

Energy Efficiency in Total Nitrogen Removal at the Kakolanmäki WWTP in Turku

– Using dynamic simulation for optimising process parameters in aeration

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Different process control parameters and their combinations were scrutinised in fluctuating flow, temperature and loading conditions to optimise energy consumption and treatment result at the Kakolanmäki waste water treatment plant. The partial by-pass of primary sedimentation used for ensuring sufficient BOD for denitrification had a significant impact on energy consumption while the effect on treatment result was varying. Aeration control based on both oxygen concentration and effluent ammonia concentration proved to be robust and well self adjusting.

Background

In an activated sludge plant aeration is crucial for the removal of organic carbon (BOD) and nitrogen and it is also typically the biggest consumer of energy. The main objectives for this work were to find optimal set-point values for aeration control and suitable ratios for pre-sedimentation by-pass at the Kakolanmäki waste water treatment plant in view of both energy efficiency and maximal total nitrogen removal.

The Kakolanmäki WWTP owned by Turun Seudun Puhdistamo Ltd is a large underground activated sludge plant with deep aeration basins and sand filtration as tertiary treatment. It is one of the largest treatment plants in Finland and it treated 28,5 Mm³ of municipal wastewater in 2010.

The treatment plant is new and well instrumented and the level of automation is high. The set-point value for oxygen

concentration in the last aerated zone and the use of aeration or mixing in the third zone are both controlled based on effluent ammonia concentration. The influent BOD/N ratio is high due to industrial wastewaters and pre-sedimentation is partially by-passed to ensure sufficient organic carbon for denitrification to achieve a high total nitrogen reduction.

