WETLAND PERFORMANCE 2019-2021

DOW - EVIDES INDUSTRIEWATER

JANUARY 27, 2022

UNIVERSITY OF APPLIED SCIENCES

WETLAND PERFORMANCE 2019-2021

DOW – EVIDES INDUSTRIEWATER

M. Martens[a] and L. Hamelink[a]

N. van Belzen[b], D.P.L. Rousseau[c], H. Khan[c], C.K. Groot[b], O. Schepers[d], D. van Oirschot[e], A. De Las Heras García[b], N. Roodbol[d] and F. Ronsse[c]

[a] HZ University of Applied Sciences, Water Technology, Middelburg, The Netherlands

[b] Dow Benelux BV, Terneuzen, The Netherlands

[c] Ghent University, Department of Green Chemistry and Technology, Kortrijk, Belgium

[d] Evides Industriewater, Rotterdam, The Netherlands

[e] Rietland bvba, Belgium

Contents

AIM

The aim of the pilot is to gain insight in the performance of an aerated HSSF (Horizontal SubSurface Flow) constructed wetland (CW) as pretreatment step for the desalination treatment train (UF, IX, RO). Firstly, removal rates of Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Ammonium-Nitrogen (NH4-N), Nitrate-Nitrogen (NO_3-N) and Total Nitrogen (TN) are monitored to conclude whether the aerated CW will provide a biologically stable effluent, reducing biofouling issues on connected membrane based polishing technologies. Less biofouling in the desalination plant results in reduced cleaning frequencies, less use of chemicals and longer membrane & resin lifetimes. Secondly, the pilot makes it possible to optimize the wetland settings: oxygen supply, carbon dosing, implementation of biochar in the filter bed and hydraulic retention time of 12h or 24h.

PILOT

The pilot consists of two HSSF CW of 350 m^2 (28m x 12,5m x 1,1m), which are each fed by 10 m^3/h of municipal effluent from WWTP Terneuzen and effluent Biox from DOW chemical. For the full scale, rainwater from the premises of the Dow site will be used as a third feed source. Both pilot cells are filled with expanded clay aggregates and are aerated by means of blowers, connected to an aeration grid at the bottom of the wetland cells. Both wetlands can work independently in parallel, or can be placed in series. Assuming a porosity of 35%, the hydraulic retention time of one cell fed with 10 m^3/h is 12h. The water flows horizontally through the filter that is planted with *Phragmites australis.*

RESULTS

1. NITROGEN REMOVAL

With respect to energy use and removal performance, the optimum Dissolved Oxygen (DO) settings are 2-2,5 mg DO/L. All the ammonium was nitrified into nitrate in the first third (9m) of the wetland, referring to the municipal wastewater with a concentration of 3mg NH_4^+ -N/L. The industrial wastewater with lower NH_4^+ -N concentration (0 – 1.5 mg/L) relies on the DO level in the influent water to nitrify the ammonia to nitrate as there is no performance incline when the wetland was not aerated (Fig. 1). During ammonium peaks (12 hours 50 mg NH4-N/l) 50% is removed due to aeration in zone 1. Extra aeration in zone 2 & 3 does not result in a lower effluent concentration, as bacteria need more time to adapt to the new situation.

