New Developments in the Design of Aeration Systems for Activated Sludge Plants

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Introduction

Precise dimensioning of the aeration system is prerequisite for energy-efficient and economically efficient management of activated sludge plants. The key design parameter in aeration systems is the oxygen transfer in clean water under standard conditions (SOTR, kg O_2/h). During the last years, this design parameter has been investigated in detail and knowledge has been extended to the dependency on different load cases. Numerous effects with impact on oxygen transfer have been implemented in design approaches. However, there are others to be considered. Adaptation of existing design approaches to specific boundary conditions (altitude of the plant location, high salt concentrations, etc.) is partly implemented and partly state of current research. Below, an overview is given on commonly applied design approaches and those still being developed.

Different oxygen demand loads

To reduce operational costs it is recommended to dimension the aeration system according to a range of load cases, based on the determination of the oxygen demand (OUR, kg O2/h). According to DWA (2013), OUR should be determined for the following four load cases:

- Load case 1: average oxygen demand for the actual situation OUR_{aM} to determine the annual energy demand,
- Load case 2: maximum oxygen demand in the actual situation OUR_{max} for dimensioning the upper limit of the aeration system,
- Load case 3: minimum oxygen demand in the actual situation OUR_{min} for dimensioning the lower limit of the aeration system,
- Load case 4: oxygen demand for the predicted situation and, if need be, for expansion.

Influence of altitude of the WWTP

DWA (2013) recommends to include the altitude of the plant location (> 600 m a.s.l.) into the dimensioning of aeration systems to account for its influence on oxygen transfer. A higher SOTR is required for plants in higher altitudes (see Fig. 1).

