THE EVERSTEKOOG CONSTRUCTED WETLAND

A FOUR YEAR RESEARCH PROJECT ON FULL SCALE TO CHANGE EFFLUENT FROM AN OXIDATION DITCH TO (RE)USABLE SURFACE WATER

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SUMMARY

The Everstekoog constructed wetland on the island of Texel in The Netherlands is a full-scale wetland system to improve the quality of the 3500-m³/day effluent from a sewage treatment plant. It is a combination of a pond and nine parallel ditches, with helophytes and submerged aquatic plants. The total surface is 1.3 ha, or 0.5 – 1 m^2 per population equivalent. The total hydraulic retention time (HRT) of the whole system is just over two days. In the second part of the project, the ditches had different HRT´s: between 0.3 and 10 days.
The treated sewage is converted in to another kind of water. The odour disappears; the water obtains a diurnal oxygen rhythm, like natural surface water. Nitrification and denitrification depend on the hydraulic retention time. E.coli-levels were under 10/ml for most of the time in 1995-1996, and around 1 per ml at the longer HRT´s in 1997-1998.

More about the project at http://www.rekel.nl/water

INTRODUCTION

The waterboard "Uitwaterende Sluizen" operates over twenty sewage treatment plants (STP's) in the northwest of the Netherlands. Five of them are located on the island of Texel, a famous tourist resort famous because of birdlife. Since the early 1970's the policy of the water board has been to keep the (fresh) STP effluents inside the surface water system of the island, rather than discharge them into the North Sea orWadden Sea. During dry summers, the island encounters a shortage of fresh water. Drinking water is transported to the island through a pipeline from the mainland. The effluents have a distinct effect on the characteristic and diverse flora and fauna of the surfacewaters. Besides that, the volume of waterbodies on the island is small. Any residual pollution in the effluent will hardly be diluted. In dry years up to 90 % of the surface water is effluent.

During the last decades water treatment in the Netherlands has evolved to a high standard. From an ecological point of view however, the treated water is still "dead" water. Originally it has been a fine water: i.e. rainwater and potable water. The bulk of the water is only used for rinsing and as a transport medium. In an activated sludge plant, the treatment process is a biological process, but it only involves organisms, common in a polluted environment. The result is an effluent with a rather low content of organics (most of the carbon pollutants have been converted into sludge) and a high level of minerals and nutrients. Most effluents in the Netherlands are very clear, with a yellowish colour. Normally the levels of suspended solids are low, below 5 mg/l. After heavy rains, it can contain up to 1000 mg sludge/l. This sludge can have a considerable impact near the discharge point. The sludge particles contain high numbers of human bacteria and viruses. Further odour (effluent smells), foam on the water surface and the sludge particles in the water may negatively effect the aquatic ecosystem receiving the effluent. Ideally, effluent quality should be as close as possible to that of the receiving surface water, or even better.
Many technological solutions exist to improve the quality of treated wastewater, for example sand filtration and membrane filtration. These processes are expensive, and above all the product is still not a "living water". We have been looking for a system between the treatment plant and the surface water to improve the "ecological" water quality. The basic idea is depicted in Figure 1 ((based on Claassen, in Klapwijk, 1996).

This model uses a "buffer" between the sewage treatment plant and the surface water. In this buffer the different fields of engineering and ecology meet each other to improve the quality of the STP effluent into more natural "living" surface water. For Texel, a constructed wetland has been chosen to convert the effluent from the Everstekoog oxidation ditch into a more natural "living water". Some of the considerations were:

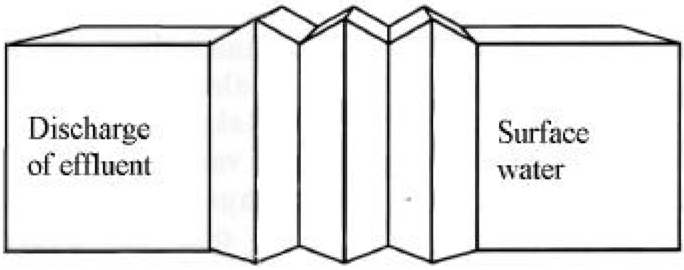

Figure 1 A Buffer Between The Sewage Plant And The Surface Water

- The constructed wetland is a simple system like the oxidation ditch;
- It runs on solar energy;
- There was sufficient space available;
- It fits in the rural Dutch landscape.