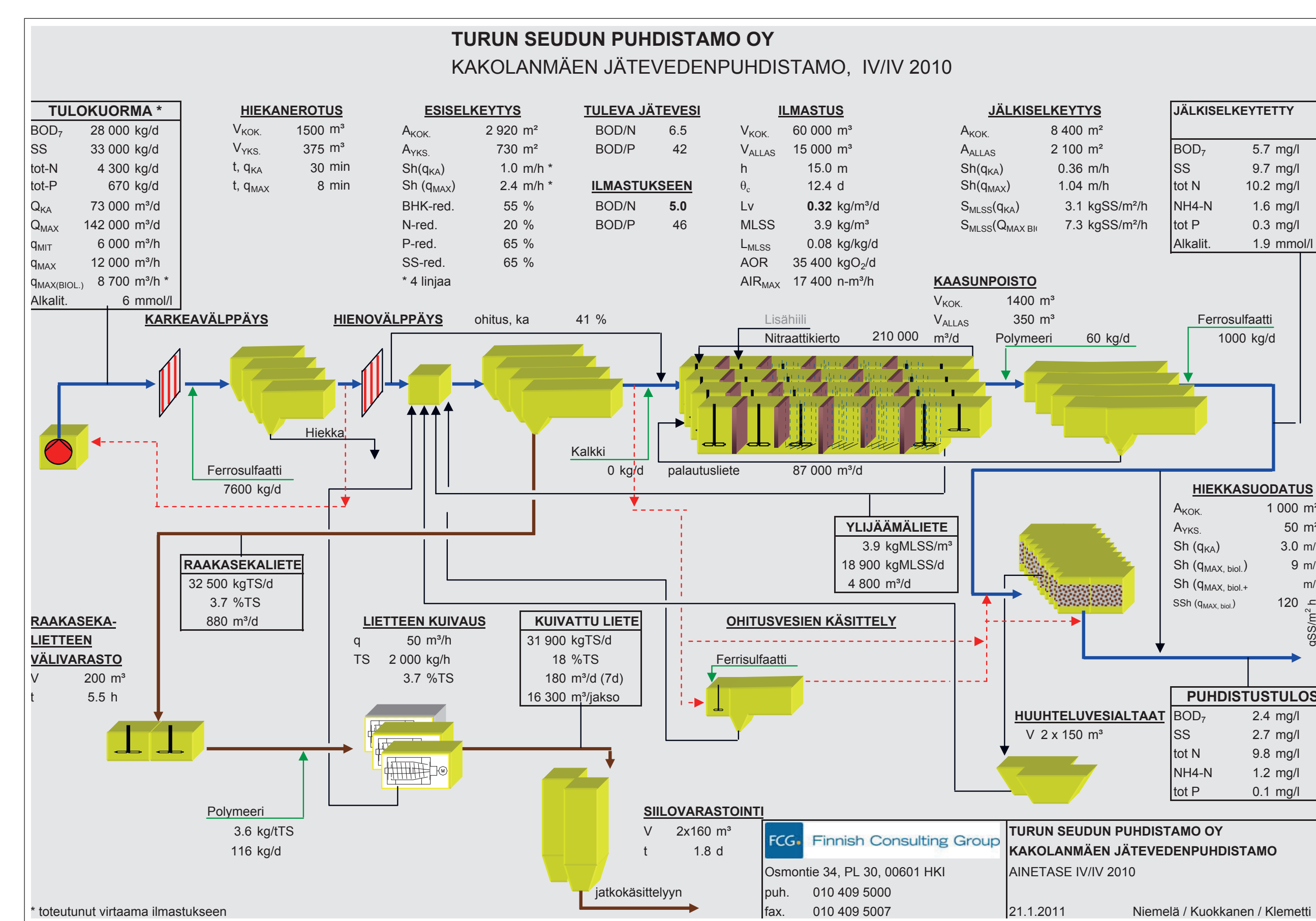


Figure 1. Process mass balance chart of Kakolanmäki WWTP.

Methods

A dynamic model of pre-sedimentation and the activated sludge process was made using the commercial software GPS-X and the Activated sludge model (ASM).

After calibrating the model, nitrogen removal results and air consumption were calculated during two different simulated four week periods using different process control strategies.

A statistical analysis of treatment results during 1.1.2010–30.6.2011 was also made comparing total nitrogen removal with e.g. nitrification result, pre-sedimentation by-pass ratio and the BOD/N-ratio in aeration.

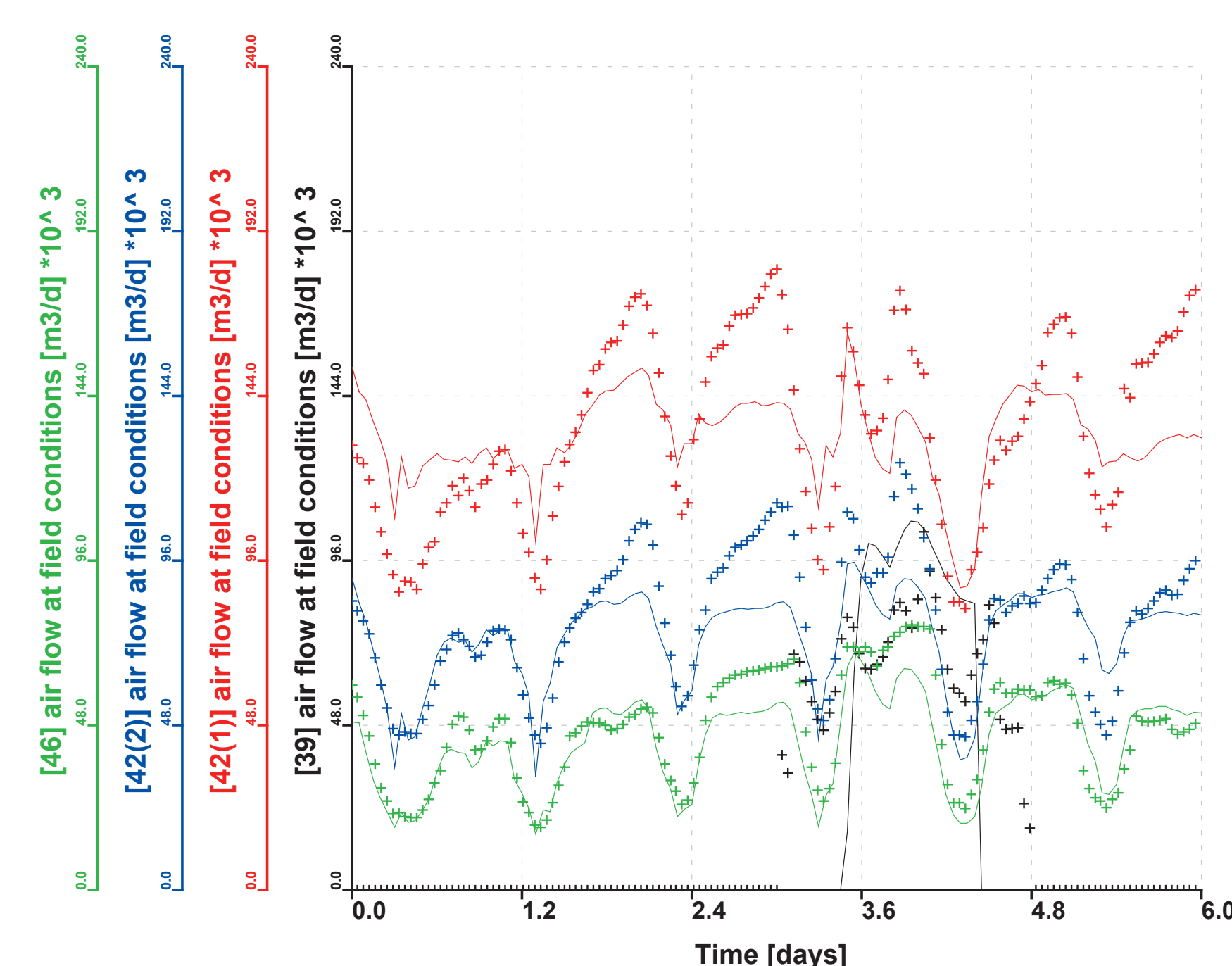


Figure 2. Air consumption during a six day period, simulated (solid line) and measured (+).

