THE HELIX IN AIRLIFT MBR

"TWISTED MEMBRANES"

ABSTRACT

As the Airlift MBR process is celebrating its second decennium, there is a new development in tubular membranes which enhances the performance of an already astonishing technology. The Helix, patented tubular flux enhancing technique, is driving the operation to higher performance against less energy consumption.

A year long experience running a 'tubular membrane with a twist' showed the improved performance of this new membrane against the state of the art, smooth membrane as applied in the dry mounted Airlift MBR plant at Ootmarsum. This plant treats municipal wastewater by means of the Airlift process and has been equipped partly with the new membrane.

Extensive testing has shown the new product shows 40% increase of flux on day to day service, reaching a continuous flux of 70 l/m²h, driving the energy consumption further down to 0,22 kWh/m³ treated effluent.

In this paper an examples of a MBR project in the Netherlands will be discussed showing how an existing conventional activated sludge system has been upgraded successfully by integrating a MBR systems. These combinations offer a cost-effective solution for purification of municipal wastewater into high quality effluent suitable for safe discharge to environment and for a durable urban water chain management.

KEY WORDS

Helix; municipal wastewater; urban water reuse;

INTRODUCTION:

In Ootmarsum a full scale plant is built using the Airlift technology to treat municipal waste water and improve the water quality to discharge level to enhance the water absorbing this effluent. The plant is in operation since 2007 and is close to its first decennium birthday. The operator – the Water Board Vechtstromen – is looking for eventual further optimization of the plant and energy constumption of its operations.

Pentair X-Flow has meanwhile developed a new membrane which finds its performance enhancing technique in changing the shape of the tubes. This shape will enhance turbulence and improve performance according to the first trials on the development. In combined efforts the existing plant was equipped with a set of these new membranes for one of the 6 existing skids and the unit was compared to the remaining 5 skids using the classic configuration.

TECHNOLOGY

The first (industrial) MBR-systems were based on the cross-flow mode due to the relatively high solids content. The advantage is a better control of the cake layer build-up resulting in a more constant flux; drawbacks are a more complex system and the higher energy costs. The application of the MBR for municipal wastewater was not attractive due to the large flow with relatively low solid contents to be treated. This technique, however, became more attractive for larger flows with the introduction of systems where the refreshing of the feed along the membrane is not realized anymore by hydraulics but by pneumatics (aeration).

The energy cost can be reduced significantly if the membranes are cleaned by means of air scouring and not anymore by cross-flowing of the feed solution. Moreover, permeation is forced not longer anymore by over-pressure, but by under-pressure (suction).

Current developments are in the direction of the subdivision of the total MBR system in (at least) two main parts being the tanks for the biological processes, and the tanks for installing the membranes. The original advantage of creating a very compact system by installing the membranes in (a part) of the aerobic section is not valid anymore caused by the call for more flexible systems.

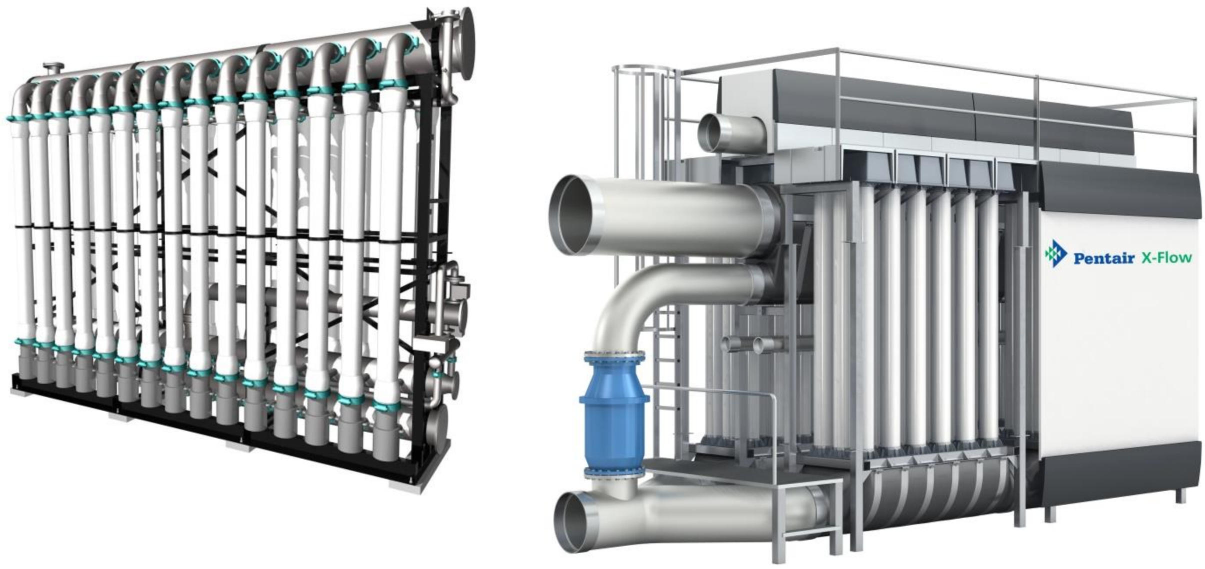


Figure 1: Airlift side-stream MBR system: (left) skid mounted; (right) Mega Block.

