Long term experiences of SBR-system and wetland treatment from a municipal WWTP in Sweden, operated with low temperature wastewater

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Abstract. A biological wastewater treatment plant, Nynäshamn treating municipal wastewater and septic sludge is operated with a combination of SBR units and constructed wetland is presented in this paper. The plant has to treat low temperature wastewater in winter time, still with demands for a biological nitrogen removal. Results from a 12 years operation is presented. Special attention is given to the nutrient removal during low temperature conditions. The combination of a SBR system with a polishing step based on "natural" extensive treatment has been a sustainable way to keep the discharge levels low. The combined treatment with SBR and the wetland at the Nynäshamn plant has resulted in improved discharge levels typically as follows (annual mean values):

- BOD_7 < 3 mg/l;
- total P <0.1mg/l;
- total N <8mg/l

It is also important to underline that the change of process train has resulted in a substantial savings of the precipitant agent for phosphorus removal. The needed dosage is now 50 % of the previous dose.

Keywords: Nitrogen, phosphorus, nitrification, SBR, wetland.

Introduction

Current biological wastewater treatment strategy may, very simplified, be defined by two quite different main strategies: The first one based on more advanced and compact technologies, such as different types of enhanced microbiological models, either attached growth or suspended sludge systems i.e. activated sludge of different modes. The second one, on the other hand seen as simple "green solutions" based on extensive models such as multi-stage oxidation ponds, infiltration systems, wetlands and root zone technologies. Sometimes these models are presented as "competitors" and arguments are raised for one of the basic model to be superior. This paper will present and discuss an alternative view: To see the two systems as supporting systems to reach high quality effluent, rather than as models excluding each other. This example is presented from Nynäshamn, Sweden.

One of the most important factors for performance of biological wastewater treatment is the variation of the water temperature during the year, typically with very low water temperatures at wintertime. The municipal plant presented in the following experience from the plant is based on 12 years of operation.

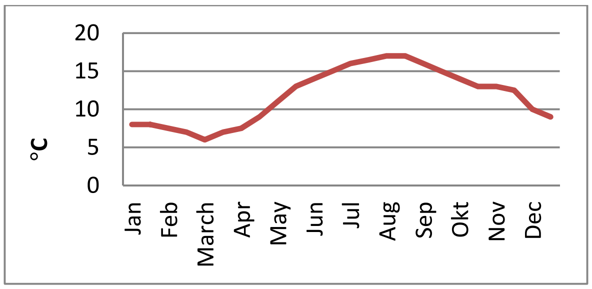

Figure 1: Annual temperature variation

Objectives of the study

The objective with this study is to present and analyse the plant operated with a treatment system including SBR facilities as the main biological treatment stage and wetland used as a downstream polishing stage. The winter conditions cause an operation at low to very low water temperatures. A typical temperature range is 6 – 17 oC (Figure 1). The aim of this study is to show how the operation and performance are influenced by the temperature variation.

Materials and methods

Long term operation data are used. Data from year 2000 through 2012 are used.

The following sources of information have been used:

- Design data for the plants from the planning stage;
- Annual environmental reports from the plant
- Operation data from the day-to-day operation of the plants
- Oral information from the plant operators

All sampling at the plant is based on flow proportional 24 hour samples, with the exception for the discharge point from the wetland. The discharge quality is considered stable over an extended period why grab samples are adequate in this case.

The used analysis methods are the following:

- For BOD_7 SS-EN 872, including nitrification inhibitor, accuracy in analysis result +/- 30 %;
- For Total P SS 028127-2, accuracy in analysis result +/- 10 %;
- For total Nitrogen SS-EN ISO 13395, accuracy in analysis result +/- 20 %;
- For NH_4-N SS-EN ISO 11732, accuracy in analysis result +/- 10 %.

Description of the Nynäshamn wastewater treatment plant

Nynäshamn community is located about 60 km south of Stockholm city on the coastline of the Baltic Sea. The nearby aquatic environment is the southern part of the large Stockholm archipelago. The community hosts about 20,000 inhabitants.

The plant has been extended and modernized at several occasions since it was built in the 1970's. In the mid 1990's the community decided to build a constructed wetland with the principal aim to reduce the nitrogen discharges from the community. The treatment objectives, set as BOD7 < 15 mg/l; total P < 0.5 mg/l and total N < 15 mg/l were maintained throughout the year, with the clear exception for the nitrogen removal.

In 2001 it was decided to modernize the handling of septic sludge, generated in the suburban area south of Stockholm. Accordingly it was stated that the nitrogen removal was insufficient. An assessment of the amounts of septic sludge showed a short term annual amount of 15,000 – 20,000 m3/year. A number of alternatives were considered, and finally it was decided to extend the main WWTP serving Nynäshamn to meet these demands. The adopted technical solution was to build a four-unit SBR facility. This treatment stage would receive the septic sludge directly after sieving and equalization. This solution was based on good experiences with this operation mode at a near-by SBR plant, see Morling (2001).

