ULTIMATE

WATER SMART INDUSTRIAL SYMBIOSIS

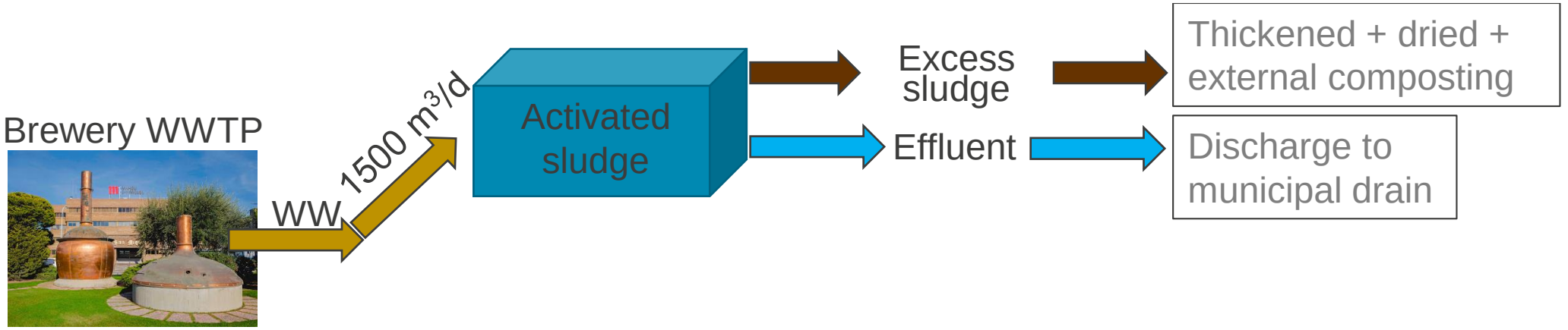
CS5 Lleida: Development and implementation of an early warning system for membrane fouling

A. Giménez-Lorang

aqualia

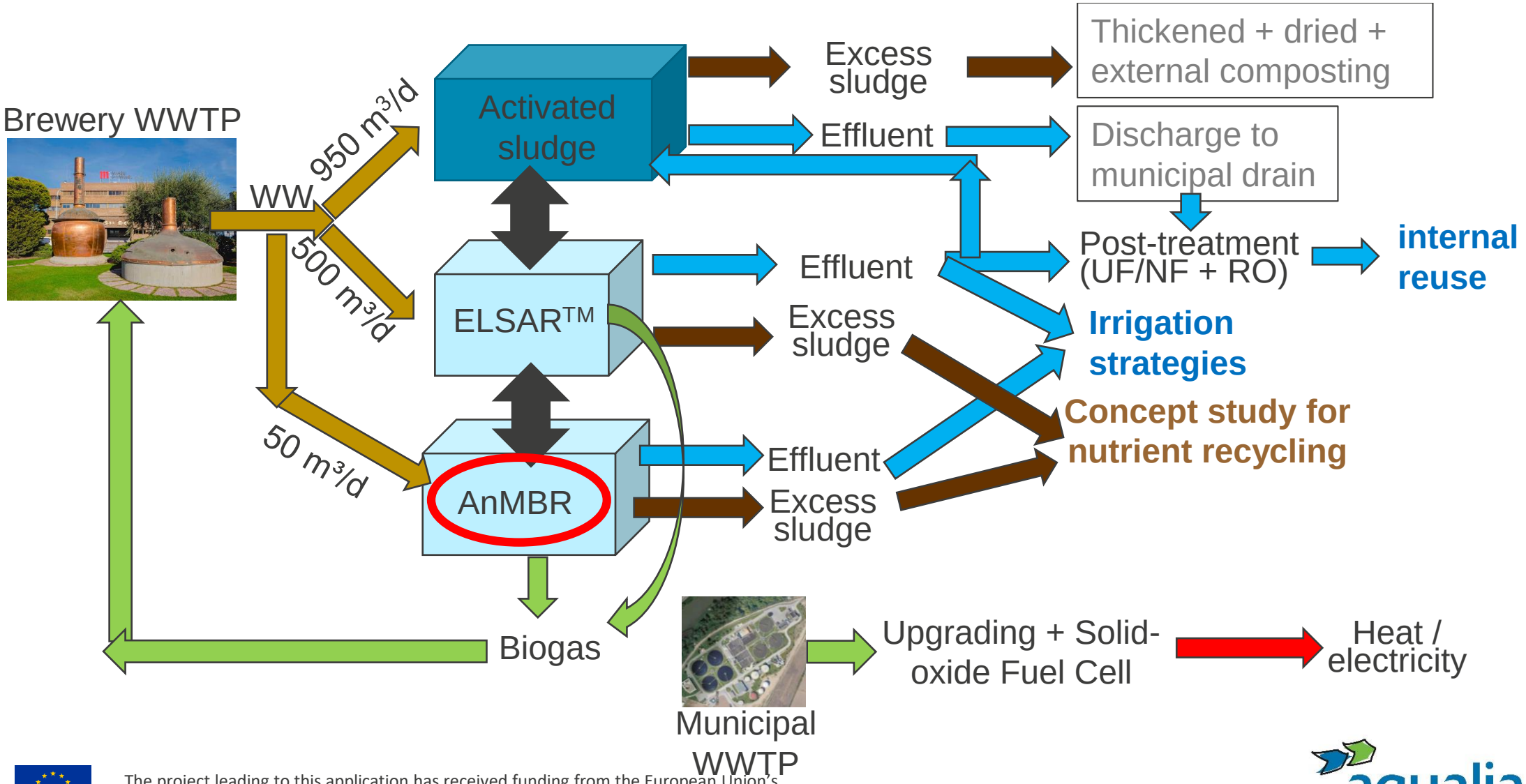
20.05.2021 CS meeting on “Digitalization”