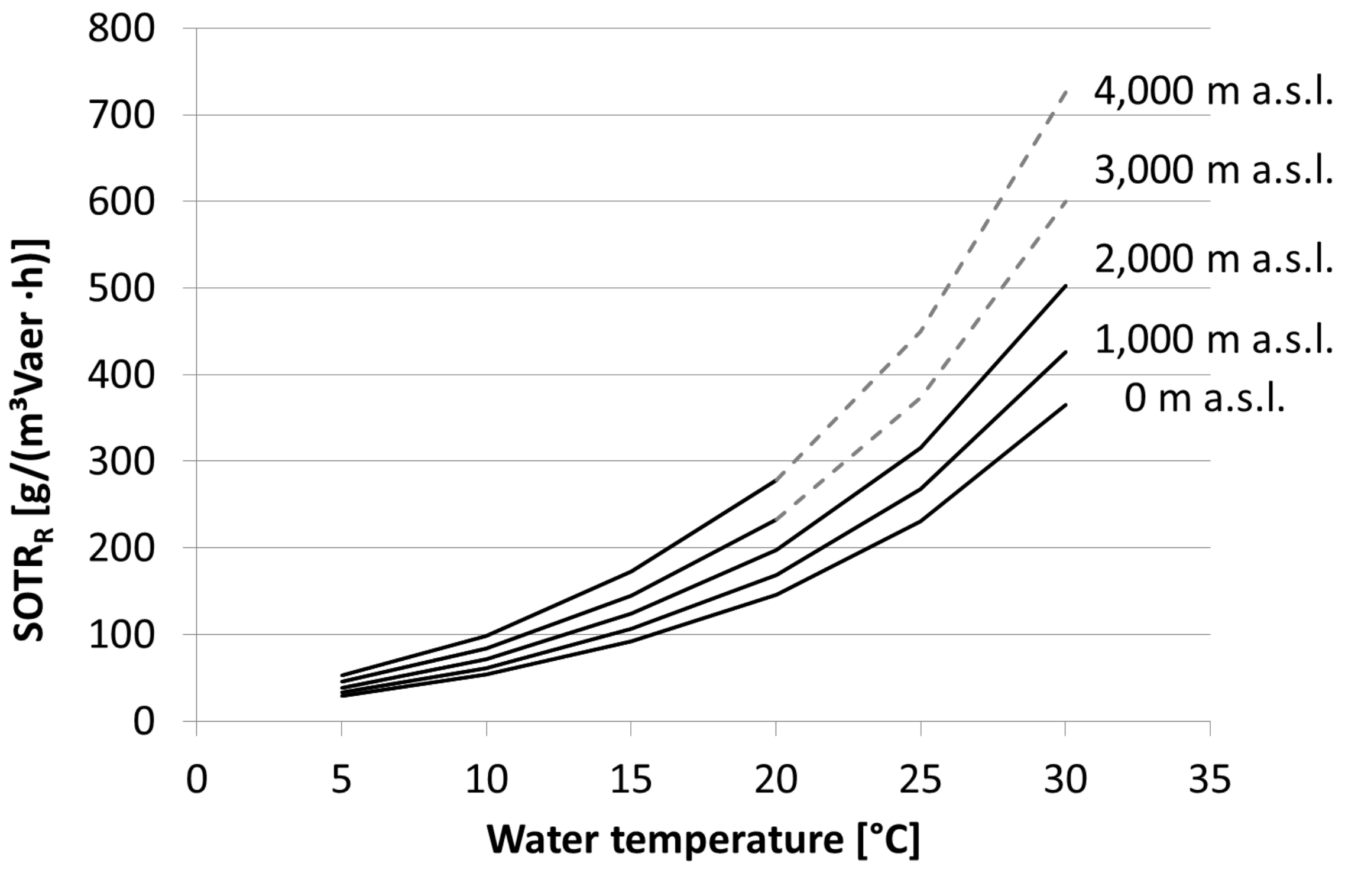

Figure 1 Influence of elevation on $SOTR_R$ as a function of water temperature according to DWA (2013)

The following equation allows for this effect by including Term $p_{atm}/1{,}013$ into the calculation of the required SOTR according to DWA (2013):

$$SOTR = \frac{f_d \cdot \beta \cdot C_{S,20}}{\alpha \cdot \left(f_d \cdot \beta \cdot C_{S,T} \cdot \frac{p_{atm}}{1{,}013} - C_X\right) \cdot \theta^{(T_W - 20)}} \cdot OUR_h$$

(kg/h O_2)

Impact of load case dependent α-factors

It is recommended to set the α-factor according to the OUR design load cases (see above): minimum α-factor (α_{min}) for OUR_{max} and maximum α-factor (α_{max}) for OUR_{min}. In addition, the α-factor should be selected according (a) to the procedural design of the activated sludge tank (continuously operated denitrification, SBR resp. MBR process, etc.) and (b) to the respective treatment goals (carbon removal, nitrogen removal, simultaneous aerobic stabilization). From these interrelationships, Günkel-Lange (2013) derived design α-factors to be used as reference factors for design (see Tab. 1).

Table 1 Recommended α-factors for different load cases for variants of fine-bubble diffused aeration systems (Günkel-Lange, 2013)

Process	α_{min} (Maximum load case)	α_{ave} (Average load case)	α_{max} (Minimum load case)
Continuously operated denitrification (simultaneous, intermittent, alternating, upstream)	0.60	0.75	0.85
SBR process for N removal	0.50	0.65	0.80
MBR process (MLSS ~ 12 g/L, SRT = 25 d)	0.50	0.60	0.70
Simultaneous aerobic stabilization	0.70	0.80	0.90
Carbon removal	0.35	0.50	0.60

Impact of high salt contents

High salt contents on municipal WWTP are caused, for example, by seawater intrusion into leaky sewers (see correlation between seawater level and electric conductivity (EC) in Fig. 2) or use of seawater for toilet flushing. In a WWTP on the coast, oxygen transfer correlates with the salt content of the activated sludge, with α-factors mostly higher then 1 (see Fig. 3). These factors considerably exceed the design factors as stated in Tab. 1. Wagner and Sander (2015) therefore recommend to increase the design α-factors respectively for WWTP with elevated salt content.

