Dynamic Process Control with ISE Sensors Decreases Energy Costs

Optimising the degradation processes in a SBR wastewater treatment plant

Figure 1: Aerial photo of the Glückstadt wastewater treatment plant

The Glückstadt municipal wastewater treatment body (SEG) near Hamburg, Germany, first operated an aeration plant and combined sludge stabilisation with a size of 36,000 population equivalent (PE). In the course of the plant modernisation, rebuilding to a Sequencing Batch Reactor (SBR) plant with a capacity of 20,000 PE was carried out in 2004 (Figure 1).

"We are very pleased with the new measuring technology which allows us to keep the discharge values stable and at the same time save energy."

Glückstadt wastewater treatment plant: Overview of the plant and procedure

The wastewater first runs through screens and sand catcher systems and is then temporarily stored in a storage basin. For further cleaning, it passes alternatingly into one of the two SB reactors. Finally it is temporarily stored in an outflow reservoir, before being directed into the River Elbe.

The plant has no digestion tower; centrifuges dewater the excess sludge which is usually used in agriculture. An overview of the wastewater treatment plant is shown in Figure 2.

The two SB reactors each have a total volume of 4500 m³ and each reactor cleans 750 m³ wastewater per cleaning cycle. Two blower units of 75 kW are available per reactor. The fixed time individual phases of the SBR operation of the Glückstadt wastewater treatment plant are based on several years of experience (Table 1).

The entire cleaning cycle per reactor is approx. 10 hours.

If necessary, e.g. during strong rainfall, the fixed times can be overridden manually. However, manual plant management requires the presence of additional, particularly experienced operating personnel. This is associated with considerable extra organisational effort, especially at night and on weekends.

The SB reactors measuring system includes an IQ SENSOR NET system (Figure 3) and optical oxygen sensors FDO (Figure 4). Up to the introduction of the dynamic control of the SBR process, only the oxygen measurement was used as a control variable, whereby the oxygen input was by means of frequency-controlled blower units in order to keep the oxygen concentration constant during the nitrification phases.

First test measurements with ISE sensors

The aim of our 2008 measurement campaign was to find out whether the fixed times of the nitrification and denitrification phases still fit to

SBR phase	Process	Time period	Active components
Phase 1	Filling 1 (500 m³) & denitrification	60 min	Filling pumps / Stirrer
Phase 2	Denitrification 1 / Bio-P	45 min	Stirrer
Phase 3	Nitrification 1	110 min	Aerator units
Phase 4	Filling 2 (250 m³) & denitrification	30 min	Filling pumps / Stirrer
Phase 5	Denitrification 2	75 min	Stirrer
Phase 6	Nitrification 2	120 min	Aerator units
Phase 7	Sedimentation	130 min	
Phase 8	Clarified water discharge (750 m³) & surplus sludge withdrawal	40 min	Decanting / Pumps
Phase 9	Pause		

Table 1: Fixed time phases of SBR operation with simple O_2 control strategy.

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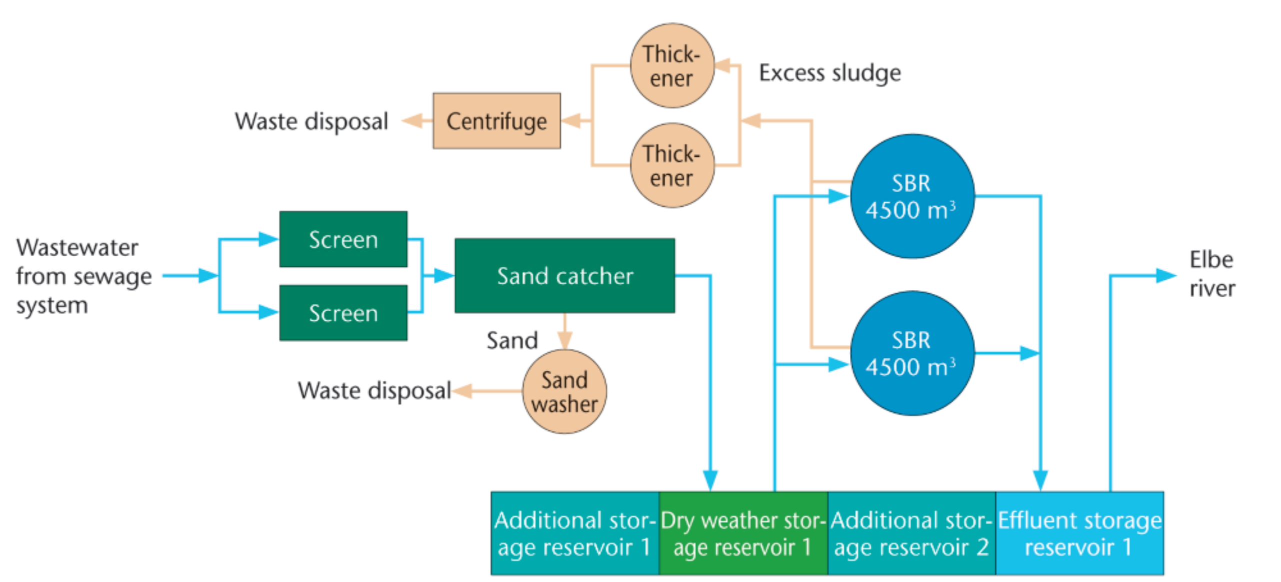