Case study nr. 5: baseline conditions



The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869318

Case study nr. 5: ULTIMATE water-smart solution



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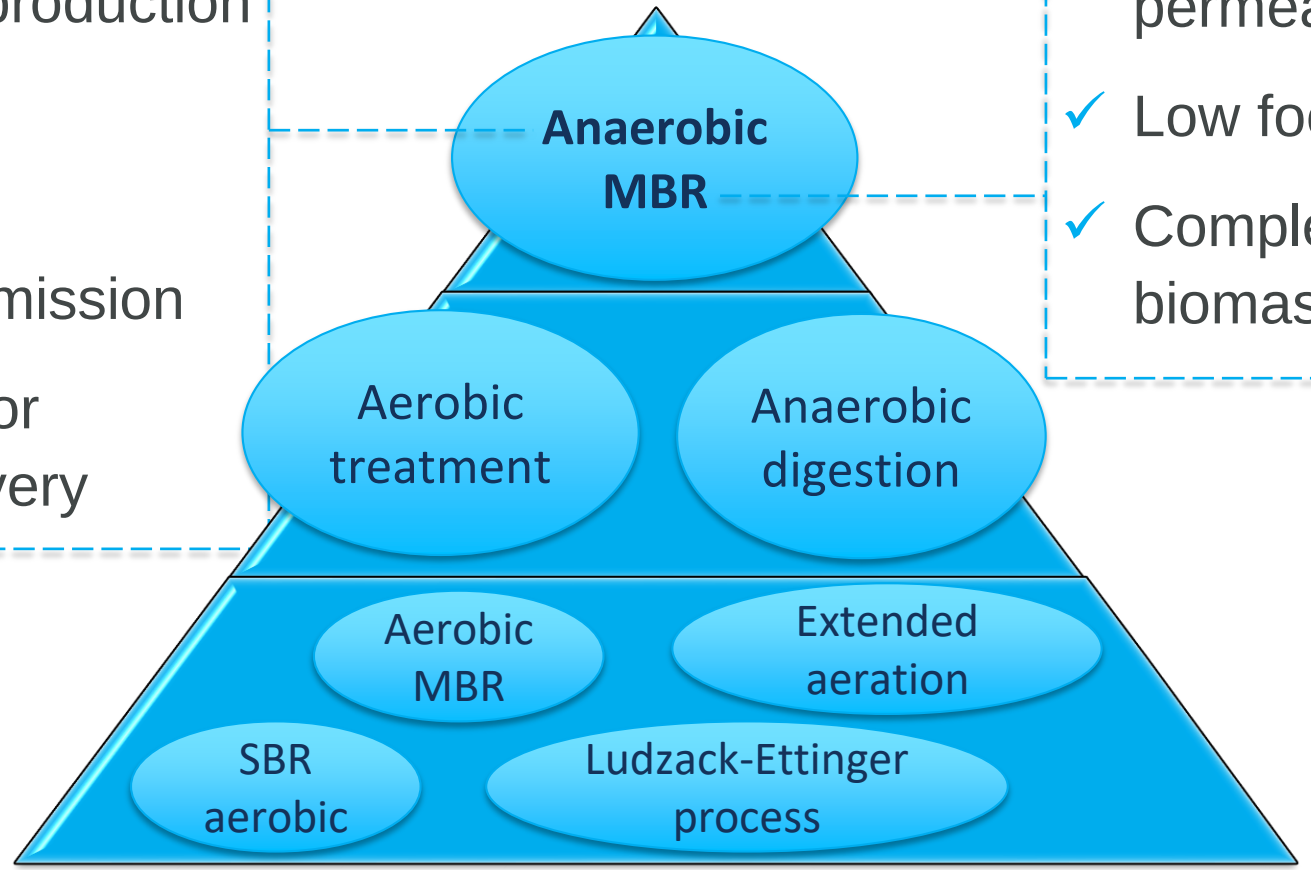
Why AnMBR?

- ✓ Lower energy demand / net energy production
- ✓ Lower sludge production
- ✓ Lower CO_2 emission
- ✓ Opportunity for nutrient recovery



- ✓ High-quality permeate
- ✓ Low footprint
- ✓ Complete biomass retention

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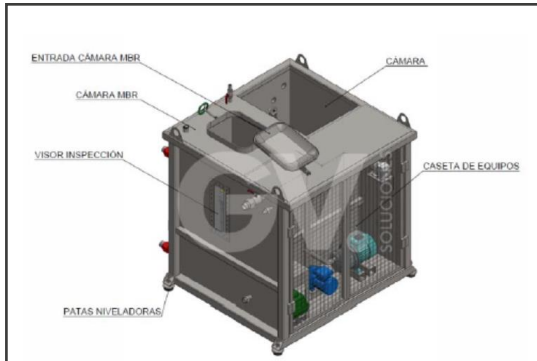
R&D projects by Aqualia in the AnMBR field