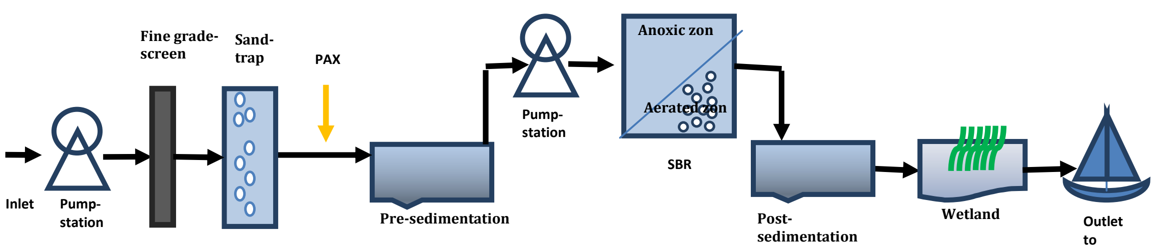

Figure 2: Process chart Nynäshamn WWTP

The upgraded Nynäshamn treatment plant has got the following treatment train (Figure 2):

- Pre-treatment including fine grade screens and sand traps;
- Pre-precipitation and primary sedimentation;
- Four SBR-units, each one with a volume of 1150 m3. A typical operation cycle for the units is 2.4 to 2.5 hours, equal to 9 to 10 cycles/d for each reactor.
- Chemical precipitation, flocculation and final sedimentation. The SBR-units are operated with a MLSS concentration of around 2.5 kg /m3;
- A constructed wetland, with a total area of 320 000 m2.

Results

An effect of the SBR installation was that the BOD load on the wetland was decreased which had a positive effect on the nitrogen removal (Figure 3).

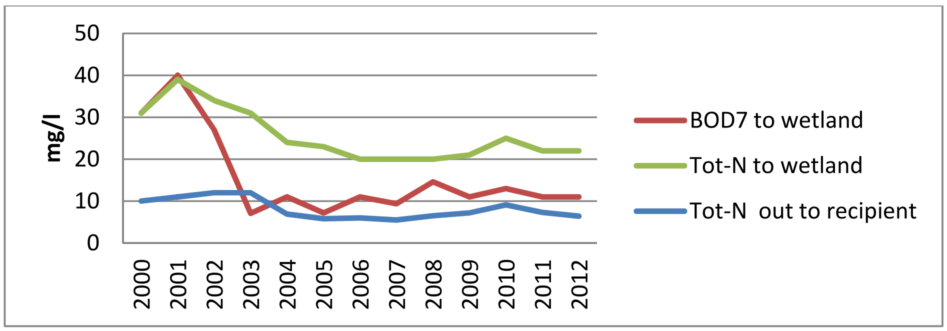

Figure 3: BOD_7 concentration in the inlet to wetland in relation to total nitrogen in the in- and outlet to wetland

After a few years operation of the wetland it was found that the treatment objectives with respect to BOD7 and total P were met at the plant. On the other side it was evident that the demands for nitrogen removal, specified as a maximum discharge level of 15 mg/l as annual mean value, and a minimum percentage removal of 50 % seldom were met. These results are illustrated in Table 1. The results are shown from the total discharge from the plant, including about 30 % of the flow that has been by-passed the wetland and only been treated by chemical precipitation.

Table 1: Inlet/outlet data Nynäshamn wetland 2000-2012. (The results are annual mean values, based on weekly sampling , that is 52 sample/year)

	2000	2001	2002	2004	2010	2011	2012	Unit
Total Flow	6134	5800	5431	5569	5758	5552	5223	m3/d
Flow to wetland	61,7	66,7	61,9	93,4	92,2	94,9	92,6	%
BOD7 to wetland	31	40	27	11	13	11	11	mg/l
BOD7 out to recipient	4,9	3,6	3,2	4,3	<3	<3	3,1	mg/l
BOD7 reduction(total)	90	91	93	98	98	98	98	%
Tot-P to wetland	0,43	0,41	0,38	0,39	0,34	0,32	0,36	mg/l
Tot-P out to recipient	0,15	0,08	0,11	0,06	0,06	0,06	0,05	mg/l
Tot-P reduction(total)	96	96	97	99	98	99	99	%
Tot-N to wetland	31	39	34	24	25	22	22	mg/l
Tot-N out to recipient	10	11	12	6,9	9,1	7,3	6,4	mg/l
Tot-N reduction(total)	47	48	53	78	70	79	80	%

An example of the improved nitrogen removal over the wetland during a full year is shown in Figure 4:

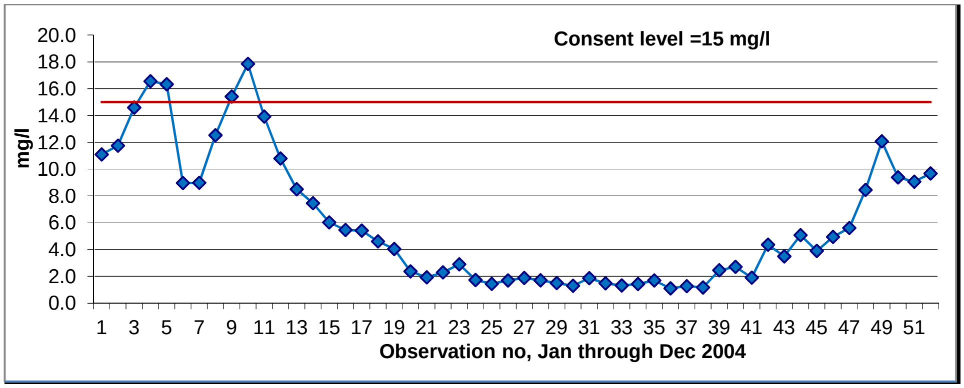

Figure 4: Variation of total nitrogen discharge level from the Nynäshamn wetland in 2004

Further to illustrate the nitrogen removal performance is shown in a material balance over the SBR-system. The balance was elaborated for the third quarter operation results in 2005, see also Morling (2009). The balance is presented in Figure 5. As shown in the balance the operators have taken on board the opportunity to balance the nitrification/denitrification degree over the SBR-system, and use the potential capacity in the wetland. This operation model is to be seen as a result of a process optimization.

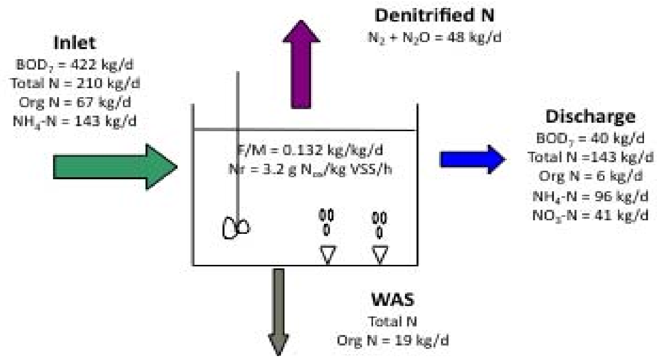

Figure 5: Material balance over the SBR-system at Nynäshamn WWTP, third quarter 2005

Discussion

An important factor when studying the results is the nominal hydraulic retention time very long for the wetland. Some circumstances must be borne in mind when studying the results:

- The discharge of treated water from the wetland takes place 35 to 70 days later than the influent of the same water volume;
- This fact will influence on the performance figures especially when the wetland has been out of operation. After 70 days stand still – no water entering the wetland under this period – the discharge of water takes place 100 to 120 days later than the inlet of the same water. During such a long period most of the environmental conditions in the wetland has changed
- The extended retention time has resulted in a false impression that the wetland is performing “best” the first month after the winter stop. In reality, the very low load during the extended period in conjunction with a dilution due to precipitation and snow melting will be the two main reasons for the found very low discharge concentrations during the first two months operation in springtime. This leads to the conclusion that only by studying the figures during at least one year a reliable picture is found.

After installation of the SBR-facility the plant performance was improved step by step from 2004. The plant performance has stabilized at new low discharge levels, as may be seen in

Table 1, showing the discharge figures from the years before extension, 2004 which was the first full year after extension and included in the table is also the last three years (2010-2012) to show the robustness of the plant operation.

Conclusions

Experiences from Nynäshamn plant facility may be concluded as follows:

- The ability to run the wetland throughout the year has been established since the introduction of the SBR-system. This fact is contributing to the improved results.
- From many aspects the wetland performed well after upgrading of the plant, providing discharge levels of BOD_7 and the total P of very high quality. BOD-removal was most likely due to an oxidation of organic matters into CO_2 and H_2O. This may be explained by a substantially lower organic load on the wetland; the BOD-concentration has decreased from about 30 mg/l to just above 10 mg/l, and the discharge of BOD is almost consistent less than3 mg/l
- By combining the SBR with the wetland in a sequence it has been possible to operate the SBR with a very short cycle time, about 2.5 hours compared to 4 to 6 hours as a normal cycle time for SBR systems. Still the SBR-system is operated with a low F/M ratio, about 0.065 kg BOD/kg SS/d;
- A fourth point to keep in mind is that the mass balance over the wetland is not possible to assess with accuracy, as long as the water balance is not known – the precipitation and evaporation over the year have to be known.
- The wetland has performed a very good nitrification and denitrification.
- The total P-concentration has been decreased by about 50% from about 0.12 to 0.06 mg /l (annual average). The phosphorous removal in a wetland is normally a function of precipitation and absorption to solids. The long term accumulation of P may become a problem, as the wetland will be saturated with respect to phosphorous. Other wetland operations have demonstrated that when the saturation level is reached, the discharge of phosphorous increases.
- The previously observed problem with odours from the inlet part of the wetland has disappeared. The need for chemical precipitant (alum salt) has been reduced by 40 to 50 % as compared with previous operations.

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