OPERATIONAL EXPERIENCE WITH PHOSPHORUS AND NITROGEN REMOVAL AT THE HIMMERFJÄRDEN PLANT, SWEDEN

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INTRODUCTION

The Himmerfjärden Sewage Treatment Plant, situated in the southwestern region of Stockholm, was built in 1974 with mechanical, biological and chemical treatment. The plant services 230,000 people and has a very high efficiency of treatment with 97 % reduction in BOD₇, 96 % reduction in SS and 94 % reduction in phosphorus. Minimum value of 95 % efficiency for BOD₇ reduction and maximum value of 2 g P/m² in effluent are required by authorities as treatment efficiency. Beginning in 1995 the Ministry of Environmental Protection is considering the establishment of 50 % reduction of nitrogen as a requirement for Swedish wastewater treatment plants.

UPGRADING THE EXISTING PLANT FOR NUTRIENT REMOVAL

In order to reduce the phosphorus content and the organic load at the activated sludge units, pre-precipitation with ferrous sulphate has been used for nine years at the Himmerfjärden Plant. The dosing of the ferrous sulphate solution is computer controlled. The mole ratio of Fe/P is controlled according to a preset value, usually 0.9 - 1.2 and to the normal content of phosphorus in the incoming sewage. Before the sewage enters the aeration tanks, 50 % of the phosphorus and 50 % of the BOD₇ content are removed. This improves the nitrification efficiency in the aeration tanks. Only the difficult degradable carbon compounds are reduced by the pre-precipitation, while the easily degradable compounds are available as a carbon source for the denitrification process. Experiments to confirm this are currently being conducted. To achieve further reduction of phosphorus a small amount of either ferrous sulphate (about 1.5 g/m²) or aluminium sulphate (about 40 g/m²) is added as post-precipitation after the biological units. This is generally the only possibility to get a concentration of total phosphorus below 0.5 mg/l in the outlet, especially when long sludge ages are used, to obtain full nitrification.

| Tab 1. Concentrations of Total Phosphorus and Phosphates in mg/l (Jan 1988 - June 1989) |
|----------------------------------------|----------------|----------------|----------------|
| Influent | Primary settled | Biological purified | Effluent |
| Total - P | 6.4 | 3.4 | 1.0 | 0.41 |
| PO₄ - P | 4.0 | 0.32 | 0.34 | 0.09 |

After many years of experiments both in laboratory, pilot-plant and in full-scale, the biological nitrogen removal was applied at the Himmerfjärden Plant starting in 1988. Although pilot-plant experiments had shown good...
FeSO₄ + H₂O

Grit chamber

Primary Anox Aeration

Secondary Flocculation

Final sediment.

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Fig.1. Flow scheme of Himmerfjarden Sewage Treatment Plant

results for post-denitrification method, full-scale operation in spite of complete nitrification (98 %) resulted in 34 % nitrogen removal as annual average value. It was caused by a short retention time and high sludge load, depending on poor sedimentation properties of the biological sludge. As it was impossible to achieve a high nitrogen removal efficiency within the existing tank volumes with post-denitrification method, pre-denitrification method was tested and optimized since 1985.

In fig.1 process configuration for the Himmerfjarden Treatment Plant after upgrading for biological nitrogen removal is presented. Nitrogen removal is conducted by introducing anoxic zones in front of the activated sludge tanks. The internal energy source from influent wastewater is used for denitrification. Excluding the periods with high flow and low temperatures during snow melting, a nitrification efficiency of over 90 % is obtained. The annual average of the nitrogen removal efficiency is only about 40 %; large oscillations occur from day to day. The denitrification process is limited by lack of organic carbon in the wastewater. The maximum degree of denitrification is not determined by the rate of return sludge as is theoretically expected; instead it is controlled by the carbon/nitrogen ratio. This was only 6.3 calculated as COD/N, which corresponds to 2.9 as BOD₇/N. In order to obtain higher nitrogen removal efficiency of the existing system, external carbon source should be dosed during low-loaded periods to increase carbon/nitrogen ratio and optimize denitrification.

UPGRADING OF THE AERATION SYSTEM

At the Himmerfjarden Plant two different products of membrane diffusers are used: Sanitaire, USA and Nopol, Finland. A flexible system with fine bubble membrane disc diffusers made it possible to change the relation between the volumes for nitrification and denitrification. With the help of on-line monitoring for the nitrate content in effluent from the anoxic zone and aerobic zone, and ammonia in effluent from the biological step, the volumes can be related to nitrogen load and the nitrification/denitrification capacity. During winter time, when nitrification efficiency decreases, anoxic zones can be changed into aerobic and improve nitrification. During summer months, when nitrification is complete, it is an advantage to operate the plant with larger anoxic zones to improve the nitrogen removal efficiency.

REFERENCES