Municipal Black water Industrial OFMSW

www.life-methamorphosis.eu

www.life-memory.eu

http://eranetbestf.eu/call/bestf2/project-results/biowamet/



www.run4life-project.eu

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Scientific background of Aqualia in the MBR field

- Silva-Teira A, **Vázquez-Padín JR**, Weiler R, **Fernández-González R**, **Rogalla F**, Garrido JM. Performance of a hybrid membrane bioreactor treating a low strength and alkalinity wastewater. Process Biochemistry, Volume 66, 2018, Pages 176-182, https://doi.org/10.1016/j.procbio.2017.12.015
- Jiménez-Benítez A, Ferrer J, **Rogalla F**, **Vázquez JR**, Seco A, Robles A. 12 - Energy and environmental impact of an anaerobic membrane bioreactor (AnMBR) demonstration plant treating urban wastewater. In: Current Developments in Biotechnology and Bioengineering, Elsevier, 2020, Pages 289-310, ISBN 9780128198544, https://doi.org/10.1016/B978-0-12-819854-4.00012-5
- Silva-Teira A, **Vázquez-Padín JR**, Reif R, Arias A, Garrido JM. Assessment of a combined UASB and MBR process for treating wastewater from a seafood factory at different temperatures. 180(2020)43-54. https://doi.org/10.5004/dwt.2020.25076
- Robles A, **Durán F**, Giménez JB, **Jiménez E**, Ribes J, Serralta J, Seco A, Ferrer J, **Rogalla F**. Anaerobic membrane bioreactors (AnMBR) treating urban wastewater in mild climates. Bioresource Technology, Volume 314, 2020. https://doi.org/10.1016/j.biortech.2020.123763
- Odriozola M, **Morales N, Vázquez-Padín JR**, Lousada-Ferreira M, Spanjers H, van Lier JB. Fouling Mitigation by Cationic Polymer Addition into a Pilot-Scale Anaerobic Membrane Bioreactor Fed with Blackwater. Polymers. 2020; 12(10):2383. https://doi.org/10.3390/polym12102383
- **Giménez-Lorang A**, **Vázquez-Padín JR**, **Dorado-Barragán C**, Sánchez-Santos G, Vila-Armadas S, Flotats-Ripoll X. Treatment of the Supernatant of Anaerobically Digested Organic Fraction of Municipal Solid Waste in a Demo-Scale Mesophilic External Anaerobic Membrane Bioreactor. Front Bioeng Biotechnol. 2021 Apr 12;9:642747. https://doi.org/10.3389/fbioe.2021.642747
- Sanchis-Perucho P, Robles Á, **Durán F, Rogalla F,** Ferrer J, Seco A. Widening the applicability of AnMBR for urban wastewater treatment through PDMS membranes for dissolved methane capture: Effect of temperature and hydrodynamics. J Environ Manage. 2021 Jun 1;287:112344. https://doi.org/10.1016/j.jenvman.2021.112344. Epub 2021 Mar 19.

EP16382140.8:

Anaerobic process with filtration procedure for treating wastewater at room temperature.

