

HYBRID MBR FOR INDUSTRIAL REUSE OF DOMESTIC WASTEWATER IN THE NETHERLANDS

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1 Introduction

Domestic wastewater from the City of Terneuzen in the Netherlands has been reused for process water for the DOW chemical industry since 2007. Currently 550 m³/h is reused for the production of demineralised water. The project is a cooperation between Evides Industry Water, operating the plant for producing demineralised water and the Water Authority of Zeeuws-Vlaanderen, operating the wwtp. Wwtp effluent is treated with microfiltration, followed by two stages of reverse osmosis. The present flow scheme is given in figure 1.

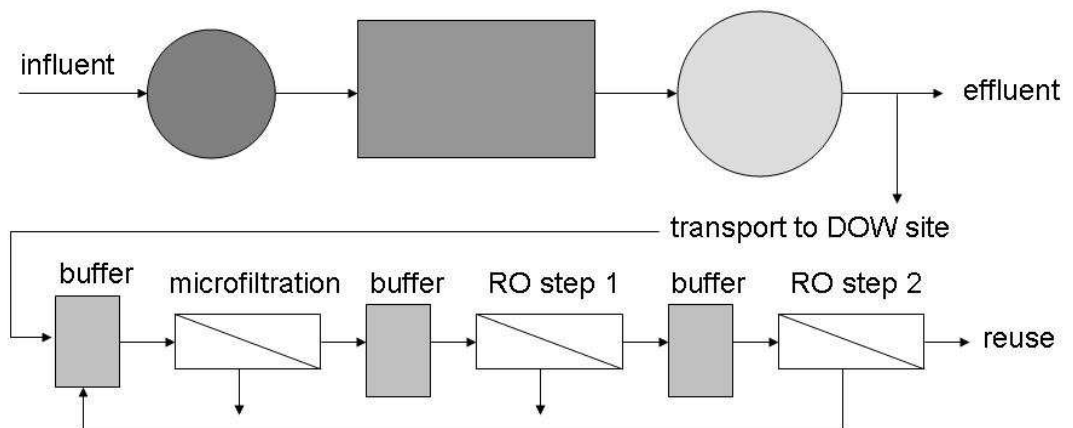


Figure 1: Flow scheme of the present situation

During the period 2001 - 2007 the reuse plant was already operational using sea water (Agtmaal 2007). As a result of the total running time the microfiltration has to be replaced in the coming years. At the same time the domestic wwtp needs refurbishment. To combine both projects the wwtp will be extended with a hybrid MBR. The MBR permeate will be treated in the reverse osmosis directly. The future flow scheme is given in figure 2. The combination of both projects will be more economical compared to extension of both plants individually.

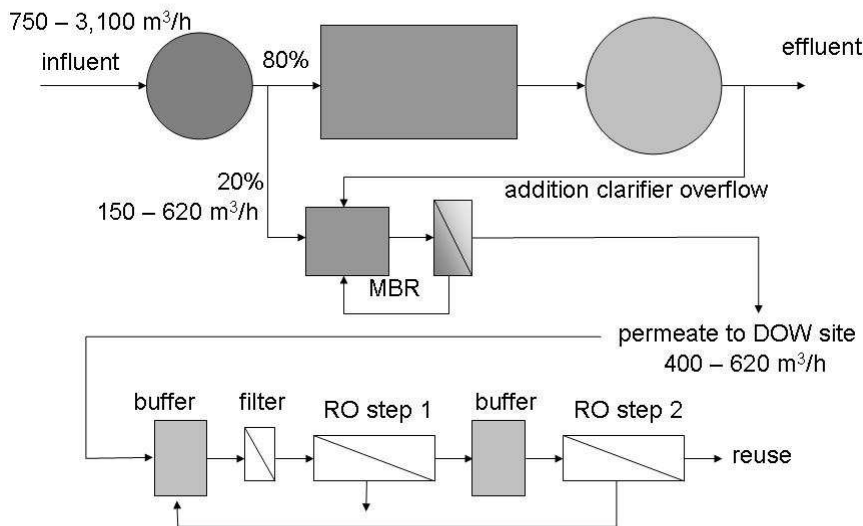


Figure 2: Flow scheme of the future situation

2 Description of the hybrid MBR

The wwtp is upgraded with an MBR in parallel with the conventional activated sludge plant. In table 1 the design data of the future wwtp have been given.

Biological capacity (p.e.)	77,500
Hydraulic capacity dry weather	1,140
Hydraulic capacity storm weather	3,100
COD load	6,850
TKN load	765
T-P load	120

Table 1: Design parameters of the wwtp of Terneuzen

Both the conventional plant and the MBR treat presettled wastewater from the primary clarifier. The MBR serves 20% of the total plant capacity. As a consequence the hydraulic load to the MBR will be variable with a maximum of 620 m³/h during storm weather flow.