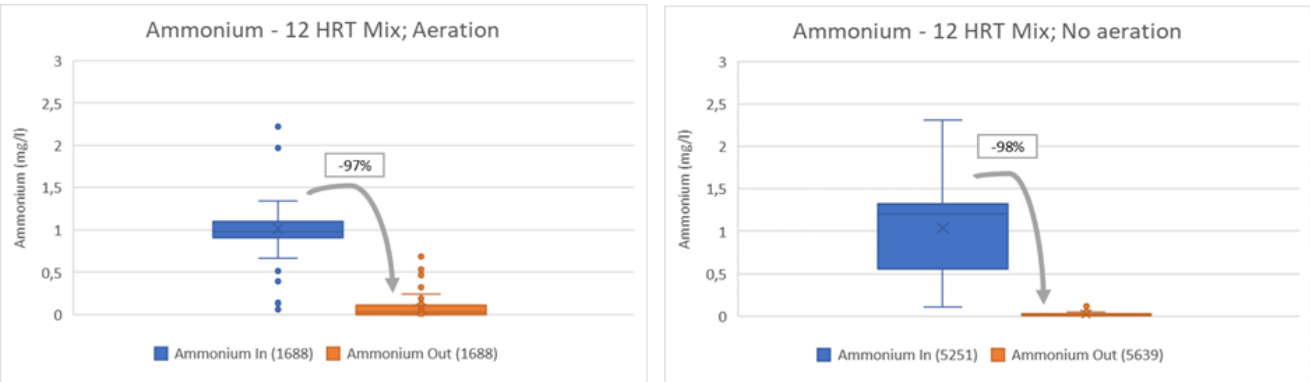

FIG. 1: COMPARISON OF NITRIFICATION BETWEEN AERATION ON AND OFF USING MIX FEED & 12HRT. PERCENTAGES = REMOVAL PERCENTAGES. NUMBER OF MEASUREMENTS BETWEEN BRACKETS.

TN in this research is the sum of nitrate + ammonium, organic nitrogen was found negligible as both feeds are effluents of WWTPs. From the mixed feed data (Fig. 2) it can be concluded that the highest removal rate (65%) is found during summer and 24h HRT. There was too little data of 12h HRT in summertime, which made it not possible to compare the TN-removal at different residence times in summer. In colder periods, the difference in HRT did not impact the TN removal rate (9% vs 13% removal).

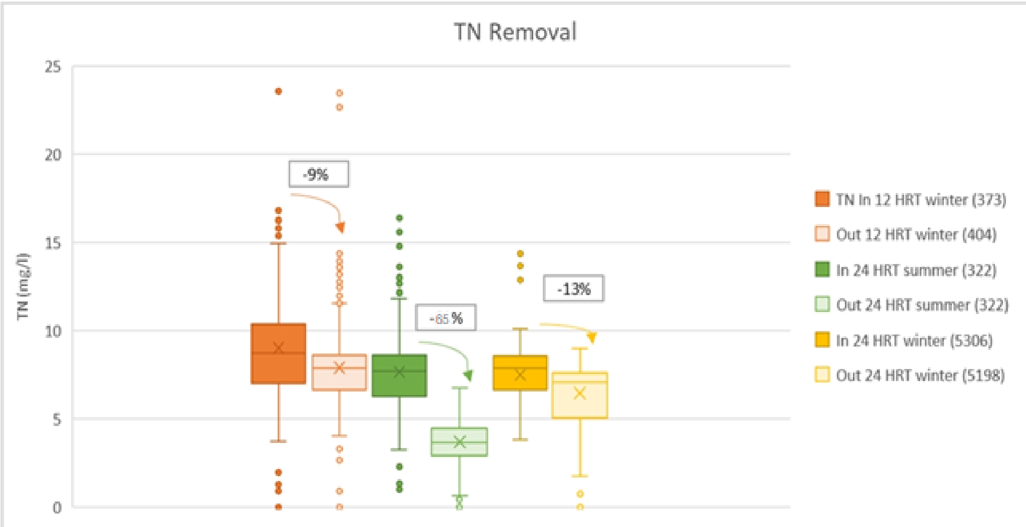

FIG. 2: TOTAL NITROGEN REMOVAL (NO3+NH4), HRT 12H VS 24H AND SUMMER VS WINTER TIME. NUMBER OF MEASUREMENTS BETWEEN BRACKETS.