FCC Aqualia, S.A., Universitat Politècnica De València, Universitat De València

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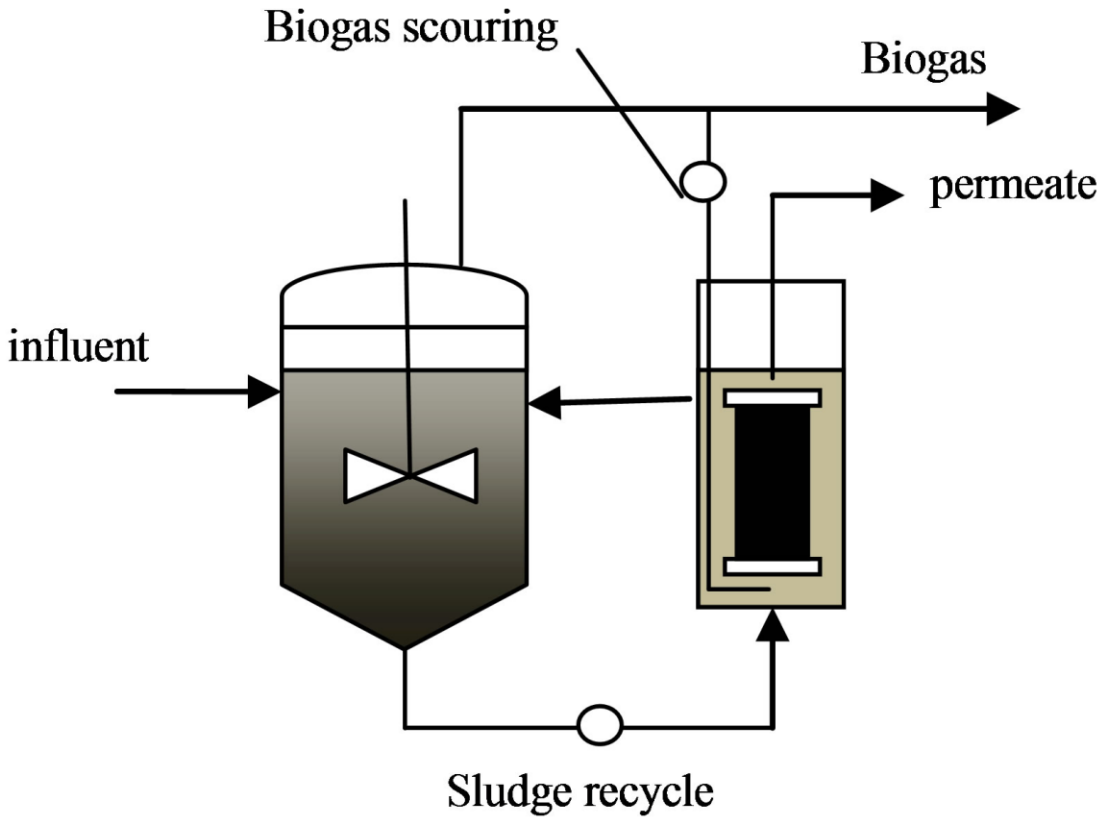
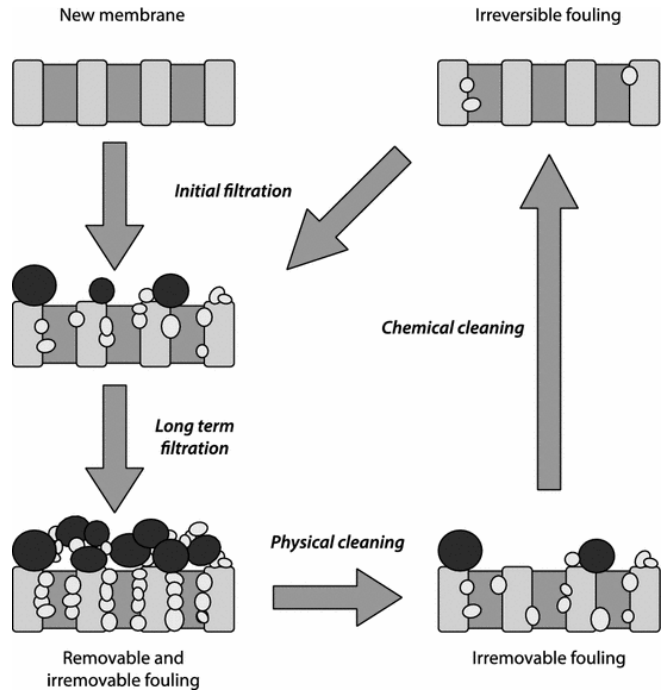
What we know from fouling… in a few words



WHAT IS FOULING?

- Process leading to deterioration of flux due to the surface or internal blockage of the membranes (Judd 2006).

Judd, S. (2006) *The MBR Book: Principles and Applications of Membrane Bioreactors in Water and Wastewater Treatment*. Elsevier, Amsterdam.



Advances in Chemical Engineering and Science
Vol.4 No.1(2014), Article ID:42423,6 pages DOI:10.4236/aces.2014.41008

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What's important about fouling (I)

WHAT IS FOULING?

- Process leading to deterioration of flux due to the surface or internal blockage of the membranes (Judd 2006).

Judd, S. (2006) *The MBR Book: Principles and Applications of Membrane Bioreactors in Water and Wastewater Treatment*. Elsevier, Amsterdam.

- It's a **complex process**, with several causes that can be interlinked and **not always well understood**.

"There is no unified statement about the mechanisms of membrane fouling"

Du X, Shi Y, Jegatheesan V, Haq IU. A Review on the Mechanism, Impacts and Control Methods of Membrane Fouling in MBR System. Membranes. 2020; 10(2):24. https://doi.org/10.3390/membranes10020024

Modified from Flavita Banana

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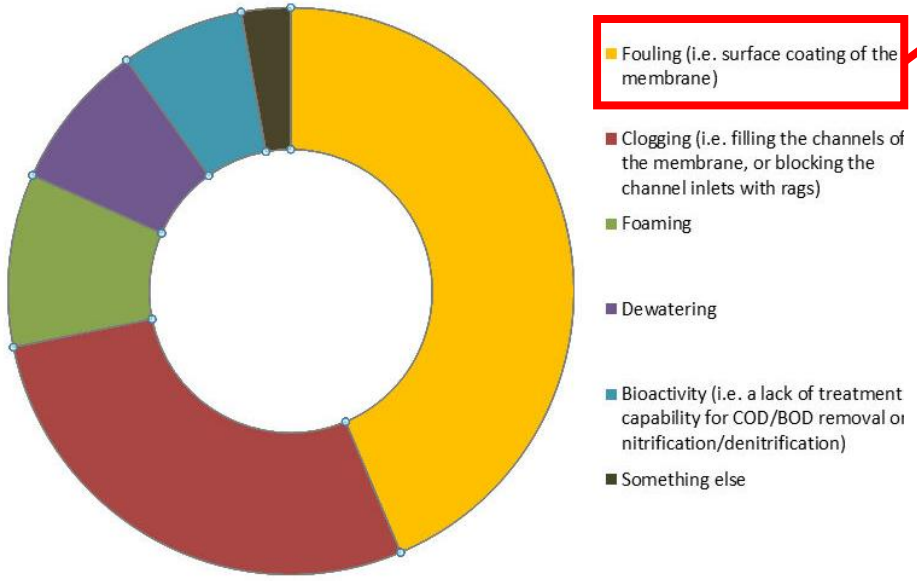
What's important about fouling (II)

- **It matters** to scientists and to operators.



