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 is incorporated:

$$SOTR = \frac{f_d \cdot \beta \cdot C_{S,20}}{\alpha \cdot \left(f_d \cdot \beta \cdot C_{S,T} \cdot \frac{p_{atm}}{1.013} - C_X\right) \cdot \theta^{(T_W-20)}} \cdot OV_h \quad (\text{kg/h } O_2)$$

where: f_d: depth factor (-), β: salt factor, $C_{S,20}$: oxygen saturation concentration at 20°C (mg/L), α-value (-), $C_{S,T}$: oxygen saturation concentration at T (mg/L), p_{atm}: atmospheric pressure (mbar), C_X: oxygen concentration during operation (mg/L), θ: temperature factor (-), OV_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.

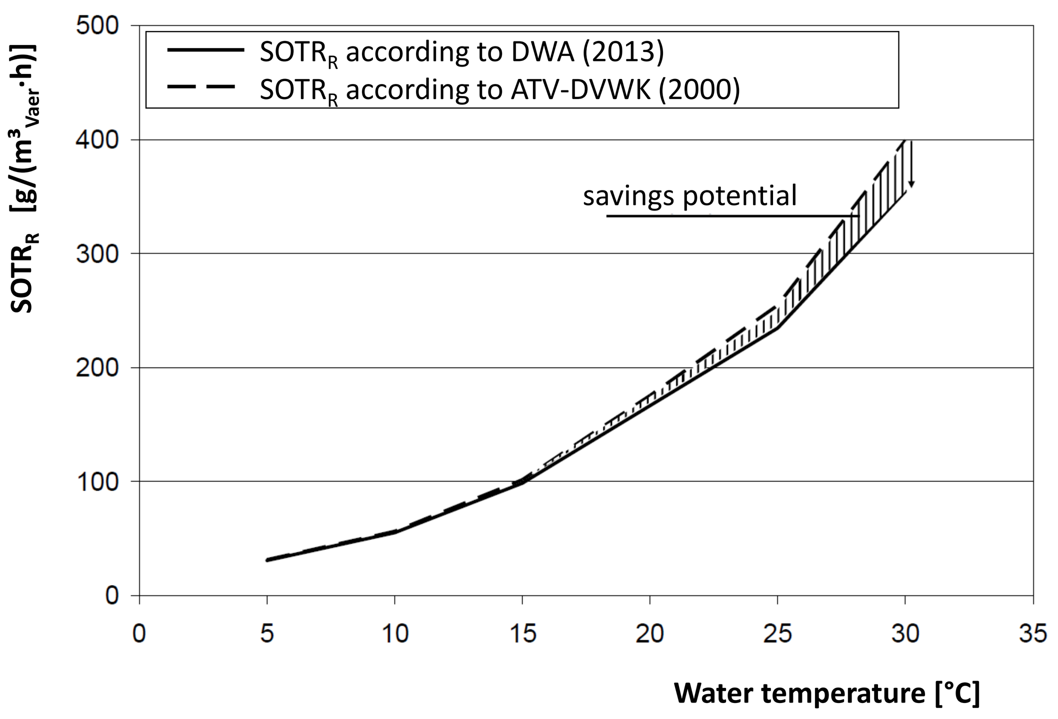

Figure 1 SOTR$_R$ of a WWTP for 50,000 C and advanced nutrient removal calculated by different dimensioning approaches (Wagner and Günkel, 2010)

Current research activities

In previous research projects, the new design approach was validated using semi-industrial scale aeration tests under defined conditions with drinking water. As part of a current research project a validation of the approach is conducted at industrial scale plants. Therefore experiments are carried out on WWTP with high and relatively low wastewater temperatures as well as elevated salt concentrations: WWTP Baishamen in Haikou and WWTP Licunhe in Qingdao, both China (see figure 2).

Figure 2 project locations (adapted from http://www.hoeckmann.de/karten/asien/china/index.htm)

For the validation of the design approach the SOTR of the aeration tanks is measured by ex-situ tests in a pilot plant. Further objectives of the project are:

- 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.

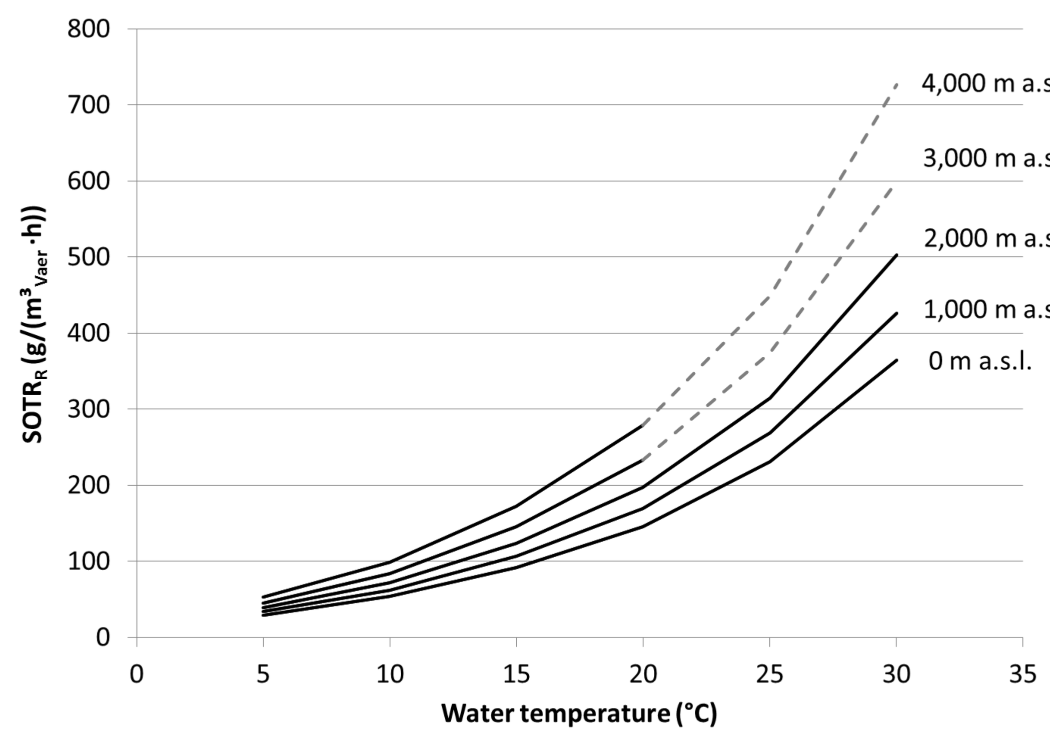

Figure 3 Influence of elevation on SOTR$_R$ as a function of water temperature according to DWA (2013)

References

DWA (2013): DWA Merkblatt 229-1, Systeme zur Belüftung und Durchmischung von Belebungsanlagen, Teil 1: Planung, Ausschreibung und Ausführung (DWA advisory leaflet M 229-1: Aeration and mixing. Systems for activated sludge plants, Part 1: Planning, invitation of tenders and accomplishment), Hennef.

Wagner M. and Günkel T. (2010): Belüftungssysteme in kalten und warmen Klimaten (Aeration systems in cold and warm climates), in: Leitfaden zur Abwassertechnologie in anderen Ländern, 2nd edn, Bochum.

Joint Project „Technology Transfer-Oriented Research and Development in the Wastewater Sector - Validation at Industrial-Scale Plants" (EXPOVAL)

EXPOVAL

Information: www.expoval.de

Subgroup 2 „Aeration Technology" research partners:

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