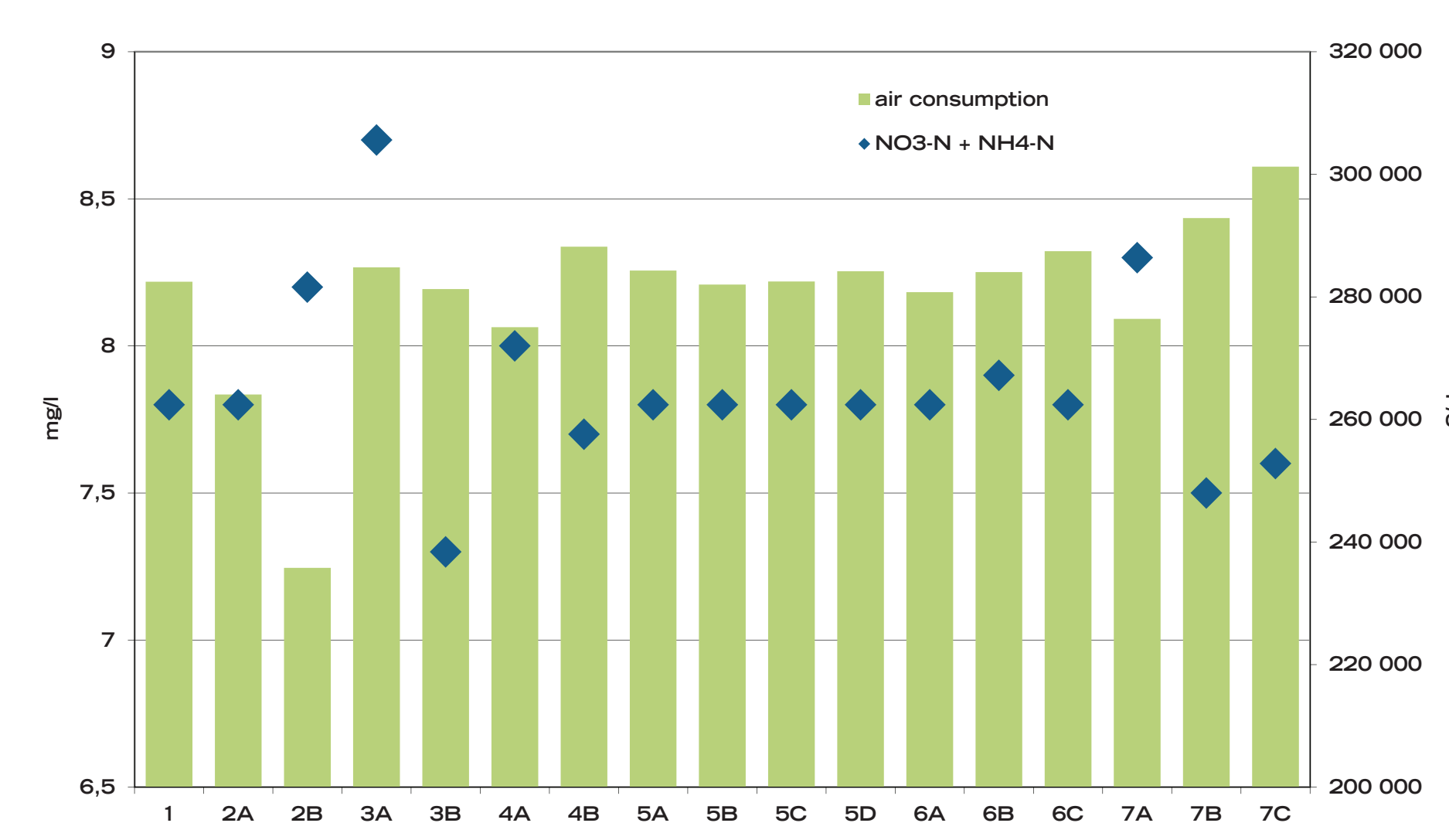


Figure 3. Air consumption (m³/d) and effluent nitrogen (mg/l) with different process control strategies.