The concentration of NH4-N and NO3-N are both higher in the municipal effluent compared to Biox effluent. Although the influent of the CW in the full scale will usually be a mixture of 3 flows, it is important to take into account the higher values of the Terneuzen WWTP for TN. The average TN concentration of the municipal wastewater is 32% (3.59 mg/L) higher compared to mixed feed. The removal rate of TN from the municipal wastewater is also higher during summer compared to winter time (Fig. 3). To improve denitrification, blowers are shut down in zone 2 and 3 to create anoxic conditions. In addition, a carbon source is added to enhance the removal efficiency of TN from 17.9% to 57% with C:N ratio’s 0 and 4 respectively. Still it is more cost effective to remove NO3-N by means of the IX in the brackish waterline. In addition, the C-dosing experiment suffered from practical issues as the zone where the C-source was dispersed clogged after 3 weeks due to high COD concentrations compared to the present DO levels. This consequently caused excessive biomass formation around the dosing zone. The C-source should be spread over a larger area to overcome the clogging.

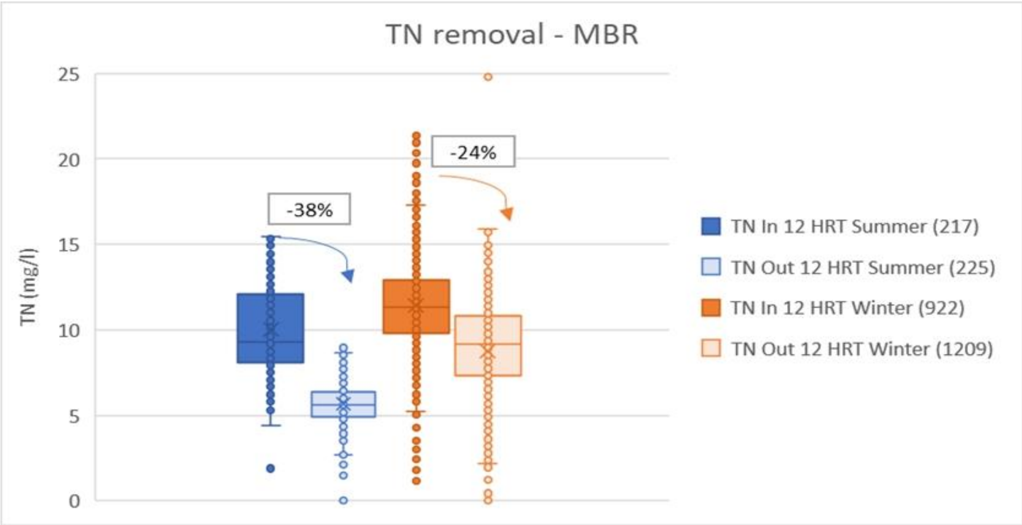

FIG. 3: REMOVAL RATE OF TN OF THE TREATED MUNICIPAL WASTEWATER DURING SUMMER AND WINTER – 12H HRT. NUMBER OF MEASUREMENTS BETWEEN BRACKETS.

2. ORGANIC MATTER REMOVAL

The COD concentrations in the feed flows are comparable, making the mixed feed representative. The mean COD removal rate is in the range of 23% to 31%, regardless of conditions such as HRT or water temperature (Fig. 4). Higher aeration did not impact the COD removal but was only a waste of energy. To treat 1 m^3 industrial wastewater effluent 8 Wh is needed and 12 Wh per m^3 municipal WWTP effluent.

The low concentration of BOD (~1 mg/L) in relation to COD indicates that the readily biodegradable organic matters were already degraded in the WWTPs and the remaining COD was recalcitrant or slowly biodegradable. Secondly, high hydraulic loads and low HRT (12 hours) reduce the contact time with substrate or/and biofilm which can also explain the lower removal rates. However, the 25% removal of COD is probably a small degradable fraction that is responsible for biofouling.

