INFLUENCE OF OPERATING PARAMETERS ON THE PERFORMANCE OF A CONTINUOUSLY AERATED SHARON REACTOR

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INTRODUCTION

Partial nitrification - the SHARON process

In the search of improving the sustainability of nitrogen removal from wastewater, partial nitrification techniques have been denoted for quite a while as very promising. During partial nitrification, ammonia is converted to nitrite (eq. 1) and further oxidation of nitrite to nitrate is prevented, thus realizing aeration costs savings in comparison with conventional nitrification to nitrate.

$$NH_4^+ + 1.5\,O_2 \rightarrow NO_2^- + H_2O + 2\,H^+ \tag{1}$$

In the SHARON (Single reactor High activity Ammonia Removal Over Nitrite) process, partial nitrification is establishing by working at high temperature (about 35°C) and maintaining an appropriate sludge retention time (SRT). The SHARON reactor is operated as a continuously stirred tank reactor (CSTR, chemostat) without biomass retention, so the sludge retention time equals the hydraulic retention time. The SHARON process is very well suited to reduce the load of streams with high ammonia concentration, rather than to meet strict effluent standards. It is applied for treating sludge digestion reject water in order to relieve the main wastewater treatment plant (WWTP) to which this stream is subsequently recycled. A full-scale SHARON process is operational since January 1999 at the Rotterdam Sluisjesdijk sludge treatment plant. In its original configuration, the SHARON process is operated under alternating aerobic and anoxic conditions, the latter serving for pH control by denitrification. Full-scale experience with the SHARON process has recently been described by van Kempen *et al.* (2001).

The combined SHARON-Anammox process

In the last few years, the coupling of the SHARON process with a so-called Anammox (ANaerobic AMMonia OXidation) process, in which ammonium and nitrite are converted to nitrogen gas under anaerobic conditions by autotrophic bacteria, has gained a lot of interest (van Dongen *et al.*, 2001). With the combined SHARON-Anammox process, low nitrogen effluent concentrations can be obtained, while aeration costs are significantly reduced, no additional carbon source is needed and sludge production is very low. Processes like CANON (Hao *et al.*, 2001) and

OLAND (Kuai and Verstraete, 1998), that combine partial nitrification and anaerobic ammonium oxidation in one reactor, are currently also being studied.

The simplified Anammox reaction (neglecting biomass growth) can be written as:

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2\,H_2O \qquad (2)$$

In case the SHARON influent contains ammonium and bicarbonate on an equimolar basis, which can be reasonably assumed for sludge digestion reject water, the protons produced during conversion of half of the ammonium are balanced ‘exactly’ via carbon dioxide stripping. For the high-concentrated streams to which the SHARON process is typically applied, the protons produced during ammonium conversion over 50% would cause a significant pH drop, preventing further nitrification. So theoretically, when assuming equimolar amounts of ammonium and bicarbonate in the influent of the SHARON reactor, its effluent will contain the required nitrite/ ammonium ratio of 1/1 that is needed to feed the Anammox reactor. This simplified reasoning is represented schematically in figure 1. Note that the SHARON reactor is continuously aerated.

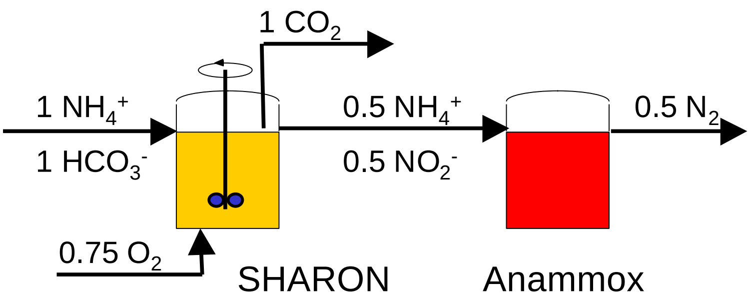

Figure 1 The combined SHARON-Anammox process

In practice, the actual nitrite/ammonium ratio needed by the Anammox process will depend on the biomass yield and potential denitrification on decayed biomass. Also the nitrite/ammonium ratio produced in practice by the SHARON process depends on a number of factors. In this contribution, simulation results on the effect of SRT, influent pH and buffer capacity are presented.

THE SHARON MODEL

The Matlab-Simulink model used, is based on the one from Hellinga *et al.* (1999). As significant pH-effects occur during nitrification of high-concentrated streams, a distinction is made between the different forms of components involved in chemical equilibria and lumped components are defined for which the concentrations equal the total concentration of the components, active in an equilibrium:

$TNH = NH_4^+ + NH_3$

$TNO2 = HNO_2 + NO_2^-$

$TIC = CO_3^{2-} + HCO_3^- + CO_2$

All chemical equilibrium reactions are assumed to be in steady state. The reactor pH is calculated at every time step via the proton concentration from the charge balance in the reactor, in order to assure the sum of all charges to be zero. More details on the model are given by Volcke *et al.* (2002).

SIMULATION RESULTS

Steady state results on the behaviour of the continuously aerated SHARON system are presented. Unless stated otherwise, simulation results have been obtained for an inlet liquid flow of 600 m^3 d^{-1}, at pH 7.8 containing 70 mole m^{-3} of TNH and an equimolar amount of TIC, besides some dissolved O_2, CO_2, N_2 and inert ions. The liquid phase volume was set at 400 m^3. The simulation results are summarized in figure 2.

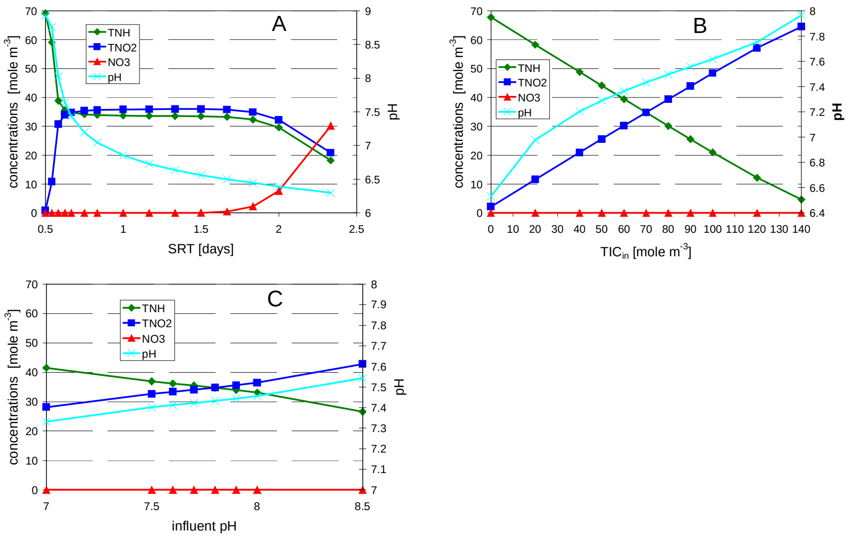

Figure 2 Influence of SRT (A), influent TIC concentration (B) and influent pH (C) on reactor concentrations and pH (steady state simulation results).

Influence of the sludge retention time

The sludge retention time (SRT), equal to the hydraulic retention time, was varied by varying the liquid phase volume. Figure 2.A shows that the SRT should be kept between 0.65 and 1.6 days to establish ingrowth of ammonium oxidizers and washout of nitrite oxidizers and in this way establish partial nitrification. In this stable operating region, the amounts of TNH and TNO2 produced hardly vary and are about the same. This implies that no problems for process stability are to be expected at varying SRT, in practice mainly caused by varying influent flow rates.

Influence of the influent TIC concentration

The influent TIC concentration was varied from 40 to 140 mole m^{-3}, while the influent pH was kept constant (figure 2.B). The influent TIC concentration determines its buffer capacity (HCO_3^- concentration). When the influent TIC/TNH ratio is smaller than 70/70, less protons can be neutralized and the ammonium oxidation will stop earlier because of the resulting pH drop, provoking a TNO2/ TNH ratio smaller than 1/1. The opposite holds for TIC/TNH ratios larger than 70/70.

Influence of the influent pH

For the simulations presented in figure 2.C, the influent pH was varied between 7 and 8.5. As its pH increases, the influent contains more bicarbonate for the same TIC concentration. This means that more protons can be neutralized, resulting in a higher TNO2/ TNH ratio.

CONCLUSIONS

The influence of SRT, influent alkalinity and influent pH on the performance of a continuously aerated SHARON reactor was examined by means of steady state simulations. It was found that the obtained TNO2/TNH ratio hardly varies with varying SRT, but is highly influenced by the buffer capacity of the influent, that varies with influent pH and TIC concentration. In this way, the latter seem suitable control handles for controlling the TNO2/TNH ratio and need to be controlled well in order to ensure stable process performance.

REFERENCES

Hao, X., Heijnen J.J. and van Loosdrecht M.C.M. (2002). Model-based evaluation of the behaviour of the CANON-process with variable temperature and inflow. Water Research, accepted for publication.

Hellinga, C., van Loosdrecht M.C.M. and Heijnen J.J. (1999). Model based design of a novel process for nitrogen removal from concentrated flows. Mathematical and Computer Modelling of Dynamical Systems, 5, 351-371 .

Kuai, L. and Verstraete, W. (1998). Ammonium removal by the oxygen limited autotrophic nitrification-denitrification system. Applied and Environmental Microbiology, 64, 4500-4506.

van Dongen, U., Jetten M.S.M. and van Loosdrecht M.C.M. (2001). The SHARON-Anammox process for treatment of ammonium rich wastewater. Water Science and Technology, 44, 153-160.

van Kempen, R., Mulder J.W., Uijterlinde C.A. and van Loosdrecht M.C.M. (2001). Overview: full scale experience of the SHARON process for treatment of rejection water of digested sludge dewatering. Water Science and Technology, 44, 145-152.

Volcke E.I.P., Hellinga C., Van Den Broeck S., van Loosdrecht M.C.M. and Vanrolleghem P.A. (2002) Modelling the SHARON process in view of coupling with Anammox. In: Proceedings 1st IFAC International Scientific and Technical Conference on Technology, Automation and Control of Wastewater and Drinking Water Systems (TiASWiK'02). Gdansk-Sobieszewo, Poland, June 19-21 2002. 65-72.