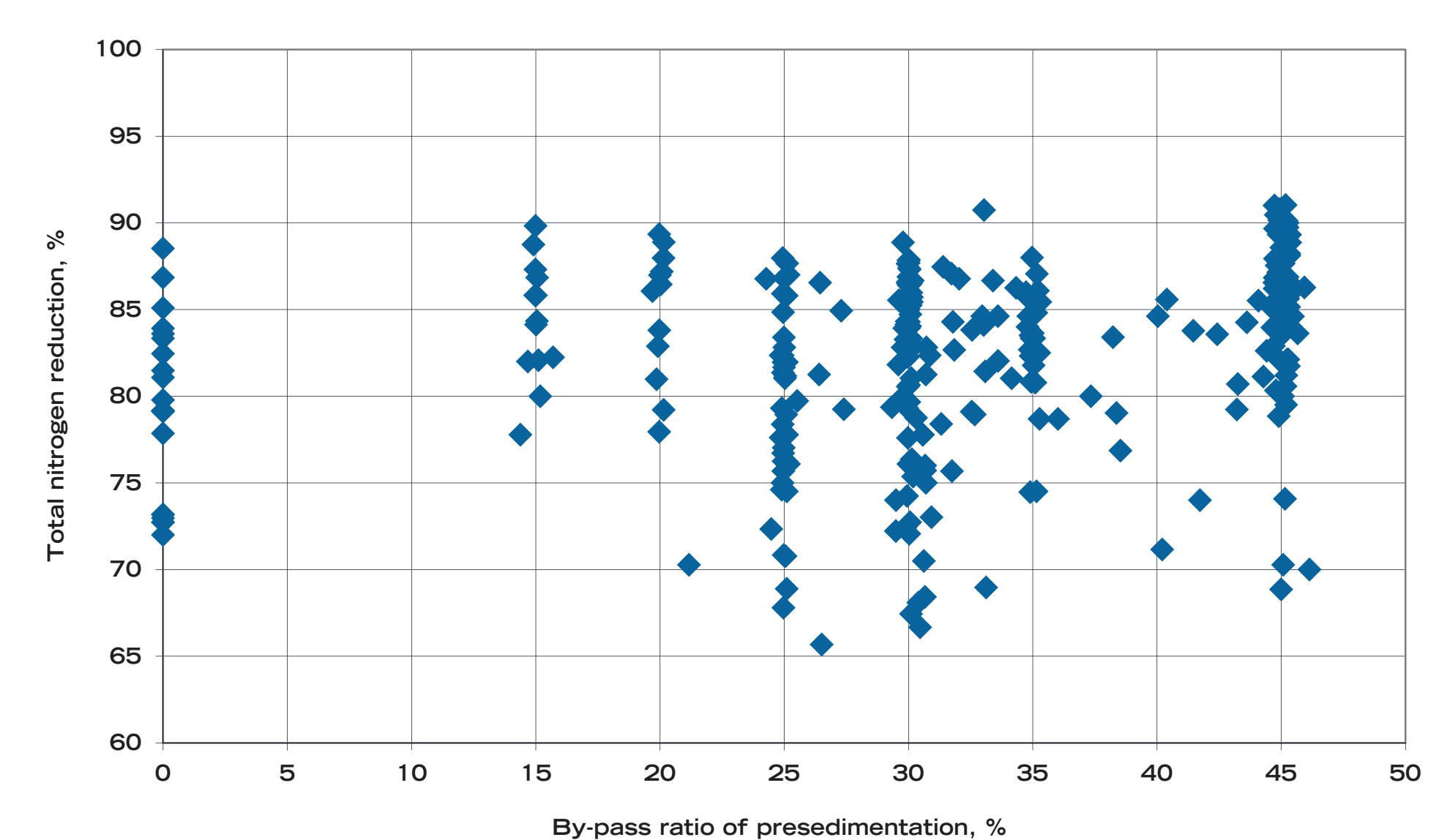


Figure 4. Nitrogen reductions at different ratios of pre-sedimentation by-pass.

Results and Conclusions

With a sufficiently high BOD/N ratio of the influent the total nitrogen removal was mainly dependent of nitrification and internal recycle. Mainly all recycled nitrate was consumed during the anoxic phase.

The role of pre-sedimentation by-pass for ensuring high nitrogen reduction was smaller than estimated in process design, due to a higher BOD content of the influent. Its impact on energy consumption was considerable. Thus smaller by-pass ratios for winter and summer were recommended.

Using on-line measurement of effluent ammonia concentration and automation control for choosing between aeration or mixing in zone 3 and adjusting the set-point values for oxygen concentration in zone 6 proved to be effective and un-sensitive for moderate changes of the user defined set point values.

The set-point values for oxygen levels in aeration zones 4 and 5 had a significant effect on air consumption while only little effect on the treatment result for values above 1 mg of oxygen per litre, indicating that using ammonia-based set-point values for aeration control of all basins could save more energy.