nextGen
Circular Water Solutions

Factsheet – Anaerobic Membrane Bioreactor (AnMBR)

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DATE: 16/12/2021

VERSION: V5

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°776541

Anaerobic Membrane Bioreactor (AnMBR)

Unique selling points:

- ✓ No aeration energy for removal of chemical and biological oxygen demand
- ✓ Low sludge production and associated treatment efforts
- ✓ Chemical free process to remove methane from liquids
- ✓ Up to 99% methane recovered from the dissolved fraction
- ✓ Pathogen and solids free effluent which can be re-used in a number of applications (e.g. farming and industrial use)
- ✓ Compact equipment with low footprint – low operation costs

Description of the technology

Anaerobic membrane bioreactor (AnMBR) combines an upflow anaerobic sludge blanket reactor (UASB) with physical separation membranes, ultrafiltration (UF) for solid-liquid separation and membrane contactor for gas-liquid separation. As shown in **Flow scheme of the technology,** the UF membrane system is integrated with an upflow anaerobic sludge blanket reactor (UASB) in a side-stream configuration. This results in organic contaminant removal from wastewater and biogas production for energy recovery.

Furthermore, a **membrane contactor unit** (MCU) has become reliable and efficient for recovering dissolved gases such as methane (CH_4) from AnMBR effluents. This methane can be used as an energy source. MCU employs a microporous hollow fibre membrane, which is the most used configuration for MCU due to its high gas-liquid separation efficiency and very high surface area as compared to flat sheet membranes. In the process, water passes through the outside (shell side) of the hollow fibr es while a sweep gas (or vacuum) is applied to the

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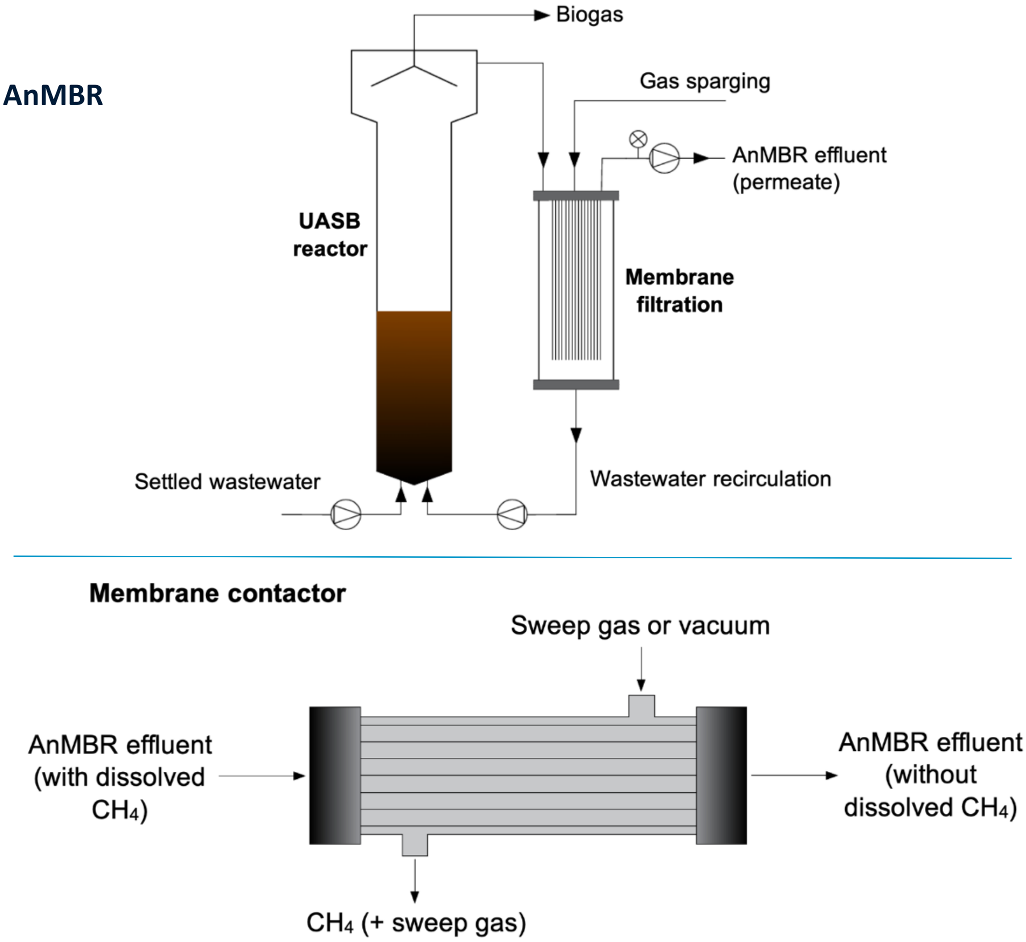
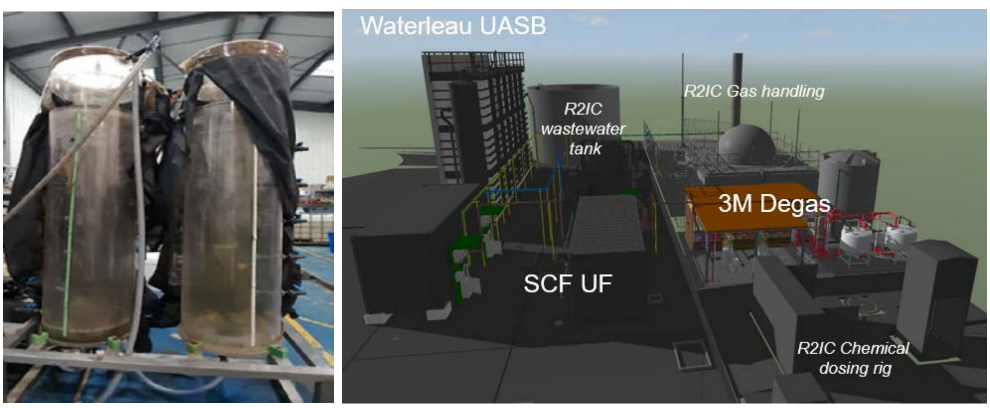
inside (lumen side) of the fibres. Because the membrane is hydrophobic it allows direct contact between gas and water without dispersion. Applying a higher pressure to the water stream relative to the gas stream creates the driving force for dissolved gas in the water to pass through the membrane pores. The gas is then carried away by a vacuum pump and/or sweep gas and combined into biogas to generate electrical and thermal energy (**Flow scheme of the technology**).

