Validation and Optimization of Fine Bubble Aeration Systems Depending on Water Temperature

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Motivation
The activated sludge (AS) process is the most common biological treatment process in the world for both municipal and industrial wastewater. For wastewater treatment plants (WWTP) with advanced nutrient removal in particular, adequately dimensioned, reliable aeration systems and mixing devices are an essential requirement for achieving high efficiency and economical operation. Aeration is usually the most energy intensive part of the AS process with 50 to 80 % of the power consumption being used for aeration and mixing (DWA, 2013). Power consumption provides great motivation for plant designers and operators to optimize aeration systems in the AS process.

Design of aeration systems
The decisive parameter in the design of aeration systems is the required standard oxygen transfer rate SOTR. In former dimensioning approaches SOTR depended only on the oxygen saturation concentration, the oxygen concentration in the aeration tank and the oxygen demand of the microorganisms. Furthermore, performance-reducing effects on the aeration system under operating conditions (primarily caused by wastewater constituents and the volume of activated sludge flocs) were taken into account by considering the α-value. In particular, at WWTP in warmer climates the application of these approaches led to an over-dimensioning of the aeration system.

The new DWA (2013) approach therefore includes the effects of dissolved salts, tank depth and plant elevation on the saturation concentration. Additionally the water temperature effect on the oxygen transfer rate is incorporated:

\[ \text{SOTR} = \frac{f_d \cdot \beta \cdot C_{S,20} \cdot \alpha \cdot (f_d \cdot \beta \cdot C_{S,T} \cdot p_{atm} - C_x \cdot e^{(T_{w} - 20)}) \cdot O_{V_h}}{1.013} \]

where: \( f_d \): depth factor (\( \cdot \)), \( \beta \): salt factor, \( C_{S,20} \): oxygen saturation concentration at 20°C (mg/L), \( \alpha \)-value (\( \cdot \)), \( C_{S,T} \): oxygen saturation concentration at T (mg/L), \( p_{atm} \): atmospheric pressure (mbar), \( C_x \): oxygen concentration during operation (mg/L), \( \theta \): temperature factor (\( \cdot \)), \( O_{V_h} \): oxygen demand. The elevation correction parameter should only be used for plants higher than 600 m.

In Figure 1, the new DWA (2013) approach is compared to the old ATV-DVWK (2000) approach on the basis of an exemplary calculation at consideration of the water temperature. It is shown that by application of the new approach and a design temperature of 30°C the specific SOTR can be lowered by about 10 %. At 20°C, the specific SOTR is reduced by about 5 %. This reduction of the specific SOTR at the dimensioning leads to savings in capital and operating costs of the plant.

- investigating the water temperature effect on oxygen transfer in activated sludge,
- studying the effect of different operation strategies on the long time performance of diffusers,
- evaluating the oxygen transfer in aeration tanks of WWTP in order to improve its operation strategy and lower its energy consumption.

Outlook
Since the saturation concentration of oxygen in water highly depends on pressure, the oxygen transfer in a WWTP also depends on its elevation. In order not to risk an under-dimensioning of the aeration system, the DWA (2013) approach therefore recommends, the application of an elevation correction parameter for plants on altitudes higher than 600 m. In Figure 3 the influence of the elevation on the specific SOTR is shown as a function of temperature based on an exemplary calculation. Especially at high temperatures the plant’s elevation influences the dimensioning result significantly. The use of this approach is of special concern for the world’s metropolis in great altitudes. The validation of the effect of elevation on oxygen transfer in activated sludge is subject of further studies.

References