OPERATING EXPERIENCE OF USING PRESSURISED MEMBRANE MBRS IN EUROPE FOR THE CLARIFICATION OF MUNICIPAL WASTEWATER

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ABSTRACT

As the municipal MBR market continues to grow R&D effort has been directed towards developing lower whole of life cost applications to the commonly used hollow fibre or flat plate submerged membranes. Recently developed side stream pressurised “dry mounted” membranes where the membrane is on the outside the bioreactor offers a relative lower whole of life cost while simplifying the maintenance of the membrane component of the MBR.

The dry mounted membrane technique is well established for industrial applications where the sludge (MLSS) is recycled from the bioreactor through tubular membranes for clarification. The conventional way of operating tubular membranes is based on high cross flow velocities and high energy consumption. With a move to a “greener” environment lower energy systems are required. Norit X-Flow has developed an application of the “dry membrane” concept called Airlift MBR which has lower energy consumption when compared to conventional submerged MBR.

Some 40 AirLift MBRs are now operating globally or under construction including four in Australia. Of particular interest is a medium sized, 14 MLD, plant operating in The Netherlands since October 2007 treating municipal wastewater in parallel with a conventional activated sludge plant with sand filtration allowing a direct comparison of the two processes with respect to product water quality, OPEX and CAPEX.

The operational data obtained since the start-up of the two processes are reviewed and compared with reference to the relevant parameters for the selection of either a conventional or an AirLift MBR process. Where the AirLift MBR is the preferred option the specification for the pre-treatment system, technical issues during construction and commissioning, process optimization and lessons learned for the design of future plants are reviewed.

INTRODUCTION

Waste water reuse is a growing market due in response to an increasing global demand for potable water replacement and in limited cases direct use. A number of technologies are applicable to treat the waste water depending by the quality required. Membrane bioreactors (MBR) have found their way into this field due to the high quality of the product water and reduced footprint.

In the past couple of years the Norit X-Flow AirLift MBR process has been developed with the specific objective of separating the biological and the membrane processes compared to submerged MBR. As a side stream membrane loop the membrane section operating variables can be specifically optimised to minimise CAPEX and OPEX when compared to submerged MBR. In earlier papers the specific technology is described in particular the automated draining procedure to remove detritus that can build up in the membrane system.

As of today the first large (3.6 MLD) municipal AirLift MBR plant has been operating for over twelve months during which time we have been able to compare full scale performance with original pilot findings and design expectations.

FIRST PLANTS

In the initial years of the development several smaller units AirLift MBR have been introduced into the market where the performance correlated well with the initial pilot plants. In Vienna a small plant has been performing for over a year at municipal waste water treatment, showing membrane performance of flux rates up to 60 $l/m^2.h$ and a permeability > 300 $l/m^2.h.bar$.

3.6 MLD MUNICIPAL PLANT

In the East of the Netherlands a small village, Ootmarsum, decided to use a special way of dealing with its wastewater.

Their waste water treatment plant (WWTP) could cope with the summer demand but was under capacity in winter due to the rise in the water table. As the receiving water is a small river the environmental impact of the discharge had to be minimised so the choice was made to use advanced treatment. A hybrid combination of conventional carrousel and AirLift MBR showed the best performance in the initial evaluation.

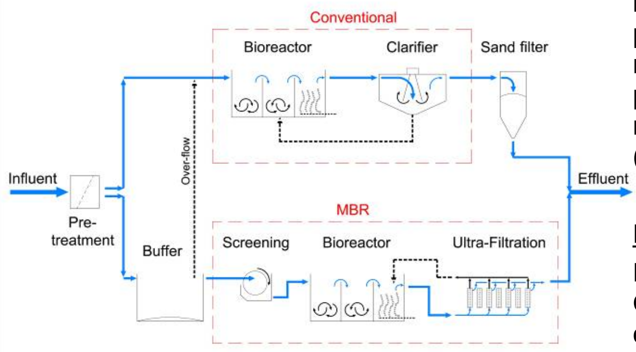

Fig I: design hybrid WWTP

UNIQUE ‘HYBRID’ CONFIGURATION

After a normal initial screening by a 6 mm bar screen and a cyclone type de-sander the influent is split into two streams shown in Fig 1. Half of the flow enters the conventional WWTP while the other half flows into a buffer tank. This buffer makes the WWTP unique. From the bottom of the buffer tank the water is treated in a drum screen as extra screening step to the AirLift MBR.

In case the influent flow to the buffer increases to over 150 m³/h, the buffer tank will overflow into the conventional section. The settled water overflows into the conventional (dealing with the peak flow). The smaller concentrated (settled) influent is treated in the MBR. In this way the high rainwater peaks are split hydraulically and biologically.