Flow scheme of the technology



Pictures of the technology



Pilot scale UASB rectors (left) and newly constructed Waterleau UASB (right)

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Synergetic effects and motivation for the implementation of the technology

✓ **Improvement of dewatering and reduction of dry matter**

Excess sludge production in the AnMBR is very low, but still this need extracted from AnMBR from time to time, to avoid high solids concentration reaching the UF side-stream module. This excess sludge can be further stabilised in an anaerobic digester (AD) and dewatered, together with the primary sludge. This sludge still has a high methane potential, and the organic matter is converted into biogas as well as leading to a further reduction in the total dry matter content in the digested sludge. The organic matter content in the sludge is reduced by about 50%, which is equal to a reduction in total dried solids of about 25-33%. As a result, transport and disposal costs can be reduced. Further to that, the treated sewage solids (i.e. biosolids) can be successfully used for fertilisation of land and for landscape purposes.

✓ **High quality product by combining with other conventional treatment processes**

Membrane contactor unit (MCU) is applied as post-treatment to the AnMBR effluent. MCU applications include removing biogenic hydrogen sulphide, carbon dioxide, oxygen and ammonia. Coupling **AnMBR with MCU** for wastewater treatment allows for the recovery of the dissolved methane, clean water rich in valuable nutrients. Under UK winter, up to 100% of the dissolved methane is found dissolved in the liquid phase, as wastewater temperatures are in the range of 6-8°C. Methane has a high greenhouse gas potential, and its recovery and management are crucial to ensure the technology low environmental impact. Furthermore, methane must be recovered to support the energy neutrality argument. Hence, the application of MCU mitigates environmental impacts and economic losses.

