Identification of wastewater processes

The introduction of on-line sensors for monitoring of nutrient salts concentrations on wastewater treatment plants with nutrient removal, opens a wide new area of modelling wastewater processes. The subject of this thesis is the formulation of operational dynamic models based on time series of ammonia, nitrate, and phosphate concentrations, which are measured in the aeration tanks of the biological nutrient removal system. The alternatign operation modes of the BIO-DENITRO and BIO-DENIPHOPRO processes are of particular interest. Time series models of the hydraulic and biological processes are very useful for gaining insight in real time operation of wastewater treatment systems with variable influent flows and pollution loads, and for the design of plant operation control. In the present context non-linear structural time series models are proposed, which are identified by combining the well-known theory of the processes with the significant effects found in data. These models are called grey box models, and they contain rate expressions for the processes of influent load of nutrients, transport of nutrients between the aeration tanks, hydrolysis and growth of biomass, nitrification, denitrification, biological phosphate uptake in biomass, and stripping of phosphate. Several of the rate expressions for the biological processes are formulated on the assumption of Monod-kinetics. The formulation of models for time-varying parameters in a new time domain divides the variations of the processes into fast dynamics and slower dynamics. In addition, this modelling in two time domains increases the interpretability of the parameters. The models are put into state space form and the parameters are estimated by the maximum likelihood method, where a Kalman filter is used in calculating the likelihood function. The grey box models are estimated on data sets from the Lundtofte pilot scale plant and the Aalborg West wastewater treatment plant. Estimation of Monod-kinetic expressions is made possible through the application of large data sets. Parameter estimates from the two plants show a reasonable consistency with suggested kinetic parameter values of the literature. A large amount of information about the two plants and their performances is obtained from the models, of which the variations of the influent ammonia load, and the autotrophic and heterotrophic biomass activity have particular interest. The models are appropriate for control, because the present states of the plants are reflected in the parameter estimates. The grey box models may be applied to control of wastewater treatment plants in many ways. In this thesis off-line simulations of control strategies and on-line model-based predictive control are discussed. Both methods include the evaluation of a cost function incorporating the cost of operation and discharge of nutrients to the recipient. The concept of prediction based control is demonstrated in a simulation study.