DIFFICULT TO REACH MAXIMUM TOLERABLE RISK QUALITY FOR NITROGEN AND PHOSPHATE

Comparison of the MBR with continuous sand filtration at the Maasbommel WWTP

Recently, a two-year research period in which the membrane bioreactor and conventional wastewater treatment with continuous sand filtration as polishing step were compared has been concluded. The aim for both was to reach Dutch Maximum Tolerable Risk Quality. The research was carried out by Water board Rivierenland, Royal Haskoning and STOWA (Foundation of Applied Water Research) at the Maasbommel wastewater treatment plant. Results showed that it was difficult to attain yearly mean MTR quality for nitrogen and phosphate applying either technology.

Around 2010 the Dutch Water board Rivierenland expects stricter demands on effluent quality of ten wastewater treatment plants (WWTP's) within rural areas. Until concrete legislation comes in effect, the Dutch Maximum Tolarable Risk (MTR) is set as standard for receiving surface water. For nitrogen and phosphate concentrations of 2.2 mg N/l and 0.15 mg P/l, respectively, have been set. With the current WWTP's such levels cannot be reached. Consequently, together with Royal Haskoning and STOWA, the Water board Rivierenland started a research programme on the applicability of the membrane bioreactor and continuous sand filtration for treatment of municipal wastewater. The research was located at Maasbommel WWTP and started in March 2002. The main goals were to determine the feasibility of MBR technology or end-of-pipe continuous sand filtration to reach MTR quality for WWTP effluent and a comparison of MBR and continuous sand filtration technology performance.

Table 1: Influent composition.

Parameter	Value	Unit
BOD influent	50 - 350	mg/l
N_{kj} influent	15 - 110	mg/l
P_{total} influent	3 - 15	mg/l
DWF	50	m^3/h
RWF	150	m^3/h

Figure 1 shows a schematic presentation of the configuration used at Maasbommel. It included a MBR pilot plant (capacity 16 m^3/h) with submerged hollow fibre membranes (440 m^2) and two full-scale upflow continuous sand filters (capacity 110 m^3/h, surface load 15 m/h).

Effluent quality

The research showed that for both technologies it is difficult to maintain MTR quality for nitrogen and phosphate throughout the year. MBR shows better phosphate removal (minimum values of 0.05 mg P/l) than sand filtration (minimum values of 0.12 mg P/l). This was mainly due to the wash-out of ferric sludge from the sand filters. Better nitrogen removal was

Sand filtration at the Maasbommel WWTP.

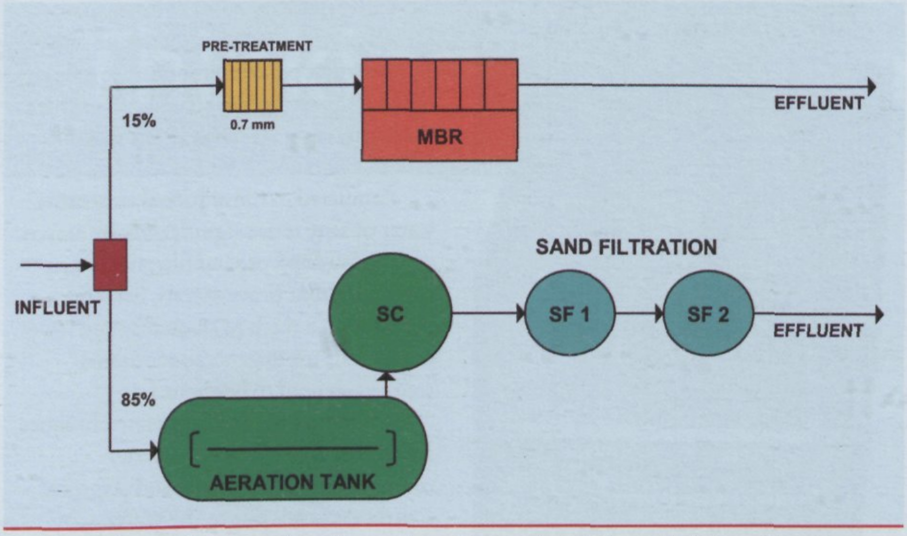

Figure 1: *Schematical representation of the Maasbommel WWTP installation and basic data of the influent. SC = secondary clarifier, SF = sand filter.*