Responses to the question: In your experience, what is the biggest challenge posed by MBR sludge?. Extracted from: https://www.thembrsite.com/features/the-2016-mbr-survey-results/

Another consequence of fouling

- Responsible for 40-50% of total specific energy consumed in submerged AeMBRs (Lousada-Ferreira, 2014).

Lousada-Ferreira M, Krzeminski P, Geilvoet S, Moreau A, Gil JA, Evenblij H, Van Lier JB, Van der Graaf JHJM. Filtration Characterization Method as Tool to Assess Membrane Bioreactor Sludge Filterability—The Delft Experience. Membranes. 2014; 4(2):227-242. https://doi.org/10.3390/membranes4020227

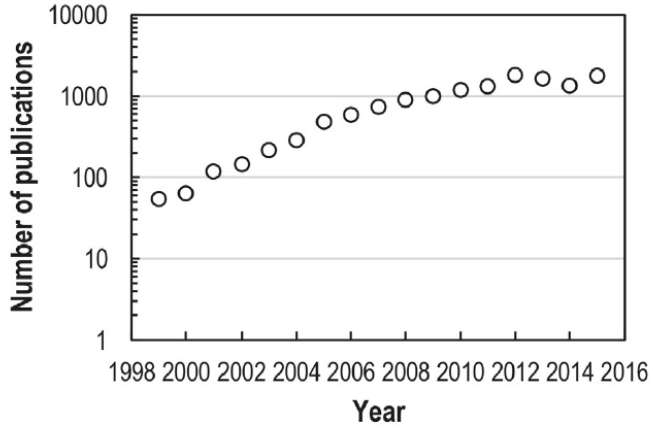


Fig. 1. The annual publications on MBR fouling (google scholar as literature database).

Cramer M, Kloth S, Tränckner J. Optimization and fouling mechanism of a thermophile submerged MBR (TSMBR) pilot plant for wastewater treatment in a paper mill, Journal of Water Process Engineering, Volume 17, 2017, Pages 110-116, https://doi.org/10.1016/j.jwpe.2017.02.008.

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Fouling indicators (I)

FOULING INDICATORS

- Other bulk classic parameters (OCR, SSV, SVI, CST, TTF…) or dead-end are debatable.
- **Sludge filterability** aims to represent the fouling propensity of sludge.

From: Lousada-Ferreira, M. Filterability and Sludge Concentration in Membrane Bioreactors; Technical University of Delft: Delft, The Netherlands, 2011.

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Fouling indicators (II)

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Filtration test cells	**Delft Filtration Characterization Method (DFCm)**	ΔR_{20}	m^{-1}	Evenblij *et al.*(2006) Moreau *et al.* (2009)
	Berlin Filtration Method (BFM)	Critical flux	$L/(m^2h)$	de la Torre *et al.* (2009a; 2010) (this study)
	VITO Fouling Measurement (MBR-VFM)	VFM_{rev}	%	Huyskens *et al.* (2008; 2010)
	***Ex situ* test cell**	Critical flux	$L/(m^2h)$	Rosenberger *et al.* (2002) Schaller *et al.* (2006)
		Filtration resistance R	m^{-1}	

From: De la Torre T. The Quest for a Universal Indicator for MBR Fouling. Technischen Universität Berlin; Berlin, Germany: 2013

	$\Delta R_{20}[\times 10^{12} m^{-1}]$
Good	< 0.1
Moderate	0.1-1
Poor	>1

Table. ΔR_{20} values and corresponding MBR activated sludge filterability-for standard DFCm measuring protocol.

From: Geilvoet, S. The Delft Filtration Characterisation Method, Assessing Membrane Bioreactor Activated Sludge Filterability; Technical University of Delft: Delft, The Netherlands, 2010.

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Advantages of monitoring sludge filterability (I)

INTEREST FOR OPERATORS

- Optimization of operation (filtration, relaxation/backwash, gas or velocity demands…).
  - F.ex. During good filterability periods

→ prolong the filtration protocol
→ decrease SGDm
→ increase hydraulic performance
→ improve the energy efficiency.

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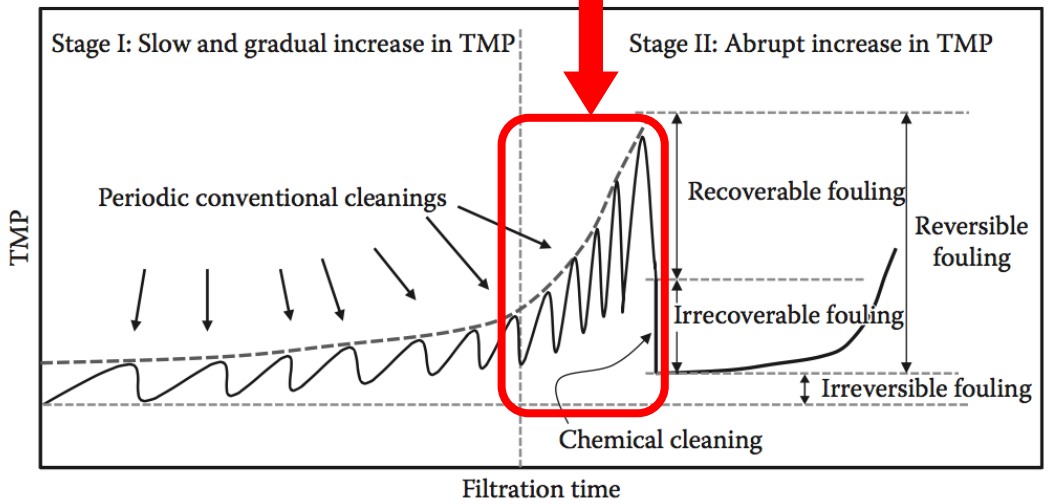
Advantages of monitoring sludge filterability (II)