Figure 2: Block diagram of Glückstadt wastewater plant

Figure 3: IQ Sensor Net terminal 2020XT by WTW

the plant, or whether there was optimisation potential in the individual phases of the degradation process. In order to be able to measure ammonium and nitrate values online, we installed the WTW ISE combination sensor VARiON (Figure 5) in each of the two reactors. Integration of the sensors into the existing IQ SENSOR NET system and their start-up was easy. Based on the recorded data, it could quickly be proven that the ammonium was already completely degraded after around half of the aeration time of the two nitrification phases (Figure 6). The one-year trial phase with the ISE sensors confirmed that there was considerable energy saving potential in operating the SBR plant. We decided therefore to change from a simple time control of the SBR processes to a dynamic control strategy using NH_4-N as control parameter.

Process optimisation

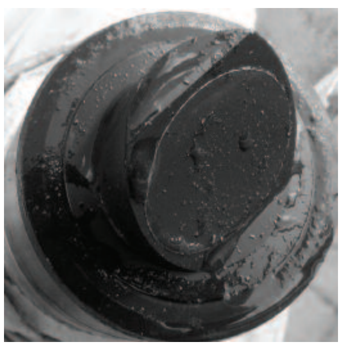


Figure 4: FDO 700 IQ optical D.O. sensor by WTW

Figure 5: VARiON 700 IQ ISE sensor by WTW

The engineering office in charge programmed an additional control program named "Energieoptimiert" (energy-optimised) for the dynamic process control, which integrates the ammonium and nitrate measured values into the existing PLC. Ammonium is the control- relevant parameter that determines the end of the nitrification phases. For the first nitrification process (Phase 3), the control value that switches off the blower units is at 1.3 mg/l NH_4-N and, for the second nitrification process (Phase 6) it is at 0.7 mg/l NH_4-N. The next SBR phase begins after the blowers are switched off. The degradation of the remaining ammonium is almost complete during the sedimentation phase (NH_4-N values < 0.4 mg/l; see Figure 7).

Fig. 6: Glückstadt wastewater plant (reactor 2) before optimization: Time-based process control