The water demand for reuse purposes is independent from the inlet of the MBR with a maximum of 620 m³/h which corresponds with the maximum inlet flow. On a regular basis the wastewater flow to the MBR will be lower than the water demand for reuse. An increase of the wastewater flow to the MBR will result in an overload of the biological process and should be avoided. To meet the permeate demand overflow from the final clarifier is added to the MBR as illustrated in figure 2.

For the membrane filtration a side stream airlift of Norit has been selected. Membranes are placed outside the bioreactor in a vertical position. Aeration is responsible for air scouring. The system is illustrated in figure 3. Full scale experiences with this system show good results, with a low energy demand (Futselaar 2007).

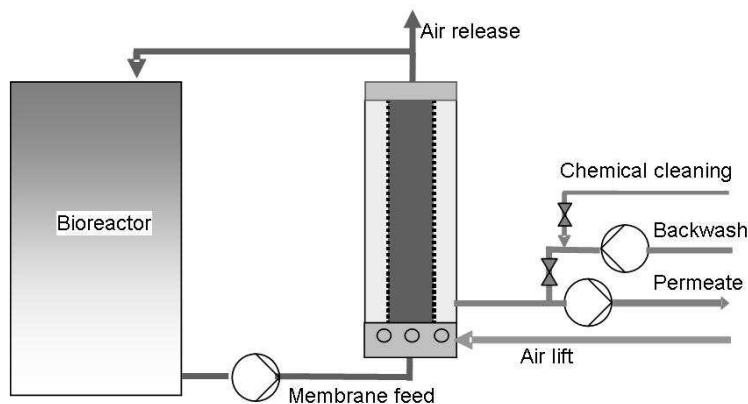


Figure 3: Principle of the airlift MBR system

3 Pilot plant research

In the hybrid MBR clarifier overflow will be added to produce enough permeate. Because clarifier overflow contains particles potentially influencing membrane filtration. As a consequence more particles will enter the membrane filtration in comparison with a normal MBR application. These particles are retained in the MBR and will finally be discharged with the waste sludge. During the design the effect of this extra effluent addition was unknown. Either the extra particles can be bound in the activated sludge, or more free particles can remain in the fluid phase. This gives a potential risk of influencing membrane performances. As a validation of the design pilot plant research has been carried out. In table 2 the pilot plant dimensions are given.

The pilot research has been carried out in 4 phases with varying ratios of wastewater to clarifier overflow. The membrane filtration capacity was unchanged during the entire research period. After introduction of clarifier overflow addition the wastewater flow was lowered to keep the membrane flux constant. As a consequence also the volume of the bioreactor had to be limited by lowering the water depth. For a further reduction of the volume during the phases 3 and 4 the denitrification compartment had been taken out of operation. Nitrification and denitrification have been controlled by intermittent aeration during these phases.

Phase		1	2	3	4
Wastewater/clarifier overflow		100:0	67:33	50:50	23:77
Nitrification tank	m ³	7	5	--	--
Total volume bioreactor	m ³	16	11	8	6
MLSS concentration	g/l	10.4	10.7	9.3	11.7
F/M ratio	g BOD/g mlss*d	0.04	0.04	0.04	0.04
Membrane modules		2	2	2	2
Total membrane surface	m ²	58	58	58	58
Gross design flux	l/(m ² *h)	40	40	40	40
Net design flux	l/(m ² *h)	32	32	32	32

Table 2: Dimensions of the pilot plant

In the presettled wastewater the BOD:N ratio amounts to 2.5. The limit for total nitrogen in the permeate is 10 mg/l. To sustain the denitrification extra carbon source from soft drink industry has been dosed. This dosage is also applied in the full scale plant. Phosphorus is removed chemically by dosage of FeCl₃. The limit for total-P in the permeate is 2 mg/l.

4 Results

a. Bioreactor performance

In table 3 the results have been summarized. For most parameters the effluent quality is meeting the demands, except for NO₃-N. High concentrations are related to practical limitations of the pilot plant, mainly the aeration capacity which appeared to be too high. Next to this there were technical failures in the equipment for the dosage of external C-source. As a result the denitrification was unstable, with both periods with high and periods with low concentrations for NO₃-N. Concentrations in the permeate varied between 1.2 and 35 mg/l.

