Side Stream Air Lift MBR Development and Successful Application of a New Generation of MBR

Peter Miller, NORIT X-Flow,
25a Avalon Parade, Avalon Beach,
NSW 2107, miller@xflow.nl
Ronald van't Oever, NORIT X-Flow,
Marssteden 50, Enschede,
The Netherlands, oever@xflow.nl
Stephan van Hoof, NORIT, Marssteden 50,
Enschede, The Netherlands,
vanhoof@noritpl.nl

One of the more recent applications of membrane technology is in membrane bioreactors (MBR). The MBR design target is an ideal combination of bacteria to reduce the organic content of waste and membrane technology to remove particulate matter to produce high quality water for reuse.

The first generation of MBRs were developed some twenty years ago for industrial applications and used tubular membranes in cross-flow mode to treat liquors with relatively high solids content. The bioreactor (BR) and membrane plant were separate process units. The advantage of better control of the cake layer build-up giving a consistent flux is offset by complexity and high energy costs and consequently was not commercially viable for treating municipal wastewater.

MBR became attractive for larger flows when pneumatics (air scouring) is used to refresh the flow across the membrane rather than hydraulics giving a significant reduction in energy consumption compared to cross-flow MBR. Consequently MBR became viable for municipal reuse leading to the second generation of MBRs.

In the second generation MBR the membranes are submerged in the BR. This is not an ideal arrangement as the BR requires good mass transfer of oxygen from the air i.e. a fine bubble size, while the membrane requires large bubbles to give adequate flow across the membrane surface to control fouling. This problem was addressed by separating the BR tank and submerged membrane tank so each can be operated at near optimum conditions. Although submerged membrane systems in the second generation are claimed to have low energy consumption, small footprint and can be adapted to existing BRs they are not ideal because of poor control of operating variables, difficult maintenance, relatively low flux and the risk of bio-contamination.

Membrane Skids positioned around BR Tank (under construction, Palm Is., Dubai. 17 MLD)

To address the deficiencies in the second generation MBR Norit X-Flow have developed, over 7 years, the third generation MBR for municipal reuse using their expertise in the first generation MBRs. The third generation uses vertical tubular membrane modules placed outside of the BR with air sparging to control the build up of biologically active cake on the membrane surface. The AirLift™ MBR is energy efficient, has a small footprint, simple to automate and maintain, uses robust long life membranes and produces high quality UF product water.

This paper reviews the development of the product through pilot plant proof of concept, demonstration plant trials for technical and commercial optimisation and presents case studies of commercial installations.

Development Objectives

The key development objective for the AirLift™ MBR was to produce high quality product water using biological degradation and membrane filtration at the lowest whole of life cost while simplifying system control and management when compared with submerged MBR.

Our objectives to achieve the key objective were –

1. Use UF filtration (high water quality)
2. Operate at a high flux (low CAPEX/OPEX)
3. Low energy consumption (low OPEX)
4. Long membrane life (low OPEX)
5. Position membrane system outside of tanks (simple maintenance)
6. Small foot print (low CAPEX)

AirLift™ Concept Design

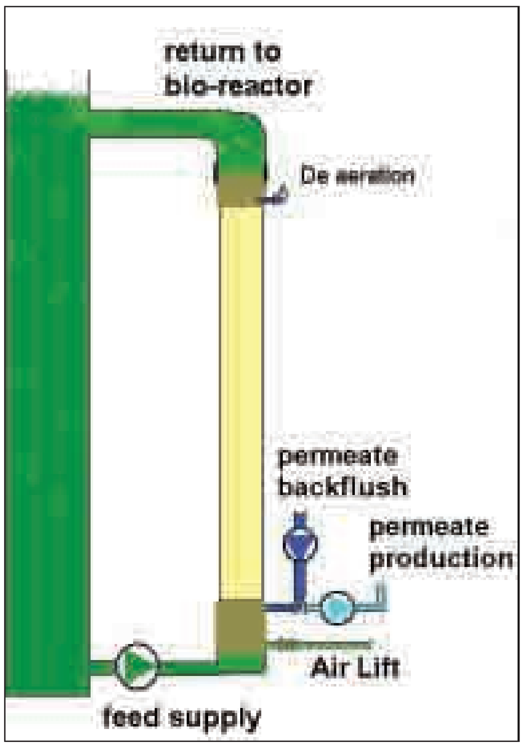
As the BR is established technology in MBR solutions, we focused our design efforts on the membrane system leading to the development of the AirLift® UF membrane system to separate the liquid phase (effluent) from the MLSS in the BR.

The UF system receives MLSS from the BR by means of a controlled circulation/booster pump. The circulation pump is used ensure a relatively constant flow of sludge from the bottom to the top of the membranes.

The AirLift™ system, where the membrane module is mounted vertically, is a modification of proven conventional cross-flow system design where the membranes are used in a horizontal configuration.

