RESEARCH TO ESTABLISH OPTIMAL PROCESS PARAMETERS AND MINIMUM COSTS FOR FUTURE MBR INSTALLATIONS

Hybrid MBR - the perfect upgrade for Heenvliet

The Heenvliet WWTP consists of a low-loaded activated sludge system, type carrousel, with one secondary clarifier and disinfection of the effluent by means of sodium hypochlorite. The WWTP will be expanded to a hybrid MBR system in which the MBR will treat 25% of the hydraulic load and will operate in parallel to the existing conventional activated sludge system. Flat sheet membrane modules have been chosen as most suitable for the Heenvliet situation. The conventional activated sludge system will be modified in order to improve the current treatment efficiency. In the initial research phase the MBR and the modified conventional lines will be run in parallel and the treatment efficiency of the MBR will be directly compared to the efficiency of the conventional plant. In the following research phase the MBR and carrousel will be operated in series, where as much water as possible will be treated in the membrane units (at DWF conditions) and as little as possible in the existing secondary clarifier (only under SWF conditions). The full-scale MBR research aims to achieve optimal effluent quality. In addition the research aims to establish optimal process parameters and the minimum required costs for future MBR installations. The research will run for a period of three years.

The MBR technique offers unique opportunities for upgrading existing wastewater treatment plants. With the European Water Framework Directive coming into effect by 2006, water boards have to consider new technologies to extend the treatment capacity and efficiency of existing wwtp's. The Heenvliet wwtp is a typical example of such a case and will serve as a demonstration project to gather experience with the relatively new application of hybrid MBR.

The wastewater treatment plant of the city Heenvliet (the Netherlands) is currently treating 8,950 p.e. of domestic wastewater. The hydraulic capacity will increase to 390 m^3/hr when the Abbenbroek WWTP (capacity 1,650 pe) will be closed and will be connected to the Heenvliet WWTP. The produced effluent is disinfected with sodiumhypochlorite before being discharged to a local surface water which is also used as bathing water in the summer time.

The Heenvliet WWTP will be upgraded to a hybrid membrane bioreactor system. The new MBR will treat approximately 25% of the total hydraulic capacity, which is equal to the dry weather flow; during storm weather events the remaining influent will be treated by the conventional part of the system. This hybrid system allows for optimisation of both sub-systems in terms of hydraulics and biological loading rate.

Process scheme

Heenvliet WWTP consists of a screen, a selector, a carrousel type aeration tank, a clarifier and a disinfection tank (see Figure 1). Sludge treatment consists of thickening and storage in a lagoon, followed by transportation for further treatment. The design sludge loading rate amounts to 0.054 g BOD/(g MLSSxday). Two surface aerators are installed and aeration is controlled by oxygen measurement only.

Objectives of the MBR project

The current capacity of Heenvliet WWTP is too small to treat the future increased influent flow, therefore the plant will be upgraded to a hybrid MBR system. The main reason for applying the MBR technique is the expected improved effluent quality in terms of nutrients. Nitrogen and phosphorus for example will have to be removed to lower concentrations, possibly down to the Maximum Tolerable Risk (MTR) level, 2.2 mg N_{total}/L and 0.15 mg P_{total}/L, when the European Water Framework Directive becomes effective.

Furthermore, other components may be reduced in a MBR system, especially those that can be adsorbed to the biomass such as micro pollutants. In combination with the absolute barrier provided by the membrane these substances, as well as bacteria and viruses, will be removed completely, making disinfection with NaOCl superfluous.

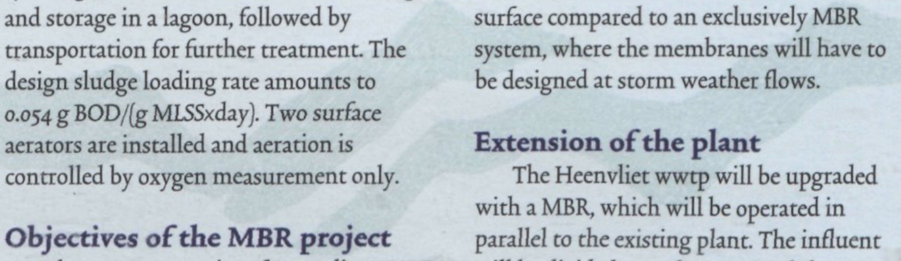
The Heenvliet case provides a good opportunity to study the system behaviour under typical Dutch circumstances and the effects of up-scaling MBR technology. In this way the development of MBR technology is supported and its potentials can be explored to the full. Since the Heenvliet MBR is designed as a hybrid system it is perfectly suited as a research case, since the two sub systems (conventional and MBR) can be tested and evaluated in parallel.

