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Combined aeration and mixing system and its use in practice

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Abstract. The article deals with combined systems, which are mainly used in wastewater treatment plants for the purpose of aeration and mixing. These systems are mainly installed in activation reactors, but their use is also possible, for example, in sludge storage tanks. The combined systems are capable of guaranteeing the required values of relevant monitored pollution indicators at the WWTP effluent. The aim of this article is to describe the activation reactor control algorithm with the combined system. Reliable functionality is proved by the presented average values at the WTP effluent, which meet the required emission limits set by relevant permits.

1. Introduction

The basic characteristic and advantage of the combined systems is that they provide mixing and aeration functions. The combined systems may use different types of aeration depending on their use, location and characteristics.

Submersible combined systems are usually installed at the bottom of the reactor in its centre and are completely submerged. Motors and air pipes are exceptions that usually run over the level or are connected to blowers. For example, some of them are capable of feeding a mixture of wastewater and air into the reactor in a radial direction. Others may have a hyperboloid shape, which supports flowing in the reactor.

Surface-type combined systems are installed on fixed bridges or floats. Floats enable movement depending on the water level. A part of the system is always in contact with water and another part is above the water level. These may be, for example, paddle aerators or turbines. Systems using air entrainment or suction from the ambient environment.

2. Aire O₂ Triton system

Equipment above the water level sucks air which is fed through a hollow shaft to the outlet with a diffuser ensuring its dispersion. Mixing is ensured by special paddles. The bubble path is thus different from conventional aeration systems (see Figure 1 and Figure 2) [2]. Normally, Triton is fixed by a firm bracket or floats at the sides or in the center of the reactor.

The Aire O₂ Triton system is used in wastewater treatment tanks in aeration reactors but it can also be used in sludge thickening or storage tanks. The system is capable of ensuring separate mixing or mixing and aeration.

The ideal reactor shape for this system is circular or oval (circulation activation system). Such reactors make the best of this system potential [1]. In rectangular reactors there may be a problem with sufficient homogenization of the entire volume and sludge settling in dead areas. For these reasons, it is possible to fit the systems installed in such reactors with a gearbox that ensures its rotation, which eliminates this problem [2]. Another possibility is to develop a model and analyse water movement in the reactor. This can help find the ideal location for the system installation.



Standard calculation of oxygenation capacity for pneumatic aeration cannot be fully relied upon for these systems. Operators' experience show that Triton is able to handle loads of up to twice the population equivalent population than as specified in this calculation [1].

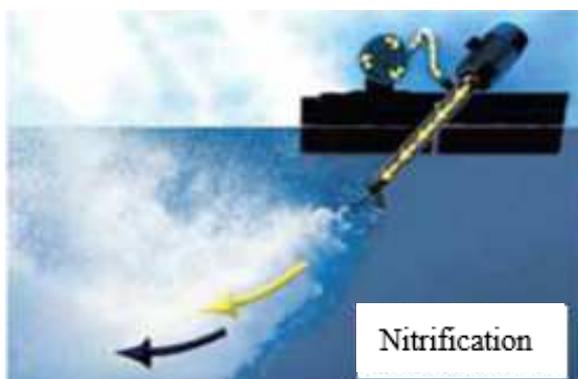


Figure 1. Triton system aeration process [2].

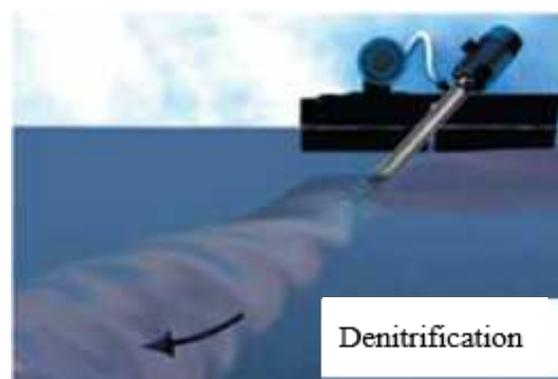


Figure 2. Triton system mixing process [2].

2.1. Other system applications

In addition to WWTPs, the system is also commonly used to improve the quality of surface water, for example in lakes or ponds. It can also be used to prevent from freezing in facilities where there is a risk of undesirable freezing of the floats etc. For these reasons, the system can only be rented out to improve the current situation. According to available information, the Triton system has been installed at about 37 WWTPs and six other sites in the Czech Republic. In total, it should be about 118 Tritons [2].

The system is patented by Aeration Industries International, Inc. (Minnesota, USA) in several modifications. Triton is commonly used worldwide also for industrial wastewater treatment. These applications include, for example, treatment of water from food industrial plants, wine-growing companies, chemical and petrochemical industries but also from landfills etc. [3].

3. Activation reactor process control

Nitrification and denitrification process control can vary. Suitable optimization can reduce the cost of electricity, reduce requirements for the operators and result in a reduced nitrogen outlet values. The input values are variable over time, both the wastewater composition and its quantity change [4].

