Politechnika Wrocławska

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PHD THESIS

ACTIVATED SLUDGE MODELLING IN THE CONTEXT OF WET WEATHER WASTEWATER TREATMENT

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SUMMARY

This dissertation addresses the issue of technological optimization of the wastewater treatment process under conditions of hydraulic overload, based on a mathematical model of the activated sludge process using the Wrocław Wastewater Treatment Plant as a case study. This work is part of a broader range of activities conducted by the Wrocław Water and Sewage Company in response to observed climate changes and upcoming legislative changes. The presented research has a deeply practical dimension and was carried out under the Ministry of Science's "Implementation Doctorate" program.

The dissertation consists of six main parts. The first part provides an introduction (Chapter 1) to the issue of stormwater management in urban areas, concluding with a justification for the chosen topic.

The literature review (Chapter 2) includes an analysis of the impact of rainfall on the operation of wastewater treatment plants, focusing on the mechanical and biological treatment units. The process of activated sludge sedimentation is discussed in detail, covering the various sedimentation regimes, and the factors influencing sludge sedimentation properties are presented. Theoretical and empirical mathematical models describing the sedimentation process are introduced, along with their application in one-dimensional secondary clarifier models, which are a key component of the whole plant model used for simulating operation under hydraulic overload conditions. The issues of selecting the constitutive functions of the secondary clarifier model and calibrating their parameters are given particular attention in the research section of the dissertation.

Based on the literature review and the justification for the chosen topic, the objective and scope of the study are defined (Chapter 3).

Chapter 4 describes the research methodology, which includes both laboratory and simulation studies, as well as a characterization of the research object (the Wrocław Wastewater Treatment Plant). The component models used to build and parameterize the mathematical model of the WOŚ technological system, which is the subject of the research, are presented.

The results presented in Chapter 5 include:

- studies on the variability of wastewater composition, used to prepare a representative dataset for steady-state and dynamic simulations,
- kinetic studies and long-term studies on the variability of sedimentation properties, illustrating the impact of gravimetric selection of activated sludge on the wastewater treatment process,
- calibration and validation of the three considered secondary clarifier models, which enabled:

- identification of the model that best reflects the actual dynamics of changes in the full-scale clarifier,
- confirmation of the effectiveness of the proposed calibration methodology for the selected model,

- simulation studies, which showed that:
  - gravimetric selection of activated sludge allows for safe operation at flow rates nearly twice the maximum current load of the biological treatment system, but the downside of this solution is its seasonality, meaning it does not maintain highly favorable sedimentation properties during the winter period,
  - strategies for reducing the load of suspended solids on individual clarifiers, which produce satisfactory results in both summer and winter, are the step-feed system and increasing the number of secondary clarifiers. Both solutions offer comparable technological effects but differ in the investment costs associated with their implementation.

The summary and final conclusions are presented in Chapter 6.

Key words: wastewater treatment optimisation,
mathematical modelling,
simulation studies,
activated sludge sedimentation,
secondary settling tank model calibration