From an operational point of view, the hybrid MBR system is advantageous because the hydraulic capacity of the membranes will be utilised to the maximum during dry weather flow. This results in a more economic use of the installed membrane surface compared to an exclusively MBR system, where the membranes will have to be designed at storm weather flows.

Extension of the plant

The Heenvliet wwtp will be upgraded with a MBR, which will be operated in parallel to the existing plant. The influent will be divided over the MBR and the

Figure 1: Flow sheet of the current situation at Heenvliet WWTP.



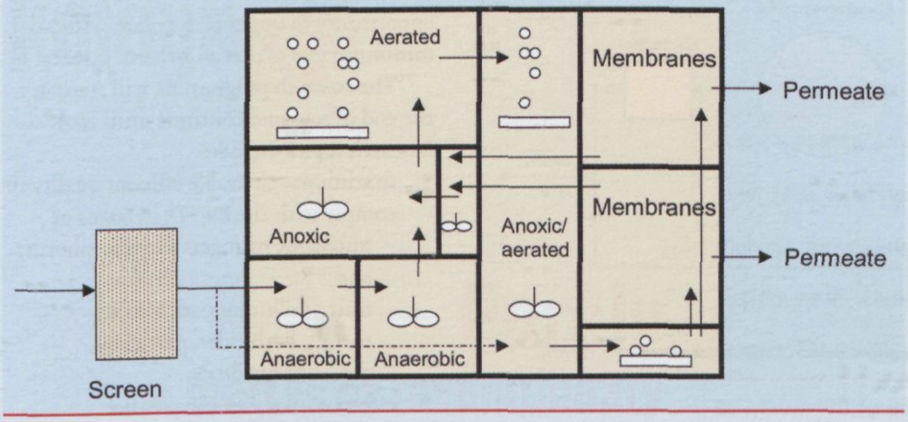


Figure 2: Flow sheet of the MBR.

conventional plant and the influent quality will be equal for both systems. The MBR consists of the following parts (figure 2):

Screening

The influent will be treated in screens with flat sheets with 3 mm perforations, because perforations are more effective than screens with bars. The selection of the size of the perforation is related to the selected flat sheet membrane system. Flat sheet membranes are expected to be less sensitive for pollution than hollow fibre membranes. Besides flat sheet membranes can be cleaned more easily than hollow fibres in case of pollution.

Figure 3:. Two Hybrid configurations during dry weather flow and storm weather flow.

