Theses of the doctoral (PhD) dissertation

DEVELOPMENT OF MODELLING, CONTROL AND OPTIMIZATION TOOLS FOR THE ACTIVATED SLUDGE PROCESS

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1. **INTRODUCTION AND AIM OF THE WORK**

Mathematical modelling is a significant part of wastewater treatment system design since it can enhance the process understanding of the operator, it can be used for process design and it can be used for the optimization of the process. For these reasons, modelling and control tools have been developed and applied to the biological wastewater treatment process in this thesis. In order to comply with the industry standards during operation, different methods have been introduced to enhance the efficiency of the aeration, furthermore, applicability and comparison of wastewater treatment models available in literature have been addressed.

2. **EXPERIMENTAL METHODS AND TOOLS**

The present thesis contributes to the application of control and optimization tools in the field of wastewater treatment engineering, however, the results presented in this thesis are based on a simulated case-study approach. Since the introduction of the first activated sludge models several studies have justified the applicability and validity of these models, and a Simulation Benchmark was published in 2002, of which the Department of Environmental Engineering and Chemical Technology participated in the development. Therefore, these internationally accepted models and model parameters have been used throughout this work assuming that these models give a reasonable approximation of the real-life processes. The simulations and other programming tasks were solved in MATLAB/Simulink environment what allowed efficient simulation of the presented case-studies.

3. **NEW SCIENTIFIC RESULTS**

1. **It was found that the effluent nitrogen pollution load of intermittently aerated wastewater treatment plants can be reduced by more than 10% using optimal aeration periods in certain cases based on the results of computer simulation.**

   Since the operation of the intermittently aerated wastewater treatment process is challenging both for economical and technical reasons, an operational optimization method has been introduced for the efficient operation of these facilities. The goal of the introduced procedure is to reduce the effluent pollution load in the receiving body by determining the adequate aeration cycle lengths. It was found that applying this stochastic optimization method on an alternating activated sludge process using simulated case study approach, the effluent pollution load can be reduced by more than 10%. It can be also concluded, that the TKN and NO₃-N can be reduced with more than 10% (0.2–0.5 g/m³), while the COD/BOD₅ reduction is not so significant.

2. **It has been shown that model predictive control algorithm can be efficiently applied for the dissolved oxygen level control of aerated basins in activated sludge wastewater treatment systems based on the results of computer simulation.**
Activated sludge wastewater treatment processes are difficult to be controlled because of their complex and nonlinear behaviour, however, the control of the dissolved oxygen level in the reactors plays an important role in the operation of the facility. For this reason a new approach has been studied: model predictive control has been applied to control the dissolved oxygen concentration in an aerobic reactor of a wastewater treatment plant. The proposed control approach has been tested on a pre-denitrification plant and on an alternating activated sludge process using simulated case-study approach. The results show that this method can be efficiently used for dissolved oxygen control: the maximum deviation of the concentration from the pre-defined setpoint remained under 0.2 gO₂/m³ in spite of the significantly changing quality and quantity of incoming wastewater.

3. Different published one-dimensional settling tank models give significantly different estimation of the over- and underflow suspended solids concentration, however, the solids distributions around the inlet point are similar for all models.

The biological reactor might be meeting the required effluent standards, however, by not capturing the suspended solids adequately, could cause a possible failure in compliance with the COD (BOD₅), total N and P standards. The applied mathematical models allow the influences of inlet arrangement, sludge collection systems and sludge density currents to be modelled accurately. For this reason, six one-dimensional secondary settler models have been introduced and compared (the model of Takács, Härte, Otterpohl, Dupont, Hamilton and a reactive model) based on a Simulation Benchmark. The results of the dynamic simulations –f under dry and wet weather conditions with daily and weekly change in the influent wastewater composition and quantity – showed that significantly differences suspended solids concentrations can be estimated with the different models using the published model parameters. The highest effluent solids concentration is estimated by the Dupont model (30–35 g/m³), the lowest concentration is predicted by the Otterpohl model (10 g/m³) while the Takács model defined in the Simulation Benchmark approximated 12.5 g/m³ effluent concentration.

4. Publications of the author related to the thesis

Articles in scientific journals:


**Publications in conference proceedings:**


**Conference presentations:**


Other publications:

[19.] Általános információk a környezetvédelemről, ismeretek a szennyvíztisztítás fejlesztéséről. Tanulmánygyűjtemény. Szerkesztő: Dr. Kárpáti Árpád (in Hungarian)