Phase		1	2	3	4
COD in	mg/l	359	370	358	283
COD permeate	mg/l	43	29	35	28
Removal COD	%	88	92	90	90
TKN in	mg/l	50	40	51	45
TKN permeate	mg/l	2.6	3.0	2.8	3.1
NO ₃ -N permeate	mg/l	15.0	7.1	13.2	13.6
Removal TKN	%	95	92	94	93
Removal N-tot	%	63	76	69	63
Total P in	mg/l	9.1	6.9	6.2	6.0
Total P permeate	mg/l	4.9	0.7	0.8	1.7
Removal P-tot	%	46	89	86	71

Table 3: Results pilot plant bioreactor

b. Membrane performance

The membranes are used with a continuous flux without daily fluctuations. Addition of clarifier overflow is responsible for maintaining the continuous flow. In the pilot plant the ratio between the wastewater flow and clarifier overflow addition was fixed during the different periods.

In the figures 4 and 5 the performance of the membranes is illustrated. The performance was very variable throughout the research period due to technical failures. In the figures only the periods have been selected with a stable operation of the MBR process. The setpoint for the gross flux was 40 l/m²*h continuously. The net flux has been between 30 and 35 l/m²*h (figure 4). The permeability varied between 200 and 500 l/m²*h*bar (figure 5). No negative influence of the addition has been noticed.

c. Membrane cleaning

Membranes have been cleaned periodically by a backwash with NaOCl (400 ppm) and citric acid (1% – 2%). The frequency of chemical cleaning is strongly dependant on the stability of the biological process. Mainly in periods with technical failures in the pilot plant a frequent cleaning is required. The interval between chemical cleanings varied between 1 weeks and 6 weeks.

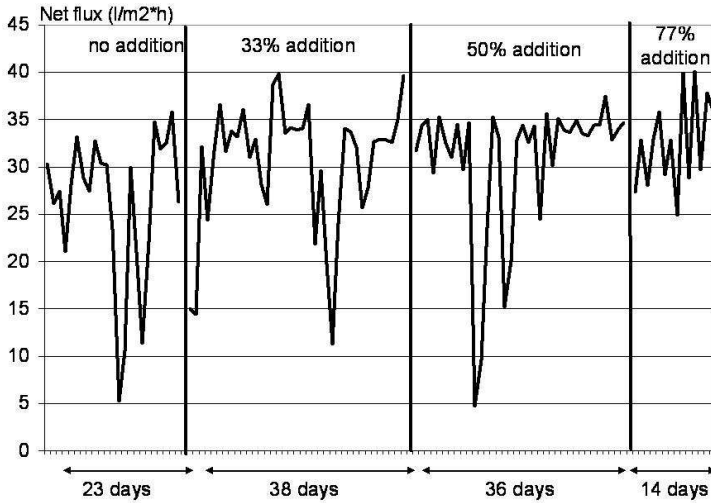


Figure 4: Net flux in the membrane modules

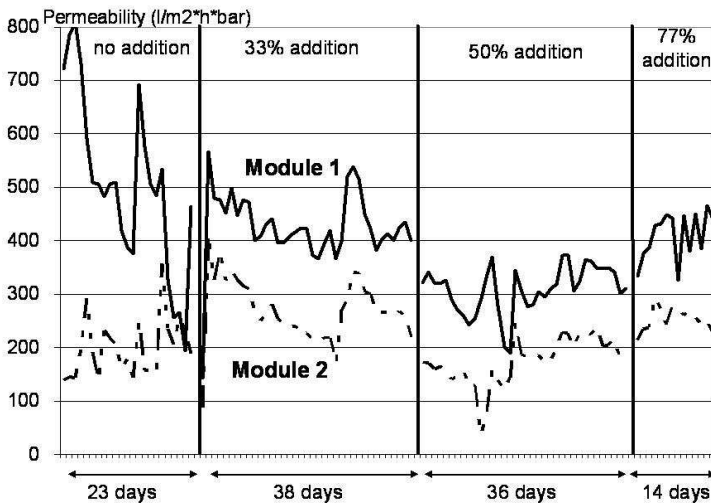


Figure 5: Permeability in the membrane modules

d. Measurement of filterability

For a better insight in the filterability of the sludge the DFCM method had been applied (Evenblij 2005). In this test permeate is produced by a tubular membrane at a supercritical flux of $80 \text{ l/m}^2\cdot\text{h}$. After 15 minutes of filtration the TMP over the membrane is a measure for the filterability of the sludge.

With the DFCM the influence of addition of clarifier overflow has been tested. Sludge samples were mixed with clarifier overflow in different ratios. All samples were thickened to the same mlss concentration. In figure 6 the results of 2 series of filtration tests are given. All figures below 1.0 can be considered as good filterable sludge. No significant influence of the addition on filtration characteristics have been noticed.