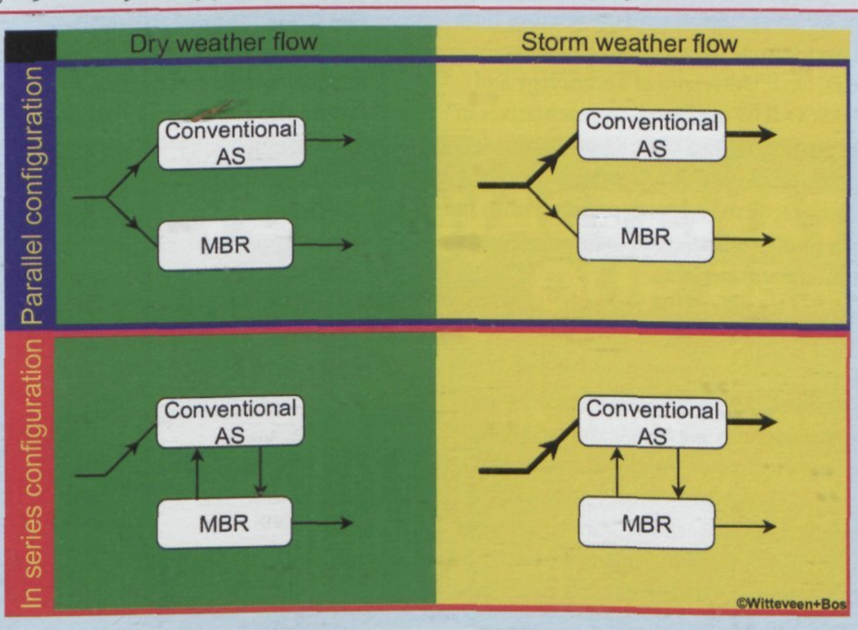


Table 1: Specifications of the plant.

		conventional	MBR
screens	mm	6 (bars)	3 (pores)
maximum hydraulic load	m^3/h	290	100
biological capacity	p.e. (136 gr BOD/p.e/day)	9,660	3,330
F/M ratio	g BOD/g MLSS x d	0.045	0.045
sludge concentration	kg MLSS/m^3	4.7	10
surface load clarifier	m^3/m^2xh	0.51	-
net membrane flux	l/m^2xh (at 100 m^3/h)	-	24.3
maximum possible flux	l/m^2xh	-	56.3
disinfection	-	NaOCl	ultrafiltration

Activated sludge tank

The activated sludge tank is divided into different compartments for P-release, denitrification, nitrification and P-uptake. The sludge passes a continuously aerated tank before entering the membrane tanks. This is expected to be favourable for the sludge quality, resulting in a better membrane performance. The return sludge from the membrane tanks passes an anoxic tank to limit the oxygen concentration before entering the denitrification tank.

Phosphorus will be removed biologically as much as possible. To support the biological removal, $FeCl_3$ can be added in order to reach the required very low effluent concentrations.

Membrane tank

The two parallel membrane tanks are equipped with Toray flat sheet membranes, provided by Seghers-Keppel. With a pore size of 0.08 µm this can be classified as ultrafiltration. By having two membrane tanks there will be flexibility in the hydraulic membrane load, because the flow can be distributed in different proportions over the two tanks.

Modifications of the existing plant

The sludge loading rate of the conventional plant will decrease because of the planned extension. This effect will be more pronounced due to the increased sludge concentration available, which is needed to ensure identical F/M ratios in both the conventional plant and the MBR. A mixer will be installed in the carrousel to increase flexibility of aerobic and anoxic zones and to avoid sludge settling in the aeration tank. The existing activated sludge tank is not provided with an anaerobic tank. Therefore, biological P-removal is expected to play a limited role, so $FeCl_3$ is added for phosphorus removal.

The hydraulic load will decrease compared to the present situation, resulting in an improved separation of solids, even at the higher sludge concentration in the activated sludge tank.

In table 1 some specifications are given for both systems in the future situation.

Two configurations of the hybrid system

The new hybrid system can be operated in two ways (figure 3).

MBR in parallel with the conventional lane

During dry weather flow, the MBR will be treating relatively more wastewater than

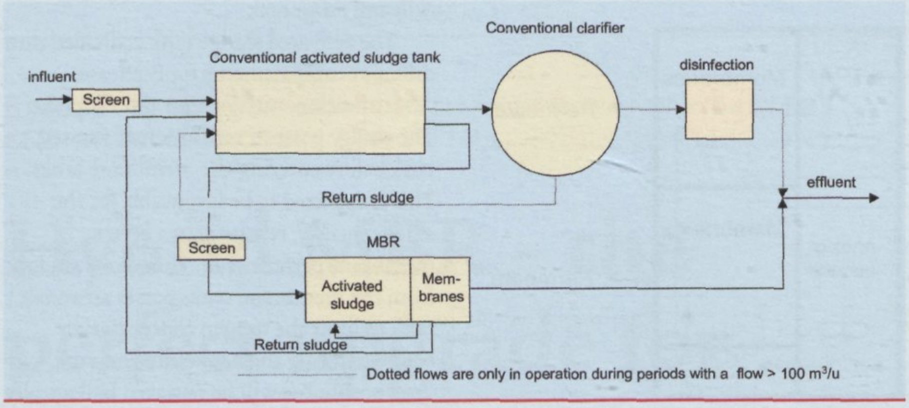


Figure 4: *Flow sheet of the in-series-hybrid configuration.*

the conventional lane. In this way the membrane capacity is utilised as much as possible. If the flow increases, e.g. during storm weather, the hydraulic loading rate of the conventional plant will increase more than proportional. The sludge loading rate of the conventional plant will also increase but the sludge loading rate of the MBR will decrease under these circumstances. This type of operation is referred to as parallel operation.

