the EYATh's S.A. (Thessaloniki Water Supply and Sewerage Co.) - Department of Plants' Operation, Maintenance and Environmental Monitoring, which is gratefully appreciated.