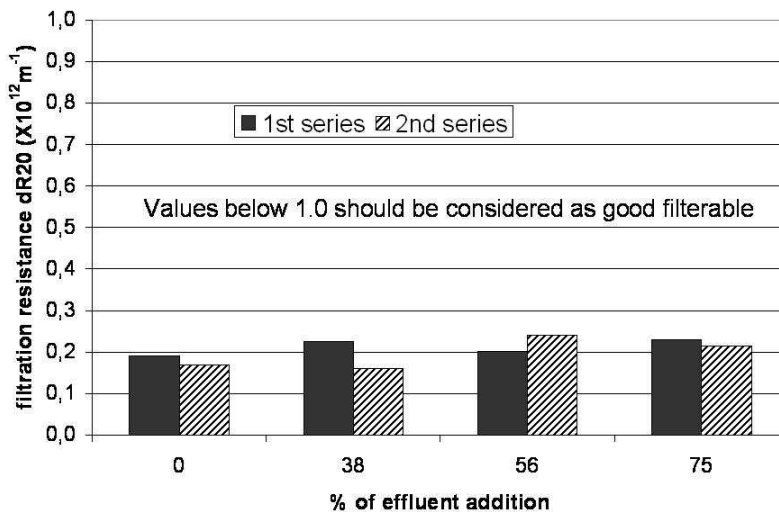


Figure 6: Results filterability experiments

5 Discussion

The results of the biological process was meeting the requirements except for nitrate. The $\text{NO}_3\text{-N}$ concentration in the permeate varied from 7.1 mg/l as an average in phase 2 and 15 mg/l as an average in phase 1. However there were big variations. The $\text{NO}_3\text{-N}$ concentration on a daily basis varied between 1.2 mg/l and 35 mg/l . High concentrations were the result of the aeration capacity, which was too strong. Besides the membrane aeration added to the total oxygen input. During the phases 3 and 4 the denitrification zone was out of operation. Therefore the denitrification results are considered to be not representative for the full scale, where the possibilities for denitrification are more favourable.

The membranes have been used at a gross flux of $40 \text{ l/m}^2\cdot\text{h}$. Dependant on the settings for backwash and relaxation the net flux varied between $30 \text{ l/m}^2\cdot\text{h}$ and 35

$\text{l/m}^2\cdot\text{h}$. This flux, which can be considered as high for MBR, was maintained easily in a temperature range from 7° till 22° . These results correspond with other experiences with the same membrane system (Futselaar 2007).

The permeability in module 1 was higher than module 2 during the entire research period. This can be explained by the history of the 2 membrane modules. Module 1 had been replaced at the start of the research. Module 2 had already been used in other pilot research. This module is supposed to contain some irrecoverable fouling. The tendency however was equal in both modules except for the first phase in module 1. Because the module was new it started with a high permeability followed by an initial decrease.

Clarifier overflow addition to the MBR was the most uncertain factor. Particles present in the clarifier overflow may have an effect on the membrane performance. Based on pilot plant results no negative influence have been noticed. During each period the permeability appeared to be stable and was mainly influenced by technical failures. Even with 77% effluent addition the permeability was stable and even tended to increase. The effect of clarifier overflow addition was also tested with the DFCM method. This test confirmed the observations in the pilot plant.

The overall conclusion is that addition of clarifier overflow is feasible for increasing the permeate production. Membranes can be used with a net flux between 30 and $35 \text{ l/m}^2\cdot\text{h}$ continuously. The MBR will be able to contribute to the reuse of wwtp effluent for industrial purposes. The combination of MBR and reuse can be considered as a sustainable and economical feasible solution compared to upgrading of both plants individually.

6 Outlook to full scale

The full scale MBR has been started up end June 2010. Figure 7 gives an impression of the plant. The first operational results show a permeability of $480 \text{ l/m}^2\cdot\text{h}\cdot\text{bar}$ at a gross flux of $38 \text{ l/m}^2\cdot\text{h}$. The permeate quality has already met the requirements after two weeks. The $\text{PO}_4\text{-P}$ concentration is below 2 mg/l , the $\text{NO}_3\text{-N}$ concentration is between 2 and 5 mg/l and the N-total concentration is between 4 and 8 mg/l . These first results confirm that the high $\text{NO}_3\text{-N}$ concentrations during the pilot research were caused by a too strong aeration capacity in combination with the configuration of the bioreactor. In the full scale plant the aeration capacity can be controlled better.



Figure 7: full scale MBR

References

- [1] Agtmaal J, Huiting H, de Boks PA, Paping LLMJ (2007) Four years of practical experience with an Integrated Membrane System treating estuary water, *Desalination* 205, 26-37.
- [2] Evenblij, H., Geilvoet, S., van der Graaf, J.H.J.M., van der Roest, H.F. (2005) Filtration Characterisation for assessing MBR performance: three cases compared, *Desalination*, 178, 115-124.
- [3] Futselaar H, Schonewille H, de Vente D, Broens I (2007) NORIT Airlift MBR: side-stream system for municipal waste water treatment, *Desalination* 204, 1-7.