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Application note

Optimization of the degradation processes in the SBR wastewater treatment plant in Glückstadt

DYNAMIC PROCESS CONTROL BY MEANS OF ISE SENSORS DECREASES ENERGY COSTS

The SBR (Sequencing Batch Reactor*) wastewater treatment plant in Glückstadt (city near Hamburg, northern Germany) has been using measurement technology from the brand WTW for several years.
The time-based process control was tested in 2008 with the VARiON® sensor (ion-selective ISE measurement technology).
This investigation showed that there was considerable energy savings potential in the aeration control during the nitrification process.
That is why, after a test phase of approximately one year, the Stadtentwässerung Glückstadt (SEG, i.e. municipal authority for wastewater collection and treatment) decided to change over from a simple time control of the SBR processes to a dynamic control with ammonium (NH_4-N) as the control parameter.

Fig: 1: Aerial photo of the Glückstadt wastewater treatment plant

Glückstadt wastewater treatment plant: Overview of the plant and procedure

On the wastewater treatment plant site, the SEG first operated an aeration plant with a plant size of 36,000 population. In the course of the plant modernization, rebuilding to an SBR plant with a capacity of 20,000 population was carried out in 2004. The wastewater first runs through screens and sand catcher systems and is then temporarily stored in a storage basin. For further cleaning, it alternately enters one of the two available SBR reactors. Before a pressure line directs the cleaned wastewater into the Elbe, it is temporarily stored in an outflow reservoir. The plant has no digestion tower; centrifuges dewater the excess sludge that is usually used in agriculture.
An overview of the wastewater treatment plant is shown in Figure 1.

The two SBR 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 for each reactor. The time-fixed individual phases of the SBR operation of the Glückstadt wastewater treatment plant are based on several years of experience (Table 1).

SBR phase	Process	Time period	Active components
Phase 1	Filling 1 (500 m³) and 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) and 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) and surplus sludge withdrawal	40 min	Decanting/Pumps
Phase 9	Pause		

Table 1: Time-fixed phases of SBR operation with simple O_2 control strategy.

*) The abbreviation SBR originates from the English description Sequencing Batch Reactor where the wastewater is cleaned on a batch-by-batch basis. In SBR aeration plants, the following phases are generally run through in each cleaning cycle: Filling of the reactor, thorough mixing (denitrification => degradation of nitrate), aeration (nitrification => degradation of ammonium), sedimentation of the activated sludge and finally decanting of the cleaned wastewater as clean water.

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The entire cleaning cycle per reactor is approx. 10 hours. If necessary, during strong rainfall, for instance, the fixed times could also be manually adapted. However, manual plant management requires the presence of additional, particularly experienced operating personnel. This is associated with considerable extra organizational effort, especially at night and on weekends. The reactors of the plant are equipped with an IQ SENSOR NET system 2020 and an optical oxygen sensor FDO® 700 IQ. Up to the introduction of the dynamic control of the SBR process, oxygen measurement was used exclusively as the control variable with control of the oxygen input by means of the frequency-controlled blower units in order to keep the oxygen concentration constant during the nitrification phases.

First test measurements with VARiON® sensors

The aim of the measurement campaign, started in 2008, was to find out whether the fixed times of the nitrification and denitrification phases still fit to the plant or whether there was optimization potential in the individual phases of the degradation process. In order to be able to measure ammonium and nitrate values online, a VARiON® 700 IQ ISE combination sensor was installed in the two reactors. Integration of the sensors in the existing IQ SENSOR NET system and their start-up was uncomplicated. During the trial phase, the measured values were recorded in the integrated data logger of the MIQ/TC 2020 XT terminal/controller and transferred onto the computer via USB stick for data analysis in Excel. 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 (Fig. 2). The one-year trial phase with the ISE sensors then confirmed that there was considerable energy savings potential in operating the SBR reactors.

Process optimization

The responsible engineering office programmed an additional control program named “Energieoptimiert” (energy-optimized) for the dynamic process control, which integrates the ammonium and nitrate measured values into the existing PLC. Ammonium is the controlrelevant 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 NH4-N and, for the second nitrification process (Phase 6) it is at 0.7 mg/l NH4-N. The next SBR phase begins after the blowers are switched off. The degradationof the remaining ammonium is almost complete during the sedimentation phase (NH4-N values < 0.4 mg/l; see Figure 3).