Few measurements were conducted in real time in the past. In this respect, it was necessary to rely on the staff experience. Nowadays, the control is greatly facilitated by automation. If necessary, equipment approved by the operator as necessary and helpful can be automated [5, 6]. Information on the operation itself, the individual facilities and parameters is thus provided to the WWTP staff and the operator. According to such information, it is also possible to control the individual pieces of equipment remotely or it can be controlled based on pre-set algorithms.

Activation reactor processes can be controlled by:

- nitrification and denitrification interval setpoints,
- dissolved oxygen concentration,
- ammonia nitrogen concentration
- ammonia nitrogen and nitrate concentration.

4. Use of the combined system in practice

The information and data below was provided by VaK Hodonín, a.s. The selected WWTP is fully automated with N-NH_4^+ and N-NO_3^- . The plant was designed for 600 PE [1].

Two Aire O_2 Triton systems are used as the aeration system. Mixers are also installed in the activation reactors. This measure is mainly introduced to save electricity. At present, after consultation with the manufacturer at other WWTPs, frequency converters are installed on the Triton systems.

In treatment plants, hysteresis is set and considered to measure concentrations in the activation reactors (which is related to the subsequent switching on and off of individual pieces of equipment). This prevents from the system fluctuations and the equipment is not unnecessarily overloaded by constant switching on and off.

4.1. Activation reactor algorithm description

Processes in the activation reactor are primarily controlled by ISE probes (i.e. according to the concentrations of ammonia nitrogen and nitrates). In case of failure of this probe, it is control the processes by an OXI probe. Both of these algorithms operate according to the setpoint if the pH of wastewater at the inlet is within the desired range and the critical temperature of the mixed liquor has not been exceeded.

4.1.1. pH control. This step preceded all other control algorithms due to frequent WWTP poisoning. The plant is located in a wine-growing area and in the past this caused considerable issues regardless of the costs of inoculation

If the pre-set pH limits are exceeded, an alarm gets triggered automatically. If the lower limit is exceeded, both aeration systems are activated. When the pH returns to the required limits, this process is maintained for a certain period of time for safety reasons and then followed by a standard start of nitrification.

4.1.2. Temperature control. Oxygen solubility drops with a rising activation temperature. For this reason, the demanded oxygen limits are shifted. There is an effort to achieve this value even if it is a rather theoretical limit. A drop by half a degree below this critical temperature returns the system to the standard control mode.

4.1.3. Process control based on the ISE probe. Normally, the system is managed based on ammonia nitrogen and nitrate values. The system reacts to changes in the N-NH_4^+ value and aeration is controlled accordingly. After the basic time needed for the system aeration, the N-NH_4^+ content is evaluated based on an algorithm. Aeration is then completed, prolonged or prolonged with a startup of a second aeration system. An oxygen probe contributes to checking the high N-NH_4^+ concentration values and useless reactor aeration - energy point of view. Regulation due to high N-NO_3^- occurs only when N-NH_4^+ is within the set limits.

4.1.4. Process control based on the OXI probe. During nitrification, the system attempts to reach a certain set limit of dissolved oxygen concentration in the reactor. The required oxygen limit varies depending on the temperature of the mixed liquor. At the same time, however, the maximum and minimum nitrification period is set.

Under standard conditions, one of the Tritons is in operation. At the end of this basic period, the system begins to decide whether or not the required limit has been reached. Thus, this is followed by prolonged nitrification, terminated aeration or startup of another Triton system. Once this limit has been reached, the mixing transition phase takes place for a fixed period of time or until the dissolved oxygen concentration has dropped to the denitrification limit. The duration of the denitrification process is also fixed and can be extended.

4.2. Concentration progress - real values

Figure 3 shows the concentrations of measured parameters in the activation reactor over 24 hours. This are values (from the bottom up) of dissolved oxygen, ammonia nitrogen (N-NH_4^+) and nitrates (N-NO_3^-). The nitrates graph, respectively its values, are related to the right axis.

The phases of nitrification and denitrification can be easily observed in the graph. This results in the degradation of ammonia nitrogen accompanied by an increase in nitrates during aeration and a decrease in nitrate content with a decrease in dissolved oxygen content during the subsequent denitrification process.