INTEREST FOR OPERATORS

- Optimization of operation (filtration, relaxation/backwash, gas or velocity demands…).
- Identify the need of physical or chemical cleanings (= only when necessary) → minimize chemical consumption and exposure to membranes
- Early warning system for operators in case of bad sludge filterability
  → change in operation conditions in order to avoid excessive fouling.
  → look for causes / check disruptions (overload, bad mixing, presence of inhibitors…).



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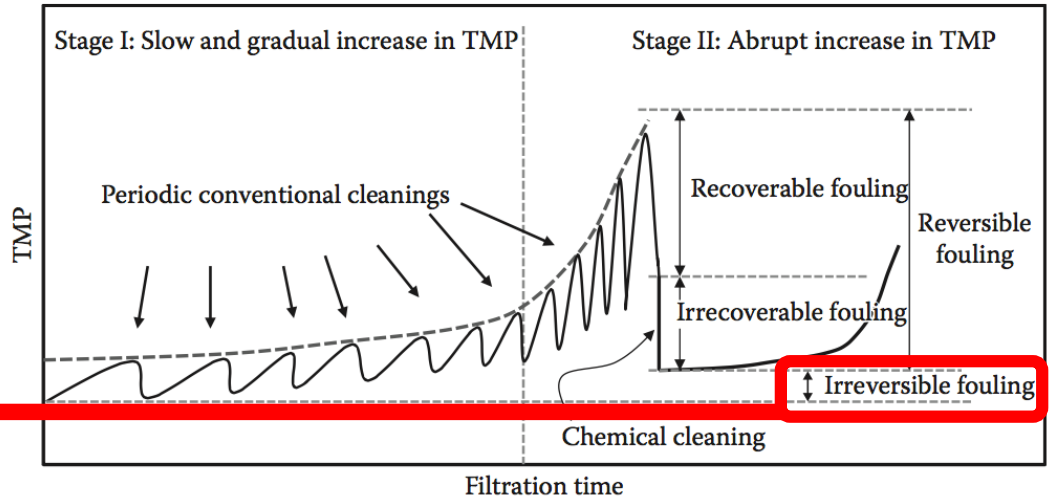
Advantages of monitoring sludge filterability (III)

INTEREST FOR OPERATORS

- Optimization of operation (filtration, relaxation/backwash, gas or velocity demands…).
- Identify the need of physical or chemical cleanings (= only when necessary) → minimize chemical consumption and exposure to membranes
- Early warning system for operators in case of bad sludge filterability
  → change in operation conditions in order to avoid excessive fouling.
  → look for causes / check disruptions (overload, bad mixing, presence of inhibitors…).
- Irreversible fouling can be estimated.



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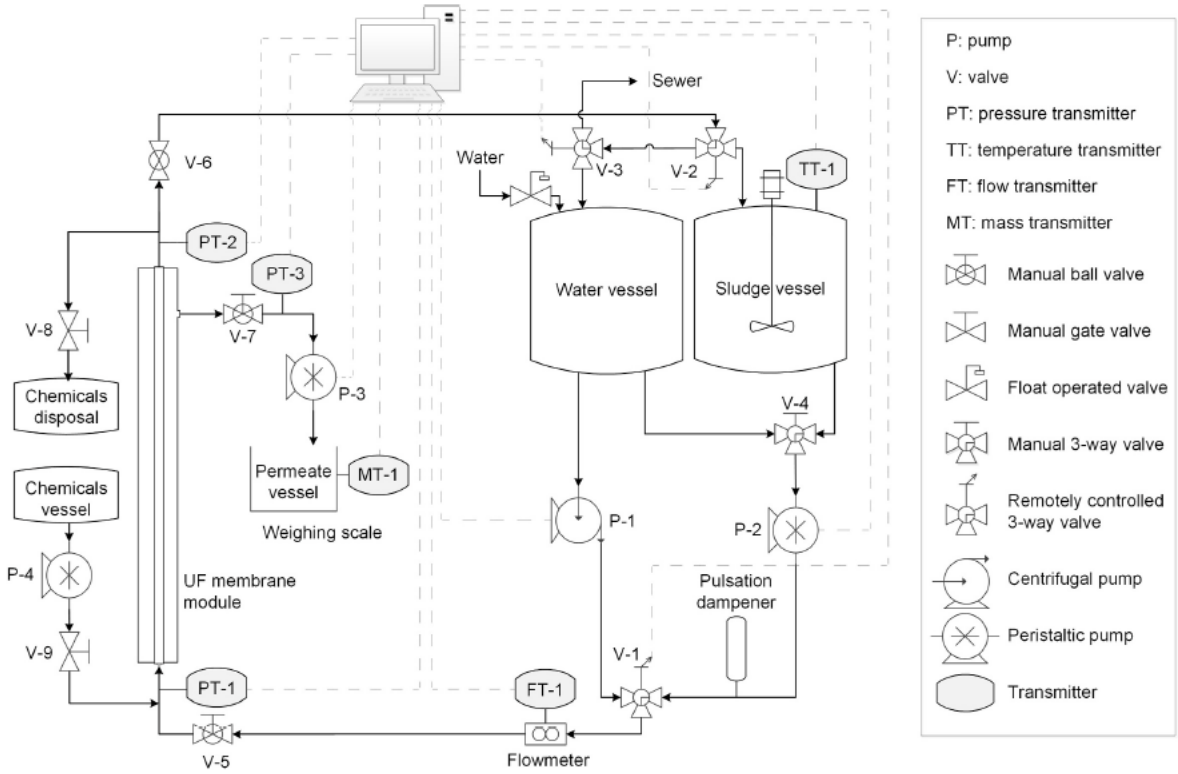
How we will do that? (I)