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 (Fig. 3). The control settings mentioned are based on existing experience values, but are freely adjustable in the new control program. This ensures a simple and uncomplicated optimization 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 NO3-N and NH4-N) and serves as a control for the effluent limit values at the end of the complete cleaning cycle. The nitrate measurement itself is, however, not used as a controlrelevant parameter. Even today the time-based program is still a component of the process control, but is used predominantly as an emergency program when for example measurement faults or implausibilities occur. The process management system also switches automatically to timecontrolled if the “energy optimized” program exceeds the old fixed times of the nitrification phases. In consequence, each nitrification phase could be shortened by up to an hour through the dynamization of the process. On the basis of 4 nitrification phases each day (with an overall cleaning cycle per SBR reactor of 2 nitrification phases), a reduction of the running time of the aeration units of up to 4 hours results. If this value is extrapolated over a year, up to 1500 operating hours of the blower units can be saved. This not only reduces the energy costs, but also lessens the wearout on the aerator units.

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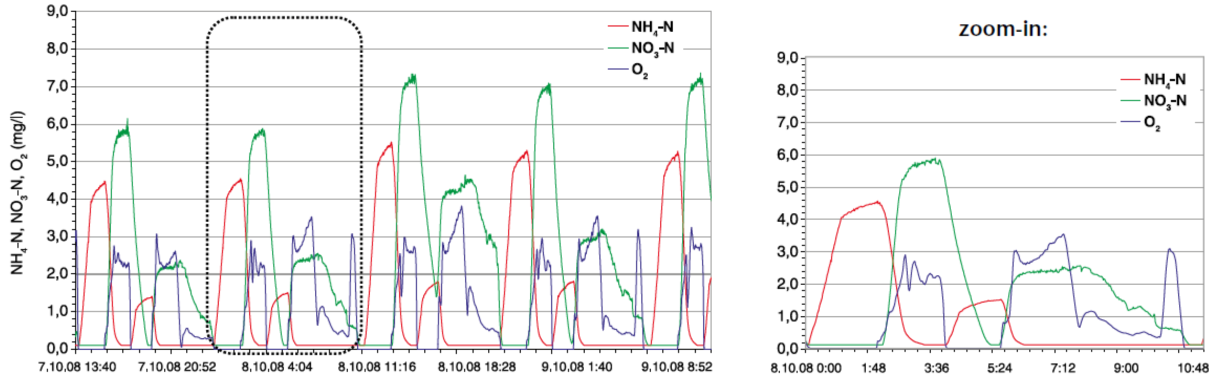

Fig. 2: Time-based control: Clearly visible is that the degradation of the ammonium (red) is already almost complete after approx. the half of the aeration time (blue).

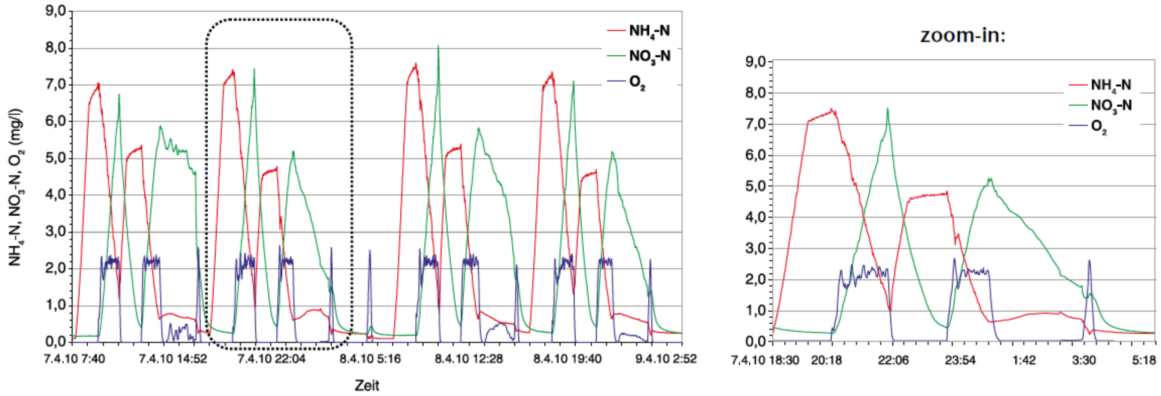

Fig. 3: Ammonium-based control: The new dynamic control acc. to ammonium stops the blowers when ammonium reaches a specific value

Conclusion

The IQ Sensor Net measurement technology employed works with minimum maintenance overhead. The reliable measured values enable continuous control of the cleaning process of the plant and an efficient use of energy. The IQ Sensor Net enables optimization of wastewater cleaning of SBR plants simply and cost effectively through the use of the proven VARiON® 700 IQ combination sensors and the FDO® 700 IQ optical oxygen sensor. The entire degradation process is transparent with regard to the process-relevant parameters ammonium, nitrate and oxygen.

The practical advantages are:

- A safe plant management due to great transparency with simultaneous energy savings
- An automatic adaptation of the dynamic control to the incoming wastewater load, manual action is thus redundant to the greatest possible extent
- Improved operational safety and secured achievement of the effluent limits
- Easing of the burden on the operating personnel.

IQ Sensor Net System 2020 and VARiON® sensor in use at Glückstadt wastewater plant

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