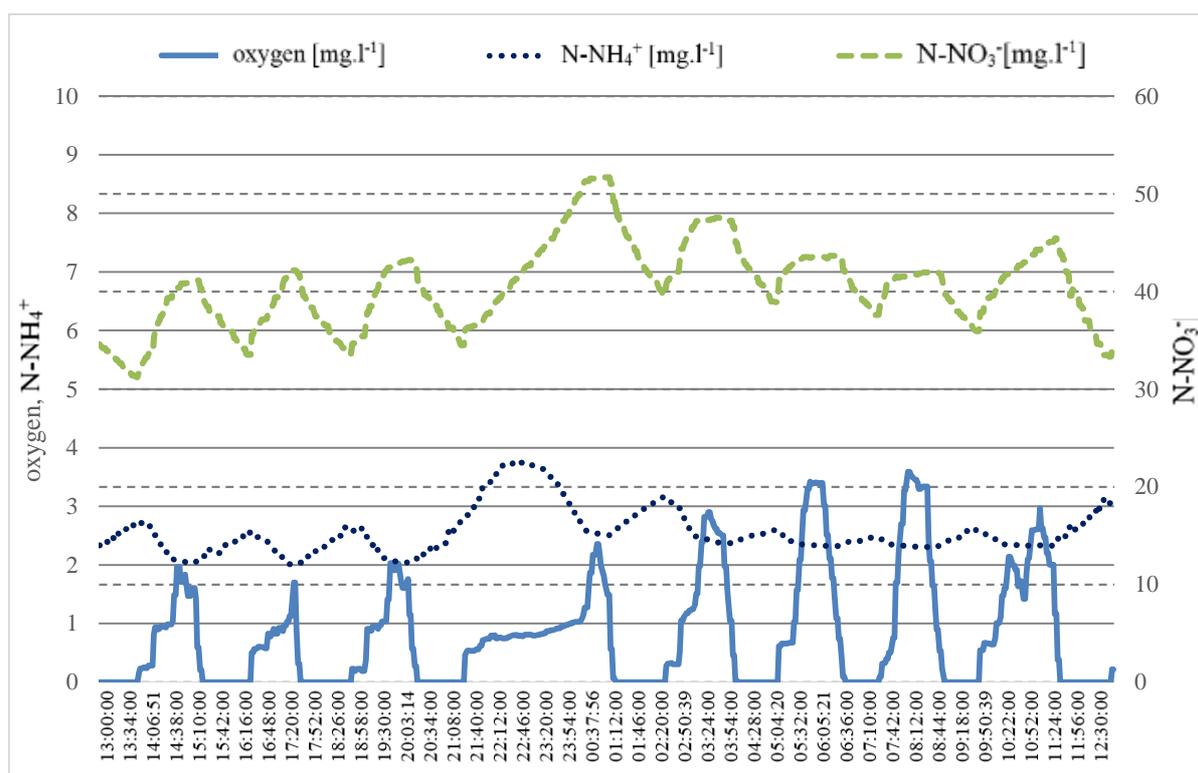


Figure 3. Concentration progress - measured parameters over 24 hours.

5. WWTP effluent operating values

The tables below show the effluent values of two wastewater treatment plants operated by one operator. Both of them use the Triton system in the activation reactors. To understand the treatment efficiency of these systems, the tables show emission limits and average values of the monitored indicators for the whole year.

Table 1. Emission limits of discharged wastewater indicators [1].

	BOD [mg.l ⁻¹]	COD [mg.l ⁻¹]	SS [mg.l ⁻¹]	N-NH ₄ ⁺ [mg.l ⁻¹]
Value “p” (permissible)	22	75	25	average 12
Value “m” (maximum)	30	140	30	20

Table 2. Average values of monitored indicators for the calendar year [1].

	BOD [mg.l ⁻¹]	COD [mg.l ⁻¹]	SS [mg.l ⁻¹]	N-NH ₄ ⁺ [mg.l ⁻¹]
WWTP “A”	3,11	28,93	6,30	0,14
WWTP “B”	3,08	24,93	8,08	1,87

Table 1 and Table 2 show that the Triton system ensures the required WWTP effluent values without any problems. This confirms very high efficiency of the entire system. This experience, together with other findings, make the operator trust the system, even in relation to the future development of municipalities and towns. The effluent values are considerably lower than the limit values prescribed by the relevant municipal authority.

6. Conclusions

There is quite a high number of combined systems available on the market. However, operators often prefer conventional blowers and aeration elements. This is one of the reasons why there are gaps in the operational experience with combined systems. The courage associated with the deployment of combined systems, their operation and subsequent modifications of control algorithms is certainly undeniable. The use of such systems helps further research, new ideas and innovations.

Parameters entering the control algorithm (i.e. all concentrations, times, temperatures,...) need to be tested and adjusted during the trial operation. Each and every municipality has its specific composition of wastewater, varying degrees of ballast water, regardless of any industrial enterprises. For these and other reasons, it is necessary to approach each WWTP and its control individually, to monitor and check the processes. It is also crucial to set a kind of safety elements when controlling the system. How the system should evaluate emergency situations, after what period and how to respond accurately. The control is of course related to the transfer of current information and data to the control centre.

In the future, these systems should be explored from the energy point of view, in terms of the necessary air demand and functionality of the activation processes at low temperatures. For the time being, the reliability of the treatment has been proven using the values of monitored indicators of the selected WWTP effluents.

Acknowledgements

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