The four-year research project was a demonstration of the possibilities of a full-scale surface flow constructed wetland behind an oxidation ditch. It was aimed to provide knowledge of: the separate processes in the constructed wetland and give insight in maintenance, control and costs of the system. Does the combination with the constructed wetland lead to savings in the STP, for instance in the construction of settling tanks because the sludge will be retarded in the wetland or in nitrification/denitrification? How is the process stability?

EVERSTEKOOG

The STP Everstekoog is an oxidation ditch with a load of 45.000 p.e. (population equivalents) in summer. The dry weather flow is 3000-4000 m³/day; the maximum flow is 10.000 m³/day. Phosphorus removal takes place simultaneously with $FeSO_4$.The full flow of the STP has been treated in the surface flow constructed wetland since 1994. The system consists of a presettling basin, nine parallel ditches with a length of 150 m and a discharge ditch. The first part of each ditch is only 0.2 m deep and has vegetation with reed (*Phragmites australis*) or cattail (*Typha latifolia*). The deeper (0.5 m) part is planted with submerged aquatic plants. One ditch is a control without macrophytes (figure 2). The total volume is 7140 m³ (Table 1). The mean hydraulic retention time (HRT) is 2.1 day at dry weather flow. In the first research period (1995-1996) all ditches received the same flow, in 1997/1998 four different flows through the ditches resulted in HRT´s of 1.6 up to 11.3 days (the retention time in the ditches alone were 0.3, 1, 3 and 10 days).

Table 1 Dimensions Of The Constructed Wetland

	Surface area (m²)	Volume (m³)	HRT at dry weather flow (days)
Presettling basin	3480	4400	1.3
9 ditches	Each 980	2360	0.7 (0.3 - 10)
Discharge ditch	830	3370	0.1
Total	13110	7140	2.1

MONITORING AND RESEARCH PROGRAMME

Pressure sensors in the presettling basin, the ditches and the discharge ditch measured the flows through the wetland. The instrumentation also included nine oxygen probes with thermometers, two redox sensors and a weather station. The results of the continuous measurements (15 minute averages) of water levels, oxygen concentration, temperature, wind speed and direction, precipitation and light intensity were stored in data loggers and transferred automatically to the Edam office. For more information Kampf et al, 1998.

RESULTS

Natural values of the constructed wetland

Constructed wetlands can have considerable values for aquatic birds (Knight, in Haberl 1997). Though the constructed wetland is situated in the agricultural part of the island, it attracts quite high numbers of birds. Spoonbills (*Platalea leucorodia*) come to feed on small fish. In 1997 40 birds of 11 species bred in the constructed wetland (Kampf et al, 1998).

A Change In Water Quality

The quality of the effluent of the STP Everstekoog is typical for a well functioning oxidation ditch (very low loaded activated sludge plant); results of 1997 - 1998 are summarised in Table 2. After treatment in the oxidation ditch, the sewage already has a much better quality. Sewage is gray, smelly. Effluent has become clear water, but still with an odour. Despite the removal of particles in the settling tank, the effluent still contains fine activated sludge particles, with a

Table 2 Effluent Quality STP Everstekoog (1997-1998)

Parameter	Mean Concentration	Standard deviation N >=22
NO_3-N (mg/l)	2.6	2.5
NH_4-N (mg/l)	1.1	1.6
Total N (mg/l)	6.2	4.3
Total P (mg/l)	1.1	0.7
COD (mg O_2/l)	32	6
E.coli (number per ml)	590	730

variety of bacteria. Already in the presettling basin in the constructed wetland the water starts to "live", starts to resemble euthrophic surface water. It becomes a home for water life; regularly the water turns red because high numbers of zooplankton, mainly *Daphnia magna*. The number of different species of plants and animals in the wetland grew each year.

It is difficult to quantify the changes in water quality. One of the surprises in this research project is the augmentation of the turbidity of the water, especially at higher hydraulic retention times. The suspended solid content of the effluent from the wetland is higher than that of the STP effluent, but it is a different kind of suspended solids. In stead of activated sludge flocs, the water contains algae, Daphnia and other wildlife.

