Med. Fac. Landbouww. Univ. Gent, 67/4, 2002

MODEL BASED OPTIMISATION OF AN INDUSTRIAL WWTP: DEALING WITH WASTEWATER MIXTURES FROM DIFFERENT PRODUCTION FACILITIES

STIJN W.H. VAN HULLE & PETER A. VANROLLEGHEM
Department for Applied Mathematics, Biometrics and Process Control (Biomath), Ghent University, Coupure Links 653, B-9000 Gent, Belgium

INTRODUCTION

Industrial WWTP's have to provide a 100 % reliability and availability for the discharging facilities (Bury et al., 2002). The industrial WWTP in this study treats wastewater the same way as most municipal WWTP, i.e. with an activated sludge process. However, some differences can be pointed out. The first problematic difference is that the composition of industrial wastewater fluctuates considerably more than domestic wastewater because of the variations in the production schedule of the facilities discharging to the WWTP. This hinders the optimisation of the WWTP considerably. A second problem is that some components occur in the industrial wastewater that are normally not present in domestic wastewater. This makes it necessary to extend the normally applied Activated Sludge Model Nr.1 (ASM1) (Henze et al., 2000).
The aim of this study is twofold. The first step is the development and calibration of a model for the industrial WWTP. This development and calibration of the model was based on the calibration protocol developed by Petersen et al. (2002b). The protocol however had to be extended to take into account the specific components in the wastewater. The second step of the study is the use of the model for optimisation of the WWTP. By simulating with the calibrated and validated model it could for example be shown how a 20 % reduction of the effluent degradable COD concentration could be achieved. This case study shows how the combination of both steps can lead to fast modelling and optimisation of an industrial WWTP.

MATERIALS AND METHODS

Description of the WWTP

The schematic lay-out of the WWTP is shown in Figure 1. All modelling and simulations were performed in the modelling and simulation environment WEST® (Hemmis NV, Kortrijk, Belgium; Vanhooren et al., 2002). Two production facilities are discharging to the plant. Especially facility 1 has a varying production schedule. The plant also treats the water coming from a landfill, but its flow rate is very low. After mixing the wastewater is sent to two parallel activated sludge tanks (AST). Although the AST's have a volume of 3000 m^3, they can still be considered as continuously stirred. In the model implemented in WEST® a connection between the two AST's is foreseen to anticipate a (partial) serial operation of the AST's. This connection does not exist yet at the actual plant, but was suggested to be a feasible upgrade scenario. The treated wastewater coming from the two AST's is sent to a clarifier which has excellent performance. The ideal settler model used in WEST® has no volume. Hence, in order to mimic the residence time in the settler, a buffer tank with the same volume is placed after the settler. The effluent of the settler is discharged to the river and the return sludge is recycled to both AST's.

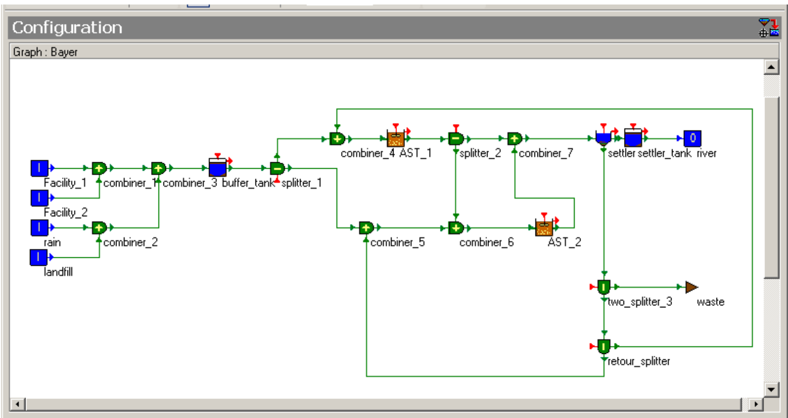

Figure 1. Schematic lay-out of the WWTP under study in WEST®

Extension of ASM1

ASM1 was extended with two extra components. A first component is representative for a specific component in the wastewater that is coming from production facility 1. A second component is a fictive component that could be discharged from a new additional production facility. This way the influence of an additional production facility can now already be evaluated with the model. A second extension of the standard ASM1 is the insertion of a temperature dependency of the kinetics, because, as reported by the operators, the temperature in the AST may vary up to 10°C in relatively short periods.

RESULTS AND DISCUSSION

Model calibration and validation

Model calibration and validation was based on the calibration protocol proposed by Petersen et al. (2002b). After a thorough investigating of the design and operational data, some measuring errors were found by making mass balances. These errors were subsequently corrected. Both the hydraulic and settling characterisation were actually already tackled with the description of the WWTP. Indeed, the AST's can be considered as completely mixed and are therefore modelled as completely stirred reactors (CSTR). The sludge settles well, so a point settler is an appropriate model for the settler. Since in this case a specific industrial wastewater is investigated it will not be possible to use the default values of the biological parameters of ASM1 as indicated by Henze et al. (2000) and therefore a thorough biological characterisation was necessary. Since no nitrification occurs, only heterotrophic activity had to be investigated. The decay coefficient (b_H) was determined by the method proposed by Ekama et al. (1986) and subsequently corrected for use in the ASM model (Petersen et al., 2002a). A value of 0.42 d^{-1} was obtained. Both the heterotrophic yield (Y_H) and the maximum specific growth rate for the heterotrophic biomass (μ_H) were derived from oxygen uptake rate (OUR) profiles, which were recorded from a batch experiment with a hybrid respirometric set-up (Vanrolleghem and Spanjers, 1998). Values of 0.74 gCOD/gCOD and 2.92 d^{-1} respectively were obtained. After the biological characterisation a steady state calibration was performed. For this the average influent and effluent data of the plant were collected. After comparing the measured and calculated data two more parameters of ASM1 were adjusted to improve the fit. The inert fraction of the biomass (f_P) which has a default value of 0.08 in ASM1 was set to 0.06 and the non-settleable fraction of the biomass (f_{ns}) was set to 0.014, i.e. 1.4 % of the incoming sludge leaves the settler via the effluent. No dynamic calibration was performed and the model was directly validated with a 10 months measurement dataset. In Figure 2 the comparison between the calculated and measured degradable COD and concentration of specific component in the effluent are shown. From Figure 2 it can be seen that the calculated and measured values agree well, in spite of the strong variations of effluent composition. Also, the measured effluent suspended solids, sludge wastage and biomass in the reactor were compared with the simulated results and good agreement was found (Van Hulle and Vanrolleghem, 2002).