The AirLift MBR-system consists of a bioreactor with an external loop with membranes outside of the bioreactor vessel (or basin) [1]. This side-stream way of sludge filtration enables almost all the possibilities to optimise individually the bioreactor and the membrane system, such as a large flexibility in coping with changes in hydraulic capacity and optimal distributions of flow over the different sections in the bioreactor.

The distinguished process parts make the membrane inspection and replacement very easily without removing complete cassettes with membranes out of the bioreactor. In industrial applications this way of applying membranes in separation of water from sludge has lead to very compact units with highly efficient transition of the waste. The introduction of air-driven sludge circulation instead of hydraulic circulation has reduced the energy consumption to typically around 0.25 to 0,30 kWh/m^3 which is nowadays fully compatible with the submerged systems. The inside-out principle of membrane operation leads to a high membrane performance with typical fluxes between 50-65 $l/(m^2.h)$.

The original AirLift MBR concept consists of a series of staggered skids which can be tailored flexibly to the customer's needs due to its modular design (Figure 1a). The new generation Airlift MBR has been redesigned completely to enlarge the output, to improve the process stability, and to offer more process flexibility, while lowering the CAPEX/OPEX balance; decreasing the system footprint; and reducing energy, chemical use and waste production.

The membranes applied for these units are 5 mm ID enforced membranes made of PVDF and have a nominal pore size of approx. 30 nm.

DESCRIPTION HELIX

Tubular ultrafiltration technology with a twist. This is the way you could describe one of the new developments of Pentair X-Flow from Enschede. The research has addressed the major bottleneck on the productivity of high-solids UF which are concentration polarization and cake buildup.

Ultrafiltration and concentration polarization.

When a stream containing particulate matter such as bacteria, viruses, proteins – is filtered, the solids are totally retained by the membrane. Only soluble compounds and water can ultimately pass through the 40 nanometer sized pores. The rejected solids accumulate at the membrane surface forming a cake layer which restricts water flux and therefore productivity of the system.

In order to keep the cake formation under control, tubular UF membranes have to operate at relatively large crossflow velocities, commonly in the order of several m/s. The higher the crossflow velocity, the more significant turbulence occurs in the tube and therefore the cake gets more efficiently removed. Unfortunately, this comes at a cost of high energy consumption. X-Flow have resolved an old conundrum- achieving high turbulence high whilst keeping the energy consumption low.

PRINCIPLE OF FUNCTION OF THE HELIX TECHNOLOGY

A tubular membrane is essentially a round pipe with selectively permeable smooth walls. The extent of turbulence in a round pipe is expressed by the Reynolds number which is a function of the tube diameter (5,2mm) volumetric flow rate (m3/s) and viscosity of the filtered medium (Pa/s). The higher the Reynolds number, the stronger the turbulence.

The importance of turbulence is especially high close to the membrane wall, where the cake accumulates.

The new generation of tubular membranes helix is introduces turbulence right to the membrane wall. The wall of the membrane is decorated with a helically winding ridge (Figure) which causes enhanced mixing and efficient removal of the cake even at low crossflow velocities. When the cake is removed, more permeate flows through the membrane which results in higher productivity and diminished operational expenditure.

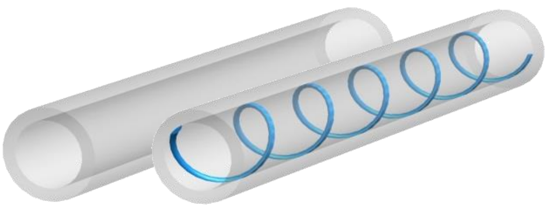


Figure 2: Helix

DESCRIPTION PLANT

In the comparison of the two membranes at the Ootmarsum site, one of the skids, in operation since 2007, were equipped with the helix membrane modules, and the remaining membrane skids absorbed the lot from the sixth skid (each of the skid had 14 modules, now each had 16).

From week 10, 2015 the plant has been in continuous operation where skid 6 (the helix-version) was prioritized to run continuous where the rest remained on duty only if flow required.

The existing plant had run under base conditions of operating as can be found in table below as per design:

Feed flow:	0,48 m/s
Airflow:	0,18 m/s
Flux (gross):	50 l/m²h
Flux (net):	ca 40 l/m²h
Typical energy:	ca. 0,3 kWh/m³

