Long term cost-efficiency and management needs in free water surface wetlands for tertiary wastewater treatment

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Introduction and aim

This study presents an evaluation of monitoring data regarding treatment results from seven Swedish constructed surface flow wetlands treating effluent from wastewater treatment plants (WWTP). The wetlands have different design and have been in operation for 7-16 years (Fig. 1). The evaluation serves as a basis for assessing long-term wetland performance and estimating costs per kg nitrogen and phosphorus removed. Also, possible reasons for differences in treatment functions are discussed, including possibilities to optimize the operation of the conventional treatment plant to minimize the resource use in the total treatment system.

Figure 1. The wetlands Brannäs (1), Trosa (2) and Alhagen (3).

Material and methods

All seven wetlands receive wastewater from treatment plants with biological and chemical treatment, but they differ in size and the hydraulic load varies with a factor 9 (Table 1). Data on water flow and quality were obtained from the monitoring programs of the respective municipalities or companies operating the wetlands. Water flow has been measured both at the inlet and outlet of most of the wetlands, except at Ekeby, where the outflow has been set equal to inflow. Water samples for quality analyses have been collected weekly/biweekly.

Results and discussion

Three of the wetlands - Magle, Ekeby and Vagnhärad - received nitrified effluent, whereas NH_4^+-N was the dominating form in the inflow to the other four, except that Alhagen and Oxelösund also receive nitrified wastewater since a few years (Table 1). The area specific removal of nitrogen was higher in wetlands that received higher loads, irrespective of form of nitrogen, up to around 1-1.5 ton per ha and year (Fig. 2). This suggests that at higher loads, nitrogen removal is limited by other factors, e.g. redox status, availability of organic matter or hydraulic factors that may result in an inefficient use of the area. All those factors may explain the exceptionally high nitrogen removal in Örsundsbro (2.5 tons per ha and year). This is a small, long wetland with alternating deep open water and shallow areas dominated by emergent vegetation, which should favor both a high hydraulic efficiency, and nitrification- denitrification. The estimated cost for wetland N removal was 30 - 190 SEK per kg N (20 yr depreciation period), with operation costs accounting for between 14 and 39 %. The relation between load and area specific removal was even stronger for phosphorus. Despite a large variation (a factor four) in inflow P concentrations almost all wetlands removed > 50% of the load (Fig. 3).

Table 1. Concentrations in inlet and outlet water, and removal of tot-N and tot-P in seven FWS treatment wetlands in Sweden.

Municipality Facility Time period		Hässleholm Magle 1996-2009	Eskilstuna Ekeby 2002-2009	Nynäshamn Alhagen 1999-2009	Oxelösund Brannäs 1994-2009	Trosa Trosa 2003-2009	Trosa Vagnhärad 2003-2009	Enköping Örsundsbro 2001-2009
Total wet area	*(ha)*	20	28	28	23	5,3	2,3	1,6/0,8
Inflow	*($m^3\ d^{-1}$)*	12 400	45 000	4 900	4 500	1 700	1 400	700
Hydraulic load	*(mm d^{-1})*	62	161	18	20	32	63	44/96
Detention time	*(d)*	7	6	~14	7	7	5	7/~4
Concentrations								
Tot-N	*In*	20	17	37/22	24/16	23	21	22/20
(mg L^{-1})	*Out*	15	14	11/7	15/10	16	16	15/13
NH_4-N	*In*	7	6	37/16	17/12	21	7	17/12
(mg L^{-1})	*Out*	6	5	9/5	12/8	13	4	12/8
Tot-P	*In*	0,17	0,25	0,39/0,30	0,50/0,43	0,36	0,52	0,49/0,42
(mg L^{-1})	*Out*	0,12	0,13	0,10/0,06	0,06/0,13	0,12	0,07	0,19/0,10
BOD_7	*In*	3,0	4,2	35/9,7	22/11	11	4,0	9,5/9,1
(mg L^{-1})	*Out*	5,1	4,3	3,9/3,0	3,9/3,2	3,1	3,0	3,3/2,2

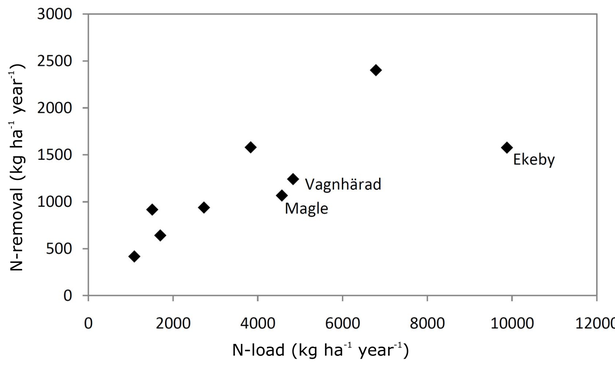

Figure 2. Load and removal of tot-N in the seven FWS Wetlands.