Requirements of the technology and operating conditions

There are several parameters that affect biogas production from anaerobic membrane bioreactors (AnMBRs), including hydraulic retention time (HRT), solids retention time (SRT), temperature, pH, organic loading rate (OLR). The feasibility of anaerobic wastewater treatment in the UK has been demonstrated through pilot-scale trials that have taken place at Cranfield University since 2003. The work completed to date has showed that treating municipal low strength wastewater (COD<400 mg/L) at real temperatures (6-22°C, with an average of 14°C) is feasible and it has potential to replace traditional energy consuming aerobic wastewater treatment processes. Hydrolysis is the limiting step, also emphasising the need to provide long sludge retention times to ensure stable biogas production and solids can be maintained in the reactor by using a membrane filtration after the UASB. This combined system has been thoroughly investigated at pilot-scale. The operational envelope includes fluxes of 8-13 LMH and HRT 4-12h. Membrane fouling is of physical nature and can be controlled by intermittent gas sparing practices using biogas, whilst still maintaining the process energy efficiency. The membrane operation can be turned up-down enabling design at average flow rather than full-flow to treatment. COD removals of 60-70% can be regularly achieved. Removals of 90-95% can be achieved when coupling the UASB with a membrane, producing effluents with 0 mg TSS/L; <20 mg COD/L and <10 mg BOD/L. Methane composition in the biogas is high (80%) facilitating its upgrading or other uses. On the other side, nutrients removal in the anaerobic reactor is negligible (5-10% phosphate removal and ammonia increase by 5-15% due to solids hydrolysis). Post-treatment for nutrients removal/recovery is necessary.

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Operating conditions

Parameter	Units	Min	Max	Reference
Anaerobic bioreactor				
pH	-	6	8.2	NextGen D1.4 (in prep.)
Temperature	°C	4	25	
Flow rate	m^3/d			
Hydraulic retention time (HRT)	day	3	15	
Sludge retention time (SRT)	day	10	150	
Membrane contactor				
pH	-	6	8.2	NextGen D1.4 (in prep.)
Temperature	°C	4	25	
Flow rate	m^3/d			
Water Flux	$L/m^2/h$	5	50	
Specific gas demand per membrane area	$m^3/m^2{\cdot}h$	1	10	

Key performance indicators

Parameter		Units	Min	Max	Reference
AnMBR Influent	pH	-			NextGen D1.3 (in prep.)
	Turbidity	NTU			
	BOD	mg/L	68	85	
	COD	mg/L	154	217	
	TSS	mg/L	117	129	
	VSS	mg/L			
	NH_4-N	mg/L			
	PO_4-P	mg/L			
	SO_4	mg/	62	70	
	E.coli	CFU/100 ml			
	Legionella spp.	CFU/100 ml			
	Faecal Coliform	CFU/100 ml			
AnMBR Effluent	pH	-			
	Turbidity	NTU			
	BOD	mg/L	37	45	
	COD	mg/L	61	100	
	TSS	mg/L	38	41	
	VSS	mg/			
	NH_4-N	mg/L			
	PO_4-P	mg/L			
	SO_4	mg/	42	45	
	E.coli	CFU/100 ml			
	Legionella spp.	CFU/100 ml			
	Faecal Coliform	CFU/100 ml			

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Removal efficiency	Turbidity	%			
	BOD	%	46	47	
	COD	%	54	60	
	TSS	%	68	68	
	VSS	%			
	NH_4-N	%			
	PO_4-P	%			
	SO_4	%	32	36	
	E.coli	%			
	Legionella spp.	%			
	Faecal Coliform	%			
Methane yield		m^3CH_4/kg COD	0.06	0.16	NextGen D1.4 (in prep.)
Biogas production		L/d	0.2	1.2	
Energy consumption		kWh/day			
Energy production (reuse)	Electricity*	kWh/day	35	105	
	Heat*	kWh/day	58	173	

*Theoretical calculation, as the biogas produced at Spernal is managed differently. These calculations assume: methane low calorific value of 35.7 MJ/m^3; Conversion efficiency of a CHP engine to electricity of 32%; Heat recovered from the CHP engine of 35% and Heat recovered from exhaust of the CHP engine of 18%.

Links to related topics and similar reference projects

Biogas Production	Reference
Anaerobic digestion	Case study "Braunschweig" (NextGen)
Thermal pressure hydrolysis	Case study "Braunschweig" (NextGen)

References

NextGen D1.3 New approaches and best practices for closing the water sector (in prep.), NextGen, Deliverable D1.3, Grant Agreement Number 776541. https://mp.nextgenwater.eu/d/Publication/73

NextGen D1.4 New approaches and best practices for closing the energy cycle in the water sector (in prep.), NextGen, Deliverable D1.4, Grant Agreement Number 776541. https://mp.nextgenwater.eu/d/Publication/74

Outlook

Case study specific information will be provided, when the results of the other work packages are available:

- Lessons learned from the case study
- Outcome of the assessments
- Legal and regulatory information concerning the whole value chain concerning the technology

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- Business opportunities

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