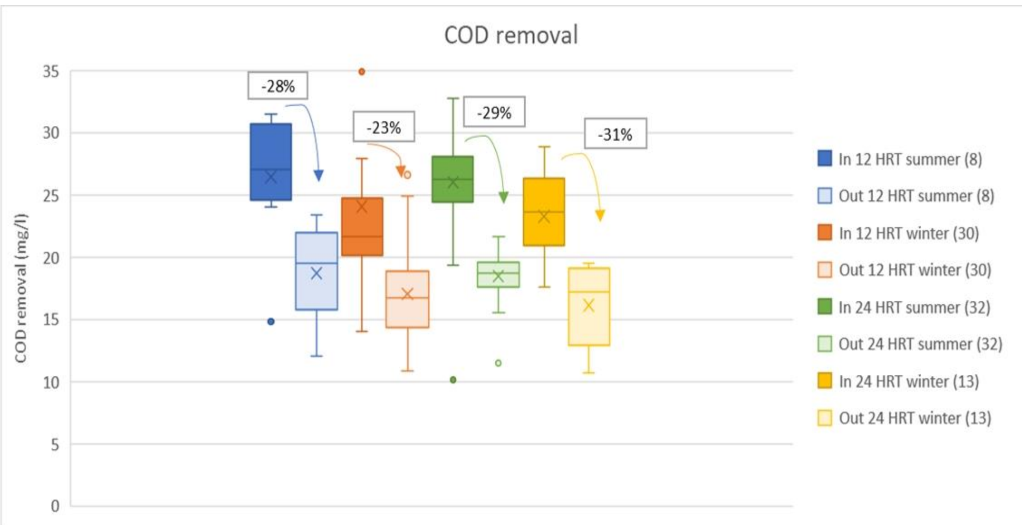

FIG. 4: COD REMOVAL IN THE PILOT: HRT 12H VS 24H AND SUMMER VS WINTER TIME. NUMBER OF MEASUREMENTS BETWEEN BRACKETS.

There is a tradeoff in the wetland between COD and TN. After nitrification in the first few meters of zone 1, the process of denitrification should occur to transfer NO_3-N into N_2 to remove N. Anoxic conditions and a relatively easily degradable carbon source. Both conditions hinder the removal of COD or even increase the concentration of carbon in the effluent. The removal rate of COD decreases 10% if zone 3 is not aerated.

3. OTHER PARAMETERS

Although seasonal **temperature** differences will have an effect on biological activity within the wetland, the temperature of the mixed feed does not fall below 15°C. Biox water is warmer compared to municipal effluent. In summer it can reach temperatures up to 31°C. On the other side of the range, the municipal water temperature is minimal 10°C in winter. Over the course of the wetland, the temperature drops by 0.5°C (max. 2°C in winter) due to the short residence time. There is insufficient data to support the assumption that COD is less degraded in winter. Temperature only seems to impact the removal rate of TN.

TABLE 1: OVERVIEW OF THE TEMPERATURE OF THE DIFFERENT FEED FLOWS

	TEMPERATURE (°C)			
	Min	Max	**Average**	**St.dev.**
Municipal WW	10,2	23,3	15,6	3,2
Industrial WW_Biox	15,5	31,4	23,4	3,9
MIX	15,5	23,9	19,9	2,1

Biochar is added to investigate if this would enhance removal of recalcitrant substances by adsorption to the biochar and consecutive biodegradation by micro-organisms. So far, the biochar has not proven to be beneficial for the removal of COD, N nor Phosphate (P).

Although **phosphate** removal is not an explicit goal of the project, ortho-phosphate removal is noted mainly through adsorption by the substrate material. The P-removal will be reduced over time as saturation occurs. There was a factor 4 difference between the influent concentrations of municipal effluent (up to 2 mg/L PO_4-P) vs. Biox effluent (max 0.5 mg/L PO_4-P). In the first two years, the removal efficiency ranged from 50 till 80%.

The mean concentration of the **TSS** influent is low (2 mg/L). However, the municipal effluent has occasional peak values up to 41.8 mg/L (table 2). Regardless the feed water, the removal rate ranges from 52%-60%.

TABLE 2: REMOVAL OF TTS (MG/L) FROM THE DIFFERENT FEED FLOWS.