Figure 2: *MBR and WWTP effluent concentrations of total nitrogen and total phosphorus. From July 1, 2003 WWTP effluent was polished using continuous sand filtration.*

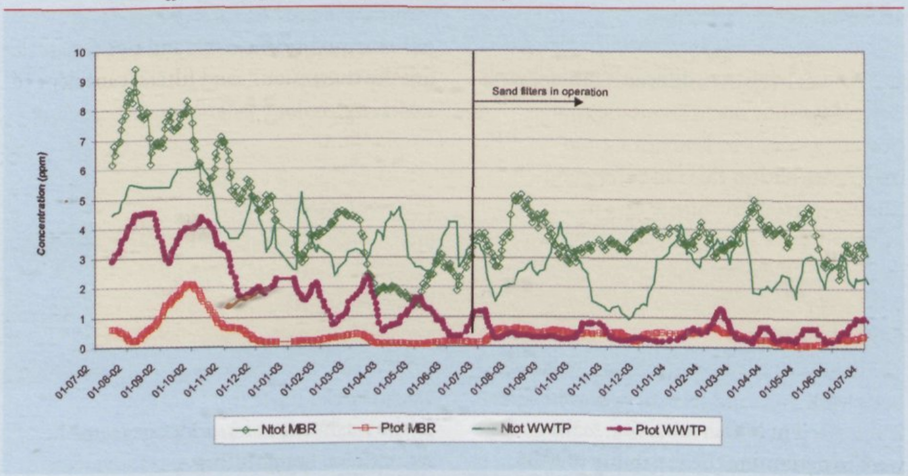

Table 2: *Average effluent concentrations of secondary settler, sand filters and MBR (during periods without disturbances) in 2003-2004.*

parameter	unit	effluent secondary settler	effluent sand filters	effluent MBR	MTR demand
nutrients					
total nitrogen	ppm	6.0	2.5	3.0	2.2
total phosphorus	ppm	2.5	0.5	0.3	0.15
metals					
copper	ppb	6.8	5.2	6.5	3.8
zinc	ppb	27	23	28	9.4
pesticides/herbicides					
glyphosphate	ppb	7.5	3.5	4.5	-
diuron	ppb	0.11	0.18	0.15	0.43
linuron	ppb	1.35	0.9	0.5	0.25
diazinon	ppb	0.1	0.08	0.09	0.037
E.coli	cfu/ml	200	130	< 1	20
estrogens					
bisphenol a	ng/l	28	33	20	-
estron	ng/l	4.75	6.9	3.3	-
β-estradiol	ng/l	1.05	0.85	1	-
EEQ (er-calux)	pm	0.014	0.011	0.004	-

achieved with sand filtration, however. Residual nitrate concentrations are easily lowered to average values of 0.5 mg/l when additional carbon source (acetol) is dosed. It proved to be difficult to attain such values with the MBR by adjusting recycle flows and carbon source dosing. Furthermore, MBR was more sensitive to RWF than sand filtration. Under RWF conditions contact times and process conditions dramatically change. The process configuration used (a highly divided cascade system) enhanced this effect. Application of an M-UCT or BCFS process may partially neutralise this negative effect. Overall, however, both MBR and sand filtration clearly show better nitrogen and phosphate removal than the conventional Maasbommel WWTP without sand filtration (figure 2).

When heavy metals are considered (table 2), only the zinc and copper demands are exceeded by both systems. Other metals are eliminated to concentrations well below the MTR demands. The difference in removal efficiency between MBR and sand filtration is minimal. The added value concerning heavy metal removal when compared with the conventional WWTP is limited as well.

Comparable removal efficiencies of pesticides and herbicides are obtained with both MBR and sand filtration. For most compounds concentrations were below the detection limit. Of the compounds in the higher concentration range, only linuron and diazinon exceeded the MTR quality demands. No additional removal of pesticides and herbicides was achieved with MBR or sand filtration compared to conventional wastewater treatment. Only glyphosphate (herbicide, active compound in Roundup) is about 50% more efficiently removed than in the conventional Maasbommel WWTP.