- Build & commissioning of the plant
  - Mobile (ex-situ), plug&play
  - Automatic
  - Integrable to SCADA



Odriozola M, Lousada-Ferreira M, Spanjers H, van Lier JB (2021). Effect of sludge characteristics on optimal required dosage of flux enhancer in anaerobic membrane bioreactors. Journal of Membrane Science 619 (2021) 118776

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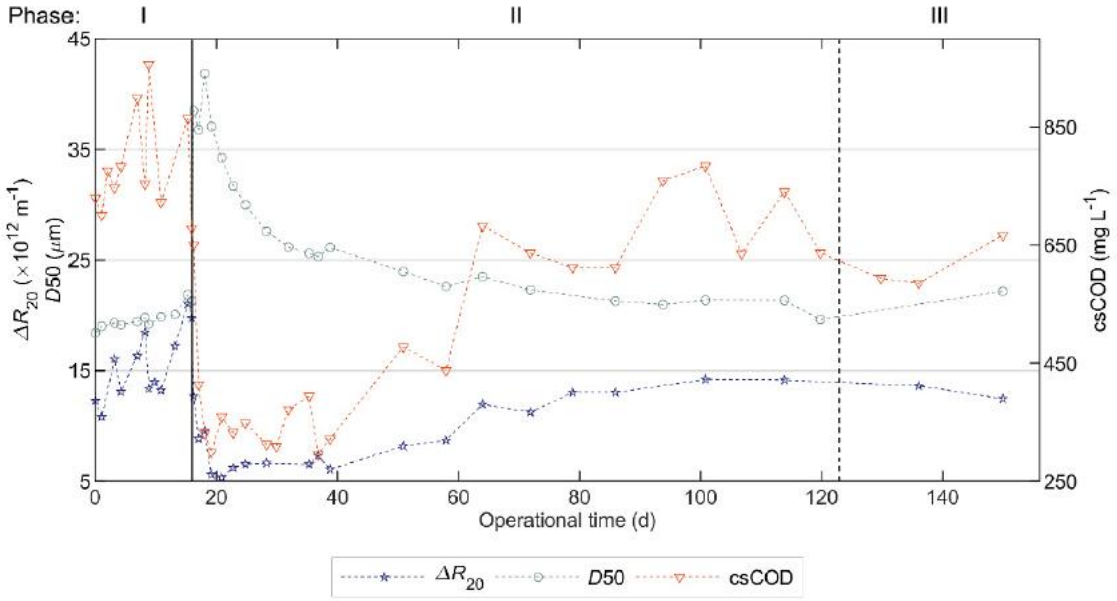
How we will do that? (II)

- Build & commissioning of the plant
  - Mobile (ex-situ), plug&play
  - Automatic
  - Integrable to SCADA
- Measure of ΔR_{20} in AnMBR in CS5
  - Correlate to permeability (K_{20}), SGD_m and other operating & analytical parameters
  - Compare with / without MB-MBR configuration
  - Procedures for operation optimization. Adapt to functioning logic.
  - Membrane screening / autopsy



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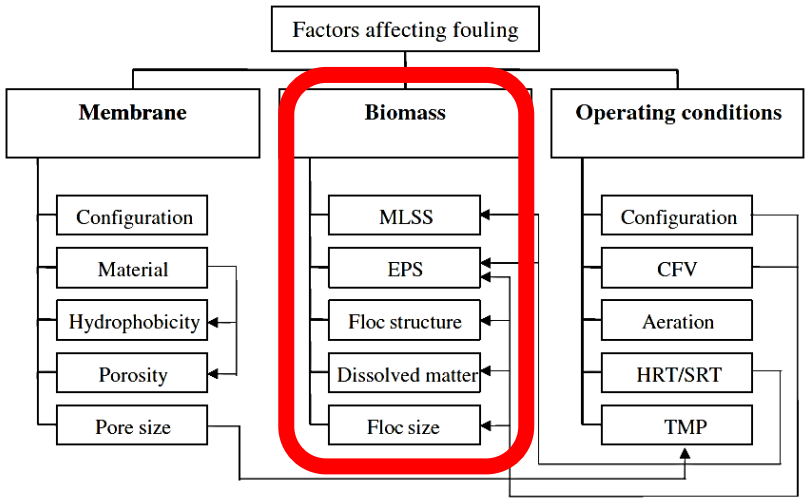
MBR + adsorbents → better filterability (I)