	BIOX		MBR		MIX	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Average	1,26	0,63	1,96	0,37	1,10	0,25
P90	2,43	1,30	2,08	1,00	2,20	0,95
Max	6,10	4,40	41,8	2,50	5,60	1,00
SD	1,17	0,84	6,57	0,51	1,11	0,42
Number of samples	48	48	62	63	46	46
Removal efficiency (average)	54%		52%		60%	

Sulphate is leaching from the expanded clay particles. The leaching occurs mainly at the start of the pilot and decreased and stabilized over time. The same applies to iron, which was only leaching for the first few months. A certain fraction of the clay particles was most likely crushed during transports and loading of the pilot cells. Smaller particles with increased surface areas can lead to more leaching of several components (Boogaard, 1999). The leaching of sulphate will impact the operational costs of the brackish waterline (i.e. scavenger – IX).

The functioning of the **UF** is more robust and reliable if the wetland serves as a pretreatment. This results is less backwashes and less chemical cleaning which leads to lower costs. Also less biofouling is found on the **RO** membrane. Tests prove that the biofilm is C and P limited so the emphasis of the tradeoff between removing TN or COD should be on COD. The wetland should be aerated in het last zone.

CONCLUSION

This research has shown that the aerated HSSF wetland can reduce biofouling on UF and RO membrane. The wetland is robust as it has similar removal efficiencies for different types of feed flow (effluent of WWTP of Terneuzen municipality or industry or a mixture of both). Setpoint aeration (2-2.5 mg/L) in the first zone only, has shown to be effective to remove 25% COD and TN.

Nitrification occurs 100% at all DO set points. Denitrification is temperature dependent and improves with longer HRT's. 24h had a higher TN removal efficiency compared to 12h plus carbon source of C:N=4 with respectively 65% and 57%. However, COD is not temperature nor HRT dependent. The focus of the tradeoff between the removal of COD and TN (aerate zone 3 or not) is on COD as the fouling on the RO membrane is P limited. In addition, nitrate will be removed by the IX in the desalination train.

Leaching out of minerals and sulfate decreases over time. Also phosphate removal will reduce over time as the filter bed (expanded clay aggregates) become saturated. This research cannot state that biochar has not proven to be beneficial for the removal of COD, N nor Phosphate (P).

APPENDIX

Figure 5 illustrates how the nitrate concentration increases throughout the first zone as ammonium is nitrified into nitrate. Ammonium will be nitrified regardless the aeration. More denitrification occurred (22% vs 6%) during non-aerated set-up. However, more nitrate removal would occur if a carbon source was present.

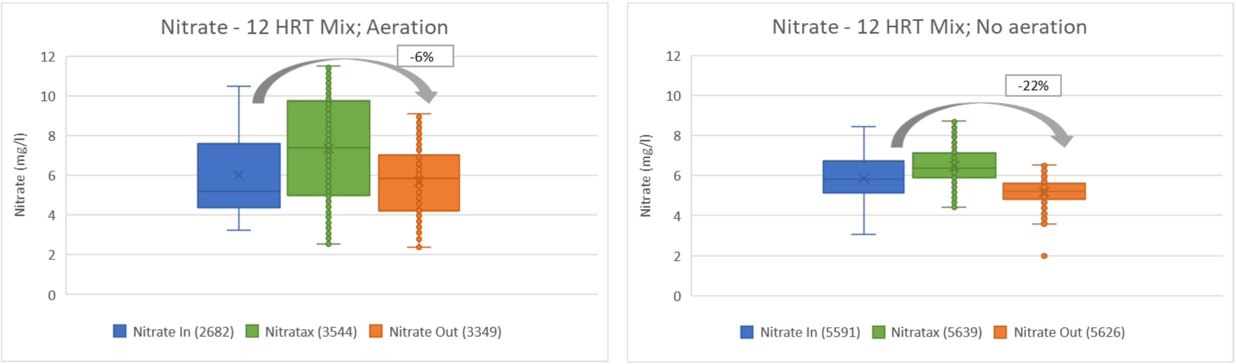

FIG. 5: NITRIFICATION WITH AND WITHOUT AERATION WITH 12H HRT

REFERENCES

Boogaard, F. D. (1999). *Praktijkproef infiltratie Zwolle-zuid Deelrapport III: infiltratievoorziening Schellerhoek.* Deventer: Tauw BV .