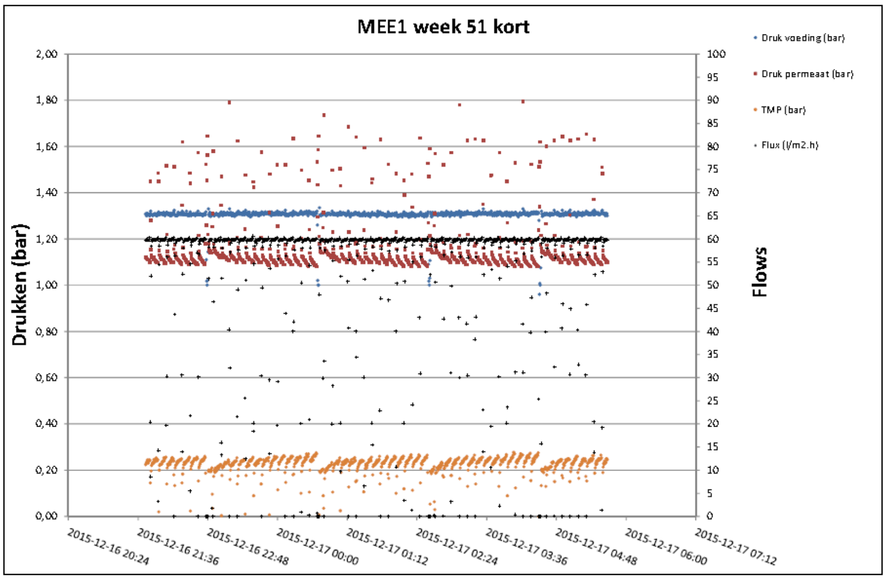
In the trials and operation applied the existing membranes were tested to its limit and the helix was tested to maintain steady conditions for continuous operation, each based on the same feed flow and air flow rates as mentioned above.

One limitation was reducing the optimization, being the capacity of the permeate pumps. The helix skid was not able to pump more water than at flux 75 l/m²h.

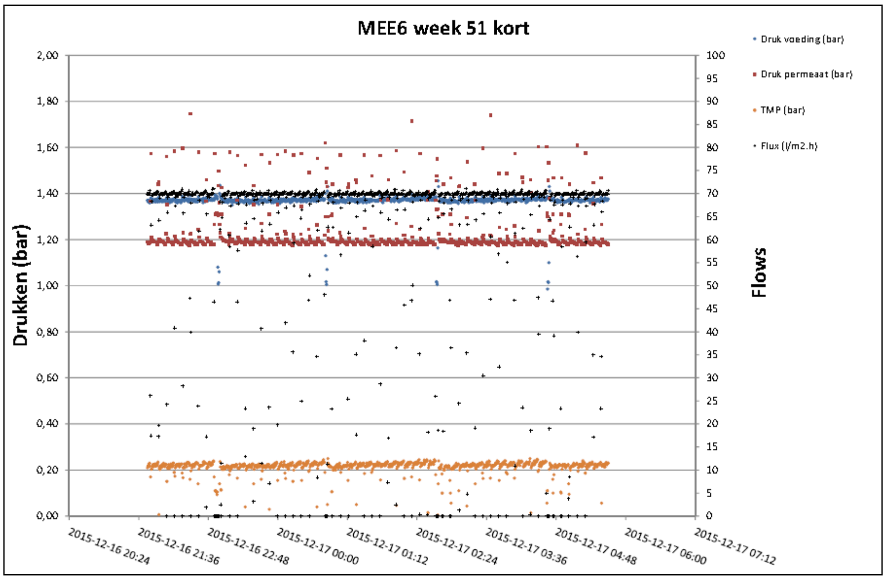
RESULTS

The design parameters found in the table above are achievable with the current lot of membranes. After thorough cleaning it was even possible to improve the operation to reach higher fluxrates than before: Below graph of first skid (MEE1) showing flux (in black) and TMP (Trans Membrane Pressure) (in orange).

Note: setpoint is flux (60 lmh); TMP to follow (here approx. 0,2 – 0,25 bar).



Graph 1: optimized performance of existing membranes.
In below graph identical conditions used on the helix product gave following results:
Note: setpoint is 70 l/m²h. TMP to follow (here just over 0,2 bar).



Graph 2: results using Helix membranes under identical conditions

Following the results of the various trials the plant has been evaluated towards operation and output.

Based on the original design values the plant can operate at significant higher output flow.

Was the original design parameter 50 lmh, the current performance shows 70 l/m²h is possible. This is a 40 % increase. But as can be concluded from the first graph shown, also the base product can be run at higher flux, improving the operation of the plant.

With the higher output, against a similar condition, the filtration capacity has gone up against the same power imput. As a result the membrane performance dropped to 0,20 kWh/m³ for the full scale plant in case it would be transferred into a complete helix plant.

In this case the client still has valid membrane life in the plant and keeps the helix in for the 6th skid. Once the other skids may need membrane replacement, the new membrane will be likely applied, given the better performance.

CONCLUSIONS

Despite the improved turbulence inside the tubular membranes reached by aeration in the Airlift process, the helix adaption of the tubes did enhance the performance a further 15 – 20 % compared to the improved performance of the base membranes.

Comparing to the design values of the original plant a 40 % improvement can be achieved.

REFERENCES

[1] H. Futselaar, R. Rosberg, J. Jacobs, L. Broens, Norit AirLift MBR: Large-Scale Side-Stream System for Municipal Waste Water Treatment, In Proc. of the IDA World Congress, Maspalomas, Gran Canaria (Spain), October 21-26, 2007.

[2] P. van Lierop, J. Nonnekens. Optimalisatie MBR Ootmarsum (2016).