A way to improve biomass characteristics: add adsorbents, like activated carbon or biochar



Chang, I.S., Le-Clech, P., Jefferson, B. and Judd, S.J. (2002). Membrane fouling in membrane bioreactors for wastewater treatment, Environ. Eng. Sci., 128(11), 1018-1029)

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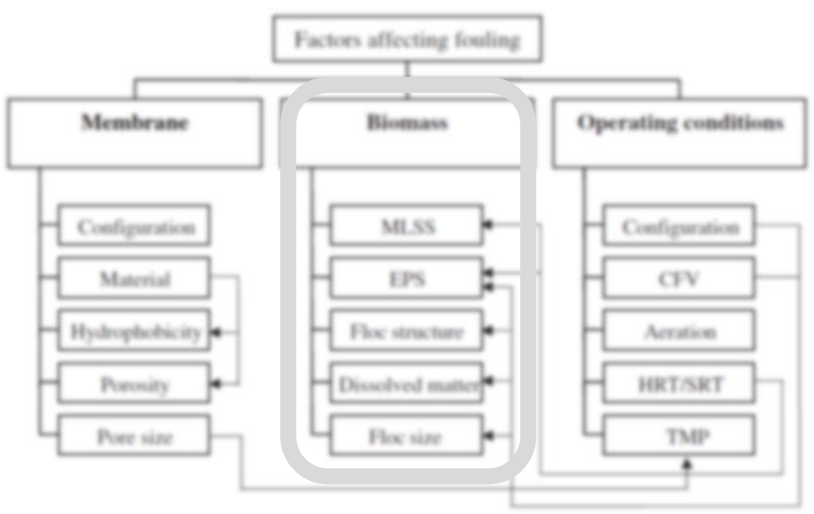
MBR + adsorbents → better filterability (II)

A way to improve biomass characteristics: add adsorbents, like activated carbon or biochar

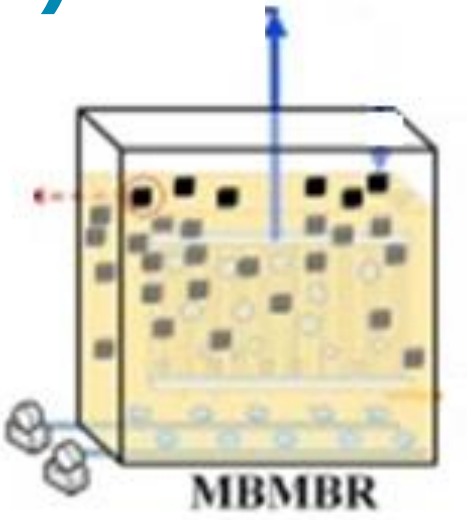


WHY ADD ACTIVATED CARBON IN A MBR?

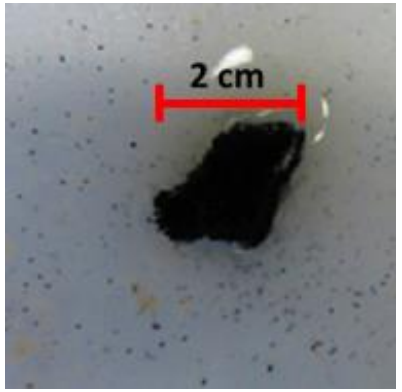
- Floc size increase
- Adsorption of soluble microbial products
- Micro-pollutant adsorption

EXPECTED RESULTS:

- Increase process stability
- Improvement of filterability
- Decrease of fouling propensity
- Increased filtration capacity
- Decrease of aeration needs
- Decrease of chemical cleanings
- Increase of membrane lifetime
- Decrease of membrane replacement
- Decrease energy expenditure



MBMBR =
Moving Bed Membrane Bioreactor.



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Valorastur project: tested MBR + biochar

AeMBR configuration	vs.	MB-AeMBR configuration
Mean permeated volume between CIPs: **9900 L**		Mean permeated volume between CIPs: **12375 L**
Consumed NaClO: 0.23 $g \cdot m^2_{membrane} \cdot treated\ m^{-3}$		Consumed NaClO: 0.19 $g \cdot m^2_{membrane} \cdot treated\ m^{-3}$

25 % more permeated volume between CIPs

17% less NaClO consump-tion

Conditions:

- Set-point TMP 250 mbarg
- $[NaClO]_{CIP}$ = 0.5 $g \cdot L^{-1}$

VALORASTUR

On behalf of the Programa RIS3-Empresa. Co-financed by:

PCTI ASTURIAS

Gobierno del Principado de Asturias

IDEPA Instituto de Desarrollo Económico del Principado de Asturias

Unión Europea

Fondo Europeo de Desarrollo Regional

More Info about Valorastur: https://www.aqualia.com/documents/14152670/14224452/6.+Ongoing+projects+-+Valorastur.pdf/eff63070-60f5-7f16-812c-ca3632f1aec1?t=1545234235000

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