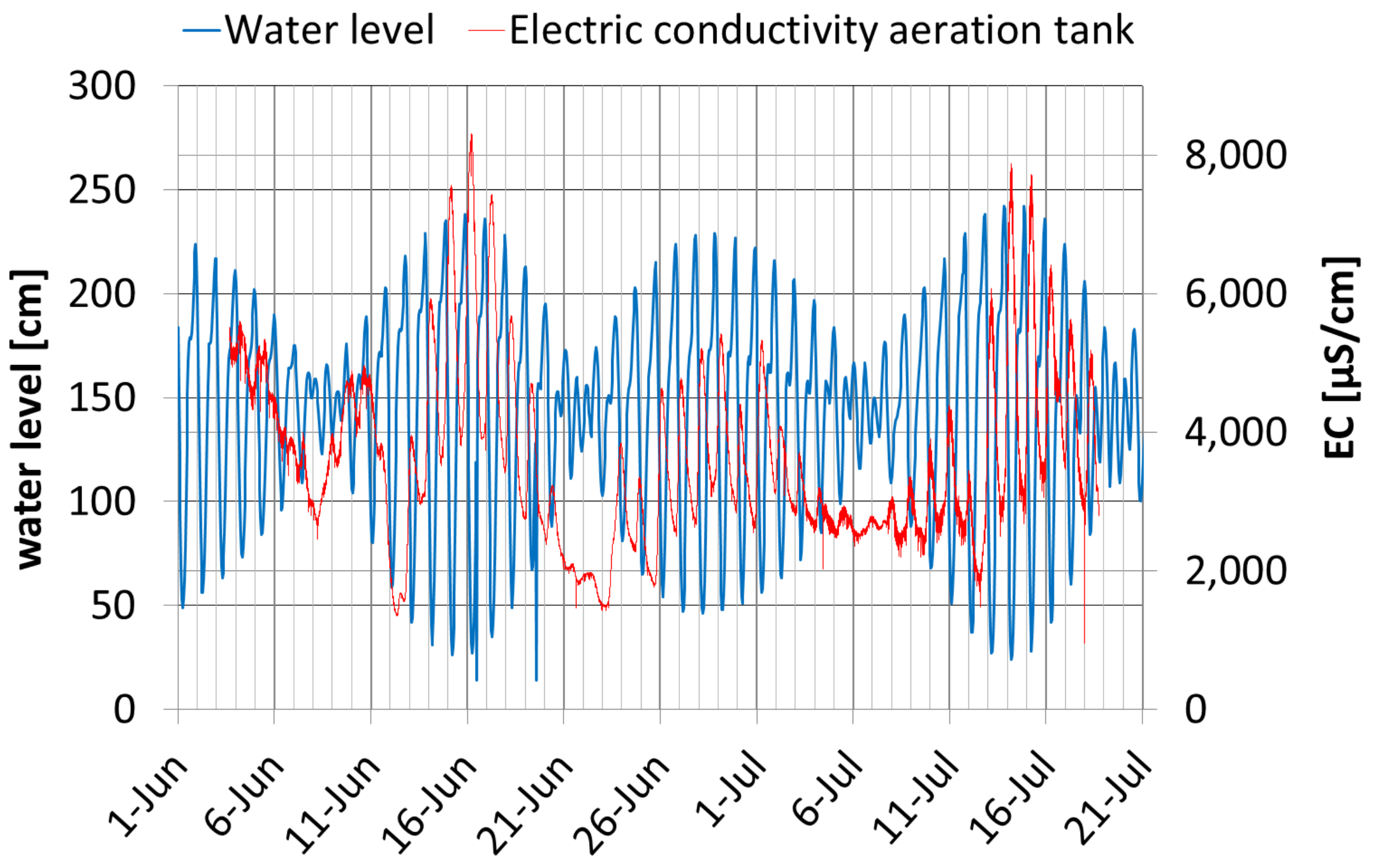

Figure 2 EC at a WWTP at the coast (South China) and sea water level in summer 2014