A vertical orientation allows the cross flow to be maintained by both a circulation pump and injecting air at the bottom of the membrane module to circulate the MLSS via a "air-lift" pump effect.

The injected air provides high turbulence at the membrane surface to maintain system flux. The net benefit of the AirLiftTM design is the use of proven tubular membrane technology with significantly reduced energy consumption.



Filtrate production in the AirLift™ design is regulated by a dedicated filtrate pump. A periodic short pulse from a back-pulse pump also helps to maintain a high flux rate.

The concept uses membrane modules assembled from Norit X-Flow 5.2 mm ID tubular membranes. The membranes are fabricated using PDVF on the inside of a non-woven polyester tube and have an absolute pore size of 35 nanometres (0.035 μm).

These membranes have been used in industrial and municipal applications for some 20 years and have a proven life of over 10 years.

Tubular Membrane Module

Proof of Concept

A number of pilot and demonstration plant studies were conducted over a 5 year period to prove the concept and establish the capability of the concept.

The first pilot was operated in Austria in the late nineties in association with local Universities and an engineering company. The BR used municipal effluent and initially 75 mm tubular pilot membrane modules later progressing to 200 mm commercial modules as operating conditions were established.

Test Results - Austrian Pilot		
Flux	$l/m^2.h$	45 – 60
Circulation flow	m^3/h	25
Airlift flow	Nm^3/h	15
BacK-pulse flow	l/m^2h	350
Interval	Filtration/backpulse	7 min / 4 sec
MLSS	g/l	9 - 13

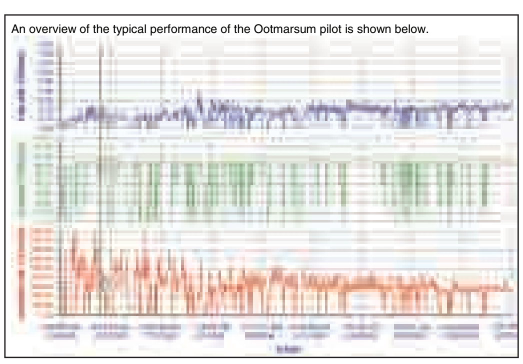
The plant was further expanded to multiple modules and the plant optimised. The results, tabulated below, for steady state operating conditions established the capability of the concept.

A second pilot was installed in Holland where initially a single module pilot was compared to submerged systems operating at the same site. A Dutch Engineering & Consulting company (DHV, Amersfoort) conducted the tests in cooperation with the Dutch Sewage Water Works Association (Stowa).

A spin off pilot from this second plant, where initial settings were established, now runs at a site in the city of Ootmarsum in the east of Holland where a municipal WWTP plant is under construction incorporating a 3.5 MLD X-Flow AirLift MBR. The plant should be on-line in the second half of 2007. The operating parameters for the pilot are tabulated below.

Ootmarsum Pilot Results		
Flux	$l/m^2.h$	45 – 60
Circulation flow	m^3/h	20
Airlift flow	Nm^3/h	10
Backwash flow	l/m^2h	350
Interval	Filtration/backwash	7 min / 7 sec
MLSS	g/l	10 - 14

An overview of the typical performance of the Ootmarsum pilot is shown below.

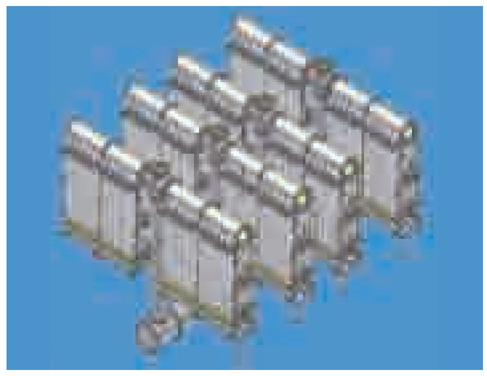


Graph of trans-membrane pressure (tmp), flux and permeability of the pilot in Holland

The third pilot to be described is in San Diego, California, and it has achieved Title 22 approval for Norit X-Flow partner Parkson Corporation. Typical operating data for the pilot is tabulated below

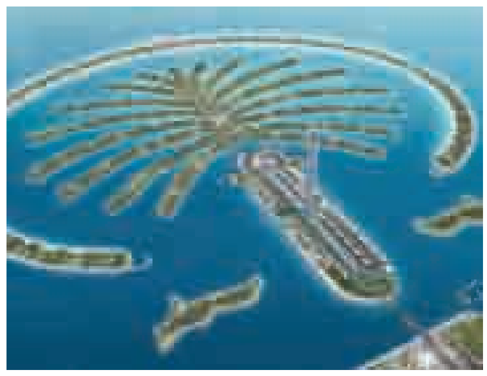
	Peak		Average	
Time	2 hours (2x per day)		except during peak	
Flux Rate	45 gfd	76.5 lmh	30 gfd	51 lmh
Circulation flow	95 gpm	$21.6m^3/hr$	70 gpm	$15.9m^3/hr$
Airlift flow	6 SCFM	$10\ m^3/hr$	6 SCFM	$10\ m^3/hr$
Backwash flow	240 gfd	408 lmh	240 gfd	408 lmh
Backwash Time	6 Seconds			
Backwash Interval	10 minutes			
Drain/Flush	Every 24 backwashes			
MLSS	10-11 g/L			
DO	1.7 mg/L			

Data from Report San Diego; MWH, Oct. 2006).