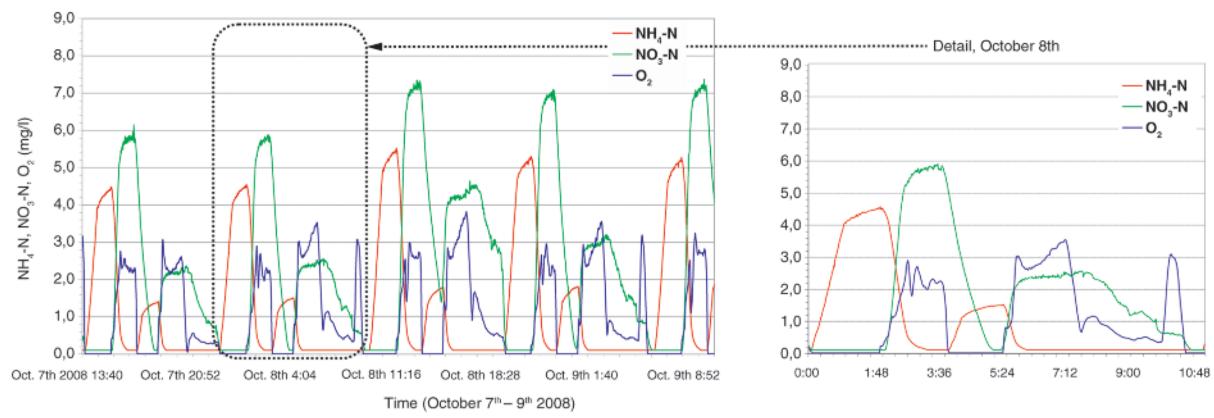
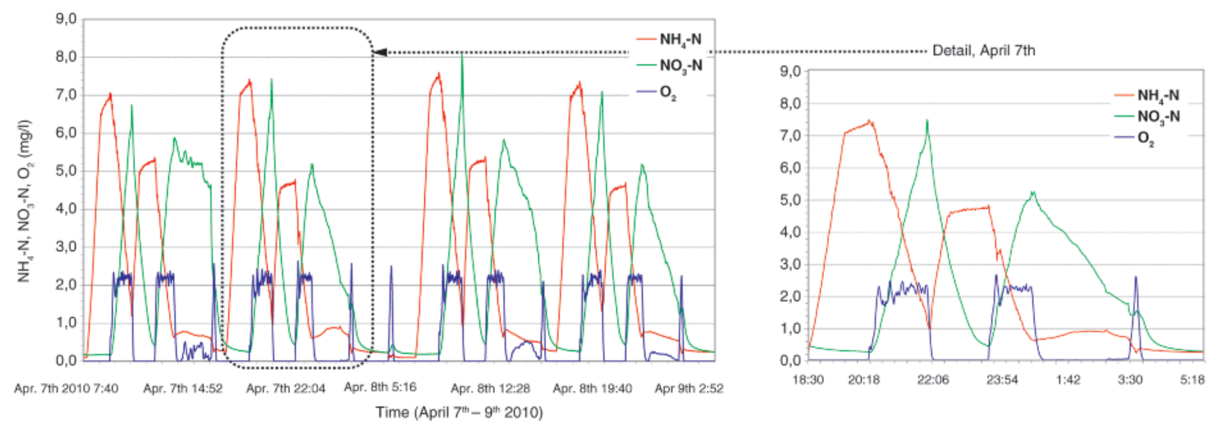


Fig. 7: Glückstadt wastewater plant (reactor 2) after optimization: Ammonium-based process control



The new dynamic control of the aeration times ensures that the nitrification runs only as long as necessary and the targeted, very low effluent value is reached safely, but without unnecessary energy consumption. The control settings mentioned are based on existing empirical values, but are freely adjustable in the new control program. This ensures a simple optimisation of the degradation process in the future, without having to invest again in costly programming.

The simultaneous measurement of nitrate and ammonium concentrations enables a plausibility check of the ammonium degradation at any time (via the stoichiometric ratio of NO_3-N and NH_4-N) and serves as a control for the effluent limit values at the end of the cleaning cycle. The nitrate measurement itself is, however, not used as a control-relevant parameter.

Even today we are using the time-based program as a component of the process control, but it is used mainly as an emergency program in case of measurement faults or implausibility's. Also, the process management system automatically switches to time-controlled operation, should the energy-optimised program surpass the former fixed times of the nitrification phases.

In consequence, by implementing a dynamic process we could shorten each nitrification phase by up to an hour. Calculating 4 nitrification phases per day (with an overall cleaning cycle of 2 nitrification phases per SBR reactor), the running time of the aeration units could be reduced by up to 4 hours. Extrapolated over a year, we could save up to 1500 operating hours. This not only reduces the energy costs, but also lessens the wear out on the aerator units.

Conclusion

We are very pleased with the new measuring technology which allows us to keep the discharge values stable and at the same time save energy.

The used measurement equipment works with minimum maintenance. The entire degradation process is transparent with regard to the process-relevant parameters ammonium, nitrate and oxygen. The ISE combination sensor and the optical oxygen sensor enable us to simply optimise the degradation process. Thanks to the dynamic control strategy manual adjustments are now practically unnecessary as the plant automatically adjusts to the incoming load of the wastewater.