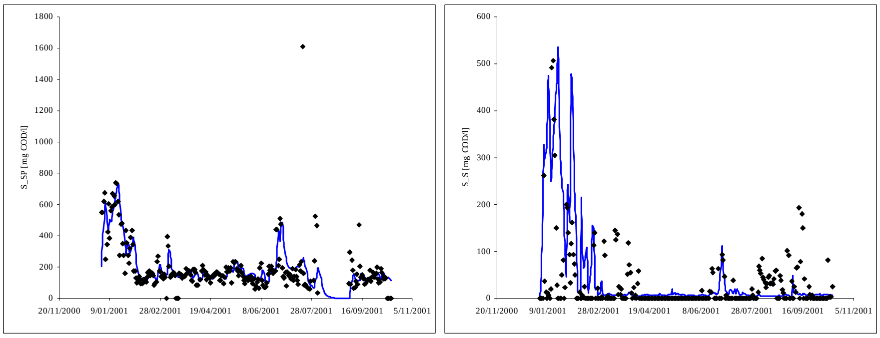

Figure 2. The calculated (—) and measured (♦) degradable COD (left) and concentration of specific component (right) in the effluent

Model based optimisation and scenario analysis

After calibration and validation the model could subsequently be used to quantify the effect of different discharge strategies of the production facilities. Many possible production schedules were simulated. Based on these simulations it could easily be predicted which schedules allow to meet the effluent standards and which do not. Simulations can also be used to investigate different operating strategies such as the in series operation of the AST's. In fact, with the model it was shown that a 20 % reduction of the effluent degradable COD could be achieved by operating in series instead of in parallel. In this way the treatment plant has a more plug flow character and hence the removal efficiency will be higher despite the increased toxicity (Froment and Bishoff, 1990). Also, it was investigated what the effect would be of a complete shutdown of one of the two AST's during production stops for maintenance purposes or holidays. The simulated effluent degradable COD of this scenario was compared with the corresponding simulated values of the normal operation, i.e. 2 AST tanks in parallel. Considerably more degradable COD would be discharged when only one AST is used, except of course for periods such as August where a significantly lower discharge occurs due to the production shut-down.

CONCLUSION

A model for an industrial WWTP was constructed and subsequently calibrated and validated. Special attention was given to the specific characteristics of industrial wastewater. A thorough biological characterisation was conducted along the calibration protocol of Petersen et al. (2002b) and the ASM1 model was extended to take into account the specific industrial components in the wastewater. A fictive component was also introduced to be able to predict the influence of a new production facility. The model has proven to be able to predict the course of strong variations in effluent composition. Hence, the model can be used to simulate different scenarios. In this way scenario-analysis and model based optimisation can be done efficiently and cost effective. An example of this was shown in this contribution.

REFERENCES

BURY, S.J., GROOT, C.K., HUTH, C. & HARDT, N. (2002). Dynamic simulations of chemical wastewater treatment plants. Water Science & Technology, 45(4 - 5), 355-363.

EKAMA G.A., DOLD, P.L. & MARAIS, G.v.R. (1986). Procedures for determining influent COD fractions and the maximum specific growth rate of heterothrophs in activated sludge systems. Water Science & Technology, 18(6) 91-114.

FROMENT, G.F. & BISHOFF K.B. (1990). Chemical reaction engineering. Wiley, New York.

HENZE, M., GUJER, W., MATSUO, T. & VAN LOOSDRECHT, M. (2000). Activated Sludge Models ASM1, ASM2, ASM2d and ASM3. IWA, Scientific and Technical Reports. London, UK.

PETERSEN B., GERNAEY K., HENZE M. AND VANROLLEGHEM P.A. (2002a). Calibration of activated sludge models: A critical review of experimental designs. In: Biotechnology for the Environment. Eds. Agathos S. and Reineke W., Focus on Biotechnology, Vol. 3. Kluwer Academic Publishers, Dordrecht, The Netherlands. pp.80. (in Press)

PETERSEN B., GERNAEY K., HENZE M. & VANROLLEGHEM P.A. (2002b). Evaluation of an ASM1 model calibration procedure on a municipal-industrial wastewater treatment plant. Journal of Hydroinformatics, 4, 15-38.

VANHOOREN, H., MEIRLAEN, J., AMERLINCK, Y., CLAEYS, F., VANGHELUWE, H. & VANROLLEGHEM, P.A. (2002). Modelling biological wastewater treatment. Journal of Hydroinformatics (Accepted).

VAN HULLE, S.W.H. & VANROLLEGHEM, P.A. (2002). Modelling an industrial WWTP using a calibration protocol. Biomath Technical Report. Ghent University, Belgium.

VANROLLEGHEM, P.A. & SPANJERS, H. (1998). A hybrid respirometric method for more reliable assessment of activated sludge model parameters. Water Science & Technology, 37(12), 237-246.