Diurnal Oxygen Pattern

A sign of the change in water quality is the diurnal oxygen fluctuation. The oxygen level in the effluent of the oxidation ditch is stable and low, in the presettling basin the oxygen level is around 3 mg/l. In the part of the ditches with submerged aquatic plants the daily oxygen pattern starts to resemble the pattern of normal surface water. During the daytime, the submerged aquatic plants and algae produced such an amount of oxygen that the levels rose well above the saturation value. In the afternoon, the high oxygen levels will help the oxygen to penetrate deeper into the sediment. At the end of the day, the oxygen levels dropped sharply. This "solar energy process" is also stable during longer periods. During the summer of 1997 the submerged water plants became covered by Duckweed (*Lemna spp.*) and floating algae. During the summer, the oxygen production came to a complete stand still, but after the removal of the *Lemna* in the end of August, the production started again quite quickly.

N and P Removal

At the rather high loading rates in the first part of the project (HRT just over 2 days, hydraulic loading around 25 cm/day) both the nitrogen and the phosphorus removal were rather low. This occurred partly because of the already low levels in the effluent of the oxidation ditch. In the summer of 1996, NH_4 was removed by 20 %, both NO_3 and PO_4 by 50 %. Other periods gave a negative P-removal through release from sediments and dying plant material. Even at low temperatures in the winter of 1995-96, the constructed wetland lowered the, temporarily, high level of 30 mg NH_4/l to 10 mg NH_4-N/l. During the second part of the research program, the ditches had different hydraulic retention times, the total HRT varied from 1.6 to 11.3 days. The HRT had a clear positive effect on both N and P removal efficiences. See Figure 2 for the concentration of NO_3 at the end of the ditches different HRT in four seasons in 1997-1998.
The harvest data of the Everstekoog are not fully known yet, some values for ditches with an HRT of 1 day (kg per ha): reed - dry solids: 15,000, N: 70, P: 13, cattail - 15,000, N 93, P 20; water plants - dry solids: 750, organics: 600, N: 16, P: 2. These figures are low compared with a constructed wetland for sewage in

More figures can be found on the Internet site http://www.rekel.nl/water/Everstekoog

Lauwersmeer: reed: dry solids: 27400, N: 456, P 44 (Toet, 1999). Literature figures for removal of P and N through harvesting of biomass vary also. On an average the removal through standing crop, incl. the litter will be around 125 kg N/ha.year (63-220) and 15 kg P per ha/year (3-19) in the Netherlands (Meuleman, 1999). The load of N and P with the STP effluent to the constructed wetland is around 5200 kg N/ha.year and 600 kg P/ha.year. Denitrification is probably the most important pathway for N-removal. In general, denitrification in periphyton on shoots of submerged parts of helophytes was much higher than in the soil, due to diffusion limitation in the soil top layer (Toet et al, 1998).

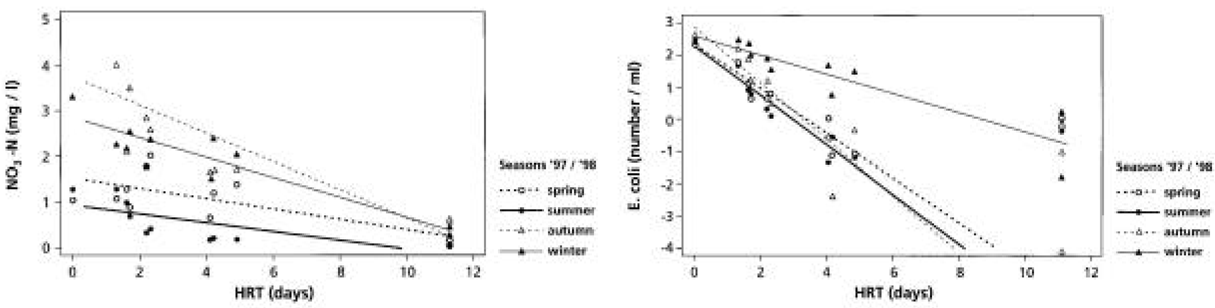

Figure 2 and Figure 3 Influence Of HRT On NO3 And On E.coli In Different Seasons In 1997-1998