Millsborough, Municipal WWTP (4.2 MLD)

Port of the Islands (0.76 MLD)



The Palm Jumeirah, Dubaï

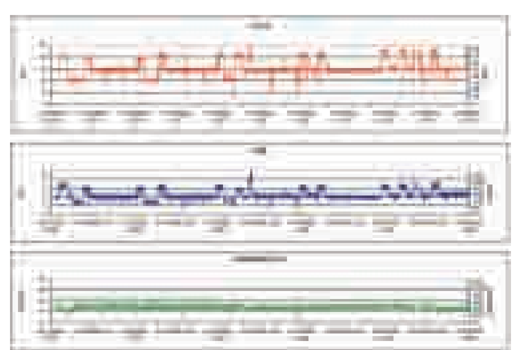
Above – Ootmarsum BR showing penetrations for return lines from membrane

The flux level (and power consumption) found in the pilot plant at a steady state flux rate of about 50 lmh and a peak flux of 75 lmh twice for 2 hrs each day are significantly higher than a submerged MBR. The peak flux is designed to handle diurnal variations in the feedwater flow.

An overview of the typical performance of the San Diego pilot is shown below.

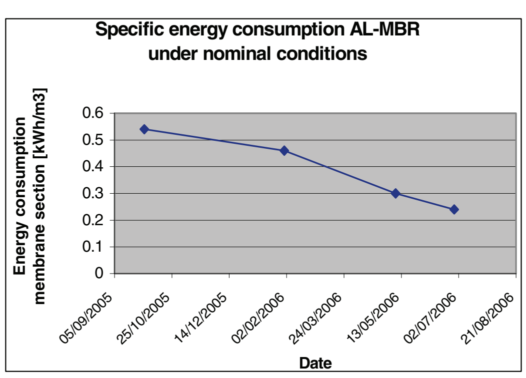
Some Highlights of Results to Date

Over the past two years plant optimisation has reduced the consumed power from 0.55 kWh/m3 to 0.25 kWh/m^3 of UF product water; among the lowest in the industry to date.



Graph of trans-membrane pressure (tmp), flux and permeability - San Diego pilot

By optimizing the hydraulic cross flow and the flow rate of air into the distributing section of the aerating device at the base of the membrane significant gains were made in flux and consumed power.



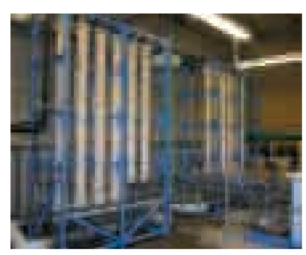
Proven Concept to Market Reality

Over the last 7 years the Norit AirLiftTM MBR has proven itself in both pilot and full scale plants, showing the capability of using membranes in a clean set up of easily serviced membranes skids installed external to the BR.

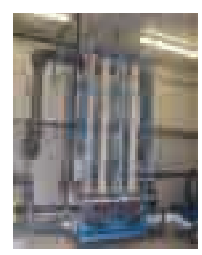
Operators look forward to running MBR plants from the HMI. This is now a reality as even the membrane cleaning can be executed automatically or by the push of a button without having to handle effluent covered modules.

Currently several smaller plants are operating in the USA and a number of larger plants are under construction in Europe and the Middle East.

The plants operating in the USA are treating municipal wastewater in small communities and pictures of two of these plants, operational since 2004, are shown below.



Glen Meadows 0.38 MLD



Saddle Ridge 0.19 MLD

Larger Municipal Plants

A number of larger plants are now under construction. The clean set up of the plant can be seen in the examples shown below.

The Netherlands: Ootmarsum, Municipal WWTP, 3.5 MLD

Designed with 6 identical skids to treat a variable feed volume and quality.

Middle East

The Palm Jumeirah, Dubaï is a prestige real estate development supplied with potable water from SWRO and reuse water from a 17 MLD Norit X-Flow UF AirLiftTM MBR currently under construction.

Conclusion

The original challenge of finding a way to apply tubular side stream membranes into a MBR application at a whole of life cost at least equal to or better than submerged MBR has been achieved while offering a small footprint, ease of automation and simple maintenance.

The THIRD generation of MBR is now a commercial reality.