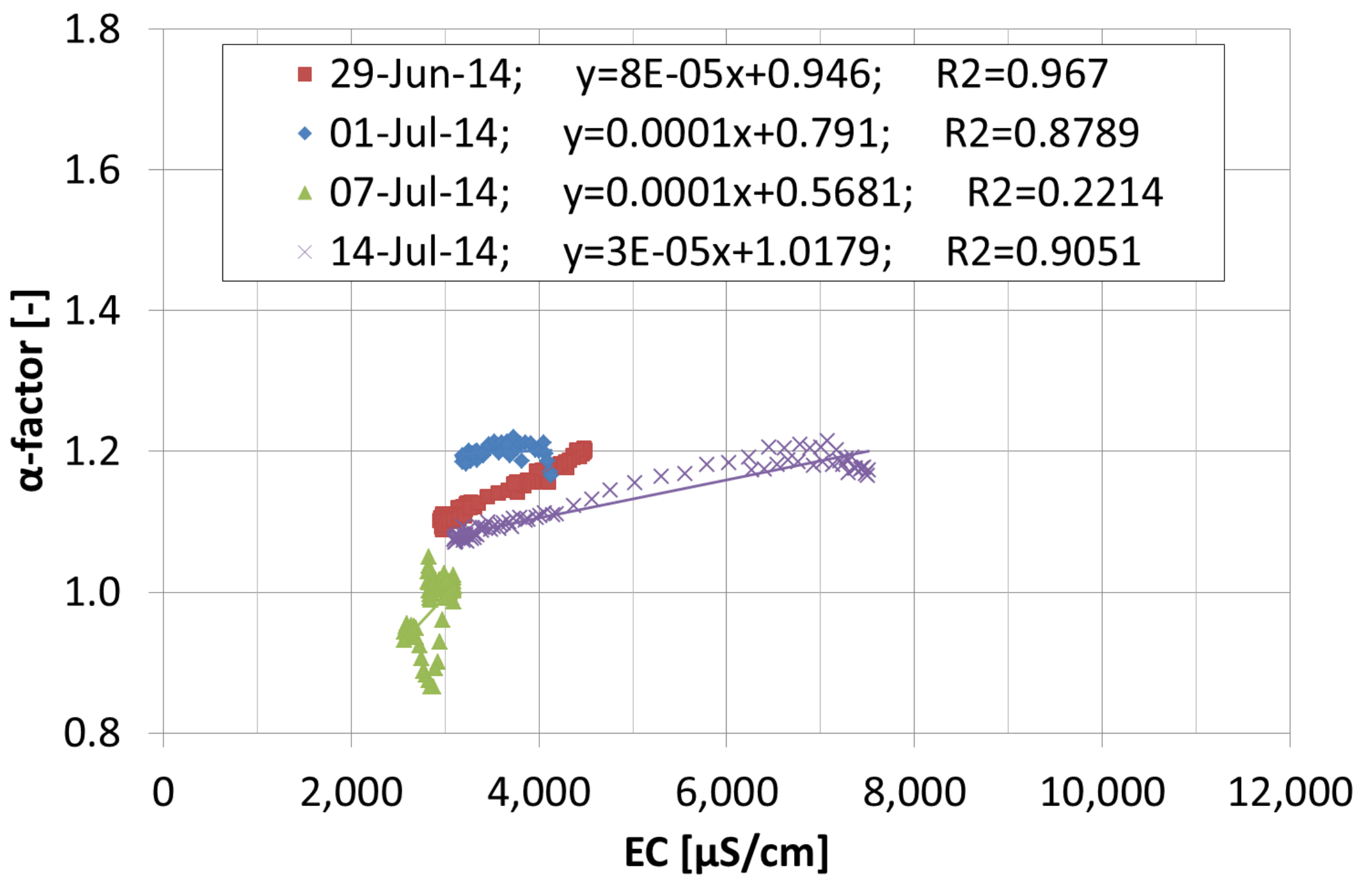

Figure 3 Ex-situ α-factors as a function EC at a WWTP on the coast

Conclusions

- Load case dependent OUR and α-factors (average, maximum, minimum, specific) have to be considered into the calculation of SOTR.
- Gradations of the aeration systems (air compressor, diffusers, etc.) between maximum and minimum load cases should range from 10:1 to 15:1.
- Specific boundary conditions of the WWTP (e.g. altitude and salt concentration) should be considered additionally.

References

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