MBR in series with the conventional lane

In this configuration the activated sludge tanks of the conventional plant and the MBR are connected in series. This results in one biological system, with a possibility to separate solids both with the membranes and in the conventional clarifier (figure 4).

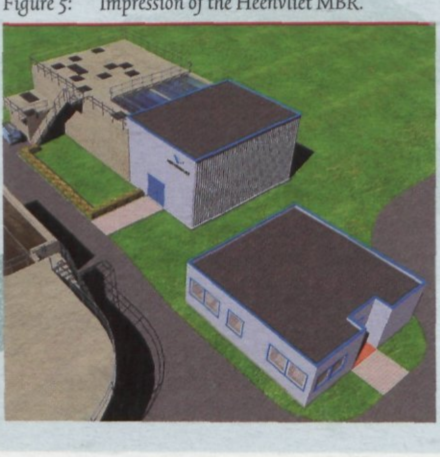
In this so called 'in series hybrid configuration' the clarifier also acts as a hydraulic buffer. If the flow is lower than the membrane capacity, the water level in the clarifiers decreases and effluent is only produced by the MBR. When the flow exceeds the membrane capacity the water level in the clarifier will increase again until the level of the overflow weirs, and the clarifiers will be used for effluent production again. In this way the overall effluent quality is increased compared to parallel configuration.

Research programme

The hybrid MBR project at Heenvliet WWTP will serve as a demonstration case for hybrid MBR systems in the Netherlands. To facilitate the further development and application of this concept an extended research programme has been designed. Part of this research programme is incorporated in a Europe-wide scientific research project in close co-operation with universities from all over Europe. Water board Hollandse Delta, Delft University of Technology and UNESCO-IHW are Dutch representatives in this project. The project proposal was submitted to the EU for a subsidy as a specific tartgeted research project within the sixth framework research programme and will start summer 2005.

The Heenvliet MBR research programme will focus on the achievable effluent quality, and minimisation of operational cost. For a MBR system, both investment and operating costs are higher at the moment compared to conventional activated sludge treatment. To accurately study and optimise the system with respect to energy requirements and other sustainability related aspects, a full-scale installation is a prerequisite.

Figure 5: *Impression of the Heenvliet MBR.*



The first year parallel operation will be investigated. The influent will always be distributed over both systems with a constant ratio and the sludge loading rate will be equal for both systems. This enables a direct comparison between performance of both systems of a very low loaded conventional system and a MBR system.

The last two years will be used to test the serial hybrid configuration. With this type of operation the membrane filtration step can be optimised without the risk of overloading the conventional plant during storm weather. This provides the opportunity to upgrade the plant with a minimum loss of overall effluent quality.

The research programme will start at the end of 2005 and continue until 2009. Research topics include:

- maximum achievable effluent quality to comply with the EWFD; in terms of
  - nutrients: nitrogen and phosphorus; and
  - micro pollutants, such as heavy metals, herbicides, pesticides, medicine residuals;
- effects of in series and parallel configuration in terms of membrane operation, activated sludge settleability, floc structure etc.;
- minimisation of energy input for aeration of the membranes and oxygen transfer;
- influent and recirculation screening requirements and efficiency;
- comparison of ultra low loaded conventional activated sludge system and MBR in terms of effluent quality;
- optimisation of the membrane separation step. Since the membrane compartment consists of two sections that can be operated separately, alternating operation can be applied to increase membrane lifetime. This feature also allows for critical flux determination tests with a part of the membrane while ensuring treatment capacity.

At this moment the MBR is under construction and is expected to be commissioned in October 2005 (an artist impression is presented in figure 5). ¶

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