MBR appeared to be more efficient for disinfection purposes than sand filtration or conventional treatment. Disinfection was quantified through viability and E. coli counts. Because of the pore size of 0.04 μm practically no E. coli can pass the membrane. E. coli counts are lowered down to less than 1 per ml. This is appreciably lower than MTR or swimming water quality demands (20 per ml).

Based on wet chemical analyses, the MBR and conventional WWTP with sand filtration as polishing step show comparable removal of estrogenic compounds. Both systems showed a removal efficiency of 95%

for bisphenol A, estron and b-estradiol. The estrogenic potential expressed in b-estradiol equivalents (EEQ) was determined as well through a bio-assay (ER-Calux). Sand filtration shows a 20% lower potential than conventional treatment alone. Estrogenic potential after MBR treatment is 60% lower than after conventional treatment with sand filtration. An explanation may be the increased removal of suspended solids due to the ultrafiltration membranes applied in the MBR. It is known that the main removal mechanism for phthalates, poly-bromine-diphenyl-ethers (PBDE's) and alkyl-phenols is adsorption to suspended solids (STOWA (2004). Vergelijkend onderzoek MBR en zandfiltratie rwzi Maasbommel. Rapport 2004-28 (in Dutch)).


Membrane tank MBR pilot plant.

Process sensitivity and stability

During the whole research period, the MBR was more prone to process disruptions than sand filtration. This was expected, since sand filtration is a proven technology. Furthermore, it was installed as a full-scale plant. After several optimization steps the MBR ran relatively stable. The pre-filtration step before the MBR system ran without any difficulty throughout the testing period. With sand filtration, the on-line measurements, sand velocity meters and chemical dosing demanded increased attention. With increased attention stable operation of the sand filtration was achieved.

It appeared to be less cumbersome to maintain a stable effluent quality with sand filtration than with the MBR. This was especially the case for nitrogen and phosphate. Even at RWF Sand filtration delivered stable effluent quality, while the MBR effluent quality started to fluctuate. MBR effluent stability may be improved, however, through process configuration and control optimization.

If MBR cleaning is fully automated, then it is expected that MBR operation will require as much operator attention as a conventional WWTP with sand filtration as polishing step. It may be roughly stated that membrane filtration requires as much attention as sand filtration.

Process measurements and control were difficult within the MTR quality range. Current analysis techniques are too inaccurate within this range for good process control. For future design, measuring and control devices require increased attention.

Conclusions

Reaching MTR quality is difficult for both MBR and sand filtration. Nevertheless, it may be stated that there is a slight preference for sand filtration for WWTP expansion or green field WWTP's due to stricter nitrogen and phosphate demands. Sand filtration delivers a more stable effluent quality for these nutrients. It must be said, though, that effluent concentration for N_{total} and P_{total} of 3 and 0.5 mg/l may be reached with MBR under proper operation. Table 3 shows a qualitative comparison of MBR with sand filtration.

When disinfection is the main demand for WWTP expansion or newly built ones, e.g. due to discharge into swimming water, MBR is preferred. Also for hormone removal, an important parameter for future effluent criteria, the estrogenic activity after MBR treatment is considerably lower than after sand filtration.

Compared to conventional treatment, water quality is not significantly improved with either MBR or sand filtration when speaking about heavy metals, herbicides or pesticides. To reach MTR quality and lower concentrations in general, additional techniques need to be applied.

Additional water treatment techniques are necessary to eliminate priority compounds and to comply with expected stricter demands due to the Water Framework Directive. Possible treatment technologies are activated carbon, denitrifying activated carbon, ozonisation, selective resins for metal removal, UV irradiation, nanofiltration or reversed osmosis systems. Specific demands on effluent quality due to the surface water quality wanted will eventually determine which technology will be implemented. ¶

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Table 3: Comparison of MBR with conventional WWTP with sand filtration as polishing step.

parameter	membrane bioreactor	conventional + sand filtration
nitrogen removal	+	++
phosphate removal	++	+
E. coli removal	+	0
heavy metal removal	0	0
pesticide/herbicide removal	0	0
hormone removal	+	0
operational aspects	0	0