DRY SET UP OF MEMBRANES

The MBR installation in Ootmarsum uses a membrane plant in the ‘dry’ configuration employing the Norit X-Flow AirLift system. The membranes are next to the bioreactor in a dry area. This is unique in Holland for municipal WWTPs.

The membrane part exists of 6 identical parallel connected ultra filtration units. Feed is directly taken from the bioreactor (BR). Each unit has its own recirculation pump to maintain and ensure constant flow across the membranes. All six units will only be put in service when the variable input flow requires so. With lower flow, fewer units will be operational.

Fig 2: Ultrafiltration units MBR Ootmarsum

During the filtration there is a continuous scouring of the membranes by air, the so called AirLift^{TM} System. Permeate is extracted in a controlled manner ensuring sufficient filtrate per membrane unit. The UF filtrate (the effluent) is collected in a permeate tank which overflows into the receiving water. The water in the permeate buffer is used for back-pulsing the membranes at regular intervals to maintain performance of the filters. It is also used as make up water in case chemical cleaning (infrequent) of the filters is required.

DRAIN

During the pilot research period (WWTP Ootmarsum 2003-2005) it showed that hair and other small particles will agglomerate within the biology despite the extra screening in the drum screens. To deal with the agglomeration a drain procedure was introduced. During this procedure all material stuck in front of the membrane modules out of the system. A backflush -cleaning the modules afterwards - is removes all remaining fouling from the modules. This development has made the operation of the plant significantly more robust allowing of the drum screen to be increase from 0.8 mm to 2.0 mm further reducing operational cost of the plant.

START-UP

In the second half of 2007 the original plant was stopped and the new conventional plant commissioned without reducing the incoming flow. The MBR was commissioned immediately after the conventional plant.

The bioreactor was fed with sludge from the conventional plant and screened via the drum screens. During the start-up the sludge loading was kept constant to avoid any negative effects of sludge on the membrane plant. The plant was started at a flux rate of 50 l/m²h, using one of the six available lines. Without further cleanings the first three months were used to grow the biomass and showed the steady state performance of the membrane plant (ref. fig 3). It shows one of the filtration units (permeability) in relation to temperature and sludge growth. During sludge growth, temperature was dropping (onset of winter), but permeability remained constant.

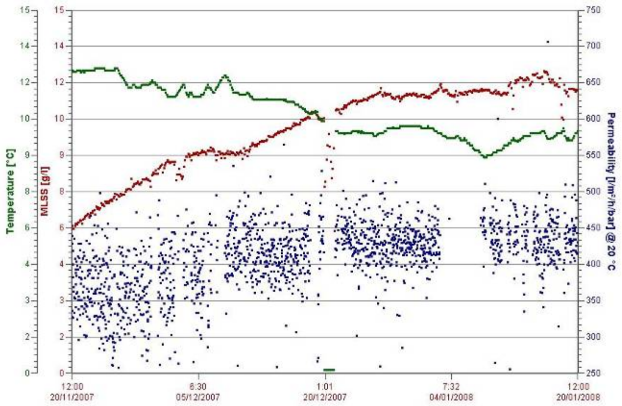

Fig 3: Membrane performance November 2007-January 2008

The frequent foaming problem usually experienced when establishing the BR did not occur. The design sludge level of 10-11 g/l, was reached in two weeks before commencing to remove excess sludge. The period did not see any sludge wasting.

When the dry matter in the BR reached 10-11 g/l sludge wasting was commenced. This waste sludge is treated on site by means of a belt press, using polymer to gain concentration of solid matter. This quick concentration is primarily done to prevent release of bio-P.

Operation was stable until the end oh January but at the beginning of February 2008 a reduction in the performance of the membranes was noted; the permeability of the membranes reduced significantly (ref. fig 4). The reduction in performance was due to a change in process settings of the sludge treatment where dry polymer dosing was substituted with liquid cationic polymer dosing. During optimization of the process large volumes of the un-dissolved polymer was discharged to sewer which was returned to the bioreactor and the membrane plant with the cationic polymer fouling the membrane.

After some research on this fouling layer, a single nights soaking in sodium hypochlorite restored the permeability to their original level. During a limited period (roughly two sludge ages) the effect of the polymer in the bioreactor reduced membrane performance but membrane performance was restored with two hypochlorite cleans.