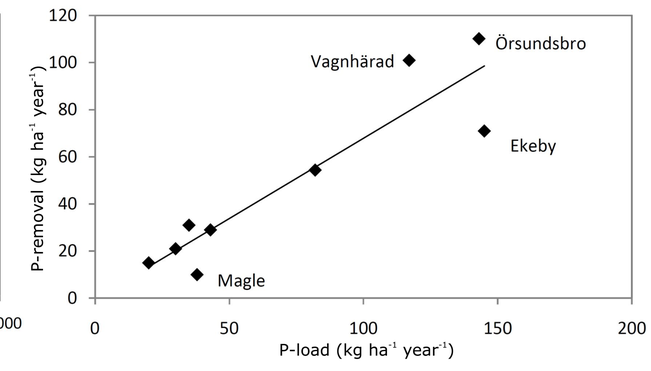

Figure 3. Load and removal of tot-P in the seven FWS Wetlands.

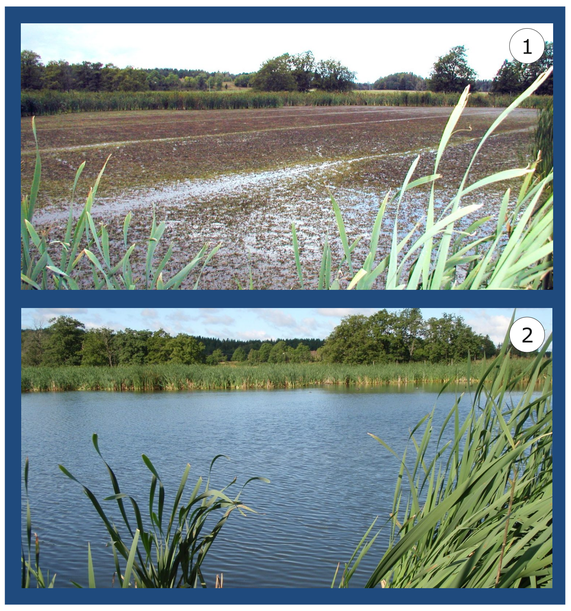

Figure 4. The "Middlepond" in Trosa wetland in September 2007 (1) and August 2009 (2). Observe the lack of submerged vegetation in photo 2.

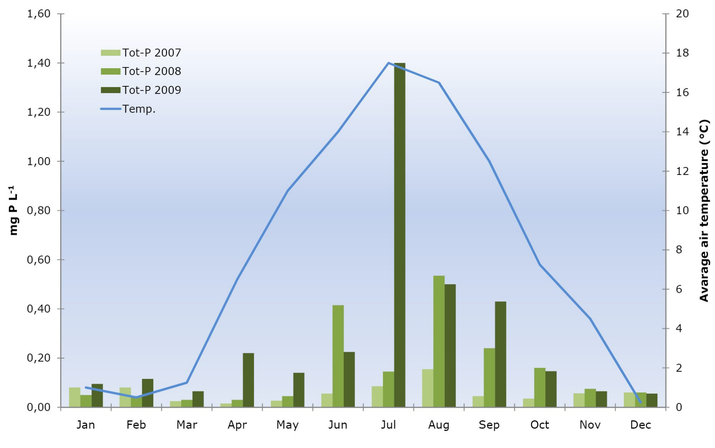

Figure 5. Average monthly concentrations of tot-P at the outlet of Trosa wetland 2007-2009, and monthly average air temperature.

The only exception, Magle wetland, has large areas covered with a mixture of submerged plants and filamentous green algae. Investigations have shown that algae cells contribute to the P outflow during the summer months (Nilsson, pers comm.), suggesting that it is important to design a wetland to prevent algae dominance close to the outlet.

During the last few years it has become clear that when P is precipitated with Fe-based chemicals in the WWTP, there is a risk for P release from anaerobic sediments in the wetlands. This occurred in Trosa the year after a massive stand of *Ceratophyllum sp*. and *Elodea sp*. collapsed, leaving large sediment surfaces with no plant cover where anaerobic conditions could easily develop (Fig. 4 and 5). Periods with P release have not been observed in wetlands where P is precipitated with Al-compounds in the WWTP, suggesting that the use of Al-compounds is beneficial for the over-all treatment results in a combined WWTP+wetland system.

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