Disinfection

The pilot-study in a small ditch like constructed wetland (Schreijer et al, 1996) had previously shown that the combination of ponds and helophytes was effective for disinfection of the effluent of the oxidation ditch. In the pilot study that the k-value in the relation $^{10}\log$ E.coli = k*time + C (E.coli in numbers per ml and the hydraulic retention time in days) was -0.65. In the last research year 1997/1998 the E.coli numbers in the effluent of the STP were 590 on an average. The k-values were in spring -0.69, in summer -0.76, in autumn -0.87 and in winter -0.29, Figure 3. Possibly, due to wildlife in the system, the E.coli numbers were rarely below 1 per ml. For E.coli values of less then 10/ml throughout the year, the HRT must be at least 4 days. For only disinfection to a level of E.coli 10/l, a HRT of 2 days will be sufficient. To minimise the influence of storm water flows it is important to buffer as much water in the system as possible, for a surface flow system this can be done by means of an appropiate design of the weirs.
In this study, we have given some attention to virus removal. The number of MS2-phagues, as an indicator for the number of viruses, in the effluent of the STP was 6.7 pfu/l (average of 4 counts in the autumn of 1997). The removal of the MS2-phague was, as expected, slower than the removal of E.coli. We have found a value of the k-value or the die-off rate of -0.16 on an average.

Costs

The investment costs of the constructed wetland alone were less than US $ 250,000, excl. the extensive instrumentation for the research project. This leads to capital costs of US $ 25,000 per year. Maintenance and supervision costs are also about US $ 25,000 per year. At a flow of 1.200,000 m^3/year the specific cost are about US $ 0.05 per m^3 at an HRT of 2 days and US $ 0.10 at a HRT of 4 days. To put this in perspective the costs to transport the waste water to the STP are estimated at US $ 0.10 per m^3 and of the treatment of the waste water in the oxidation ditch, including sludge treatment US $ 0.50/m^3.

CONCLUSIONS ON THE 4-YEAR RESEARCH PROJECT

The constructed wetland increased the water quality of the effluent from an oxidation ditch:

- An important feature of the presettling basin is that it acts as a buffer when during storm water flows the STP effluent contain high contents of dry solids. Retaining these high peaks in discharge of sludge can lead to savings in settling tanks.
- The oxygen regime improved, the effluent obtained a clear diurnal pattern of oxygen as long as the sunlight could reach the submerged plants. This pattern also existed even in wintertime at low temperatures;
- The hydraulic retention time has a distinct effect on the output of the constructed wetland. Especially the removal of ammonium, nitrate and E.coli becomes effective at longer HRT´s even in wintertime. The turbidity increases at longer HRT´s due to the production of biomass in the wetland.

An HRT of two days is sufficient for a reliant disinfection in summer, at a HRT of around four days the disinfection is also effective in wintertime. At this HRT, also a substantial removal of nitrogen has been found. A stable P-removal in all seasons needs either a much longer retention time or, in most cases more practical, chemical precipitation.

A surface flow constructed wetland, like the Everstekoog system, is a simple attractive system. It is also cheap as long as land costs are not too high. It looks like a Dutch polder landscape; the maintenance of the system resembles the maintenance of our ditches and canals. Near populated areas one of the features of the constructed wetland is that it can be combined with recreation areas and wildlife.

FURTHER DEVELOPMENTS

The Everstekoog constructed wetland proves the values and the possibilities of a simple semi-natural/constructed ecosystem for the improvement of effluents from sewage treatment plants. Currently the waterboard “Uitwaterende Sluizen” is studying for which of the other plants of the waterboard constructed wetland for this purpose is feasible. Another waterboard in the Netherlands, De Maaskant, is constructing an “Everstekoog” type wetland with a capacity of 35.000 m^3/day (van der Pluijm, 1999).

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[i] *4th International Conference on Ecological Engineering for Wastewater Treatment, Ås, Norway, 7-11 June 1999, paper_EcoEng99_helo_06.doc,*