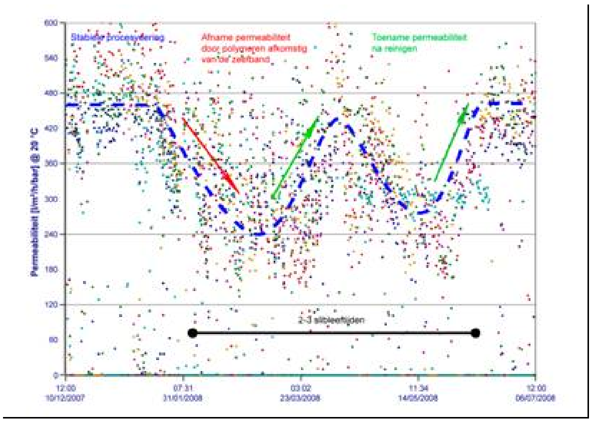

Fig 4: membrane performance ultrafiltration units 1 to 6 before and after polymer incident

ACTUAL PERFORMANCE

The MBR performance is now stable with
A typical membrane performance of 300 – 400 l/m².h.bar permeability at a flux of 50 l/m².h with sometimes increased flux rates (during rain water flow events) of 65 l/m².h. There are no intensive actions required to maintain the plant operation yet, based on our experience of other plants, there is room for further optimization. Operators are in control of the plant remotely most of the time and the required operational hours are less than budgeted.

SLUDGE QUALITY

In 2008 the sludge volume index (SVI) of both lines is constant. The conventional treatment plant has a SVI between 90 and 100, the SVI of the MBR is between 95 and 105. This is expected to be due to well chosen design of mechanical equipment, especially the re-circulating pumps.

The sludge production of the WWTP is also reviewed and as there has been significant period of sludge growth, it is more difficult to get a good view on sludge production. Currently specific research is ongoing to have data available on this production.

NUTRIENT REMOVAL

The feed to the WWTP show a clear summer/winter balance. This balance shows a clear influence of nutrient removal. The design was based on equal hydraulic loading during both summer and winter. In winter more ‘thin’ water would be brought in as the ground water level would be higher and in summer the water would be higher biologically loaded as the summer tourist season would be apparent.

Despite decoupling projects in the area the feed flow during winter is significantly higher than in summer (ca. 2.600 resp. 2.100 m^3/day). Higher ground water levels in combination with more buffer capacity of the sewer piping system are probably due to this. In the winter period the

WWTP has lower water temperatures with a high hydraulic loading of relatively ‘thin’ water. This will result in higher nitrogen emissions and a reduced biological phosphorus removal. In the beginning of the summer period a better nutrient removal developed, due to a higher biological loading of the system.

Table 1 shows the nutrient removal during the start up period.

Sample point	**TSS [mg/l]**	**BOD [mg/l]**	**N-Kj [mg/l]**	**NH_4-N [mg/l]**	**NO_3-N [mg/l]**	**P-total [mg/l]**
Total influent	225	223	50	29.6	nvt	7.7
Effluent NBT	1.4-12^{*1}	2.3	1.7	<0.1	2.0	1.4
Effluent Sandfltr	<1.2 – 2.7^{*1}	1.3	1.4	<0.1	2.0	1.1
Permeate MBR	<1.2^{*1}	0.8	1.3	0.18	2.5	2.3
Total effluent	<1.2-7.2^{*1}	1.2	1.4	0.11	2.2	1.7

Table I: average sampling start-up period January - August 2008
**1 Differentiation concentration un-dissolved components.*
Note: 1,2 mg/l is detection limit on TSS

All the air required for the membranes, sand filter and the bioreactors is supplied by a general air blower system. The disadvantage of this is that always a minimum amount of air needs to be supplied to the biology of the MBR. Especially during winter this amount is excessive, as it is combined with the amount coming from the membrane units. Currently the parties involved are reviewing the optimization of the oxygen balance. From the current analysis it shows that the blower capacity can be reduced based on the oxygen increase of the sludge via the membrane units.

MEMBRANE ENERGY CONSUMPTION

With stable operation of the membrane units and easily achievable fluxes up to 65 l/m^2.h the sludge and air recirculation velocities are being optimized (reduced) and the first energy savings achieved:

Energy consumpt.	**2003 (design)**		**2008**		**Future**	
	DW	**WW**	**DW**	**WW**	**DW**	**WW**
M. Feed pumps	0,24	0,18	0,12	0,09	0,06	0,08
M. aeration	0,30	0,23	0,22	0,17	0,15	0,14
rest	0,01	0,01	0,01	0,02	0,01	0,02
Total (kwh/m^3)	**0,55**	**0,42**	**0,35**	**0,28**	**0,22**	**0,24**

Table: overview energy consumption MBR
DW = Dry weather flow; RW = Wet weather flow.

With the expectation of further reductions in the future due mainly to current trials results from minimizing recirculation at optimum flux.

CONCLUSION

With the presented information it is shown that a full years’ running of a side stream tubular membrane plant performs significantly better than design. Energy consumption is proven to be significantly lower and reliability being higher with even higher expectations for the future.

REFERENCES

Buitenweg, J; Borgerink, R. 2008. H2O article: Hybrid MBR Ootmarsum exceeds expectation (translated).

Klegraf, F; Lahnsteiner, J. 2008. IWA presentation Vie