# Design of nutrient removal activated sludge systems

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**Abstract** A mechanistic mathematical model for nutrient and organic matter removal was used to describe the behavior of a nitrification denitrification enhanced biological phosphorus removal (NDEBPR) system. This model was implemented in a user-friendly software DESASS (*design and simulation of activated sludge systems*). A 484-L pilot plant was operated to verify the model results. The pilot plant was operated for three years over three different sludge ages. The validity of the model was confirmed with data from the pilot plant. Also, the utility of DESASS as a valuable tool for designing NDEBPR systems was confirmed.
**Keywords** Activated sludge model No. 2 (ASM2); design; models; nutrient removal; nitrogen; phosphorus

## Introduction

Wastewater treatment plants (WWTP) design is becoming an increasingly difficult calculation process, involving a great number of engineering decisions. Design tasks can be made much easier through the use of the mathematical models, which are useful tools in designing and controlling biological wastewater treatment systems.

The mathematical models are particularly interesting in describing the behavior of activated sludge systems for nutrient and organic matter removal, due to the large number of interacting processes which they included. Several models that can simulate the nitrification denitrification enhanced biological phosphorus removal (NDEBPR) process have been proposed in the literature (Henze *et al*., 1995; Barker and Dold, 1997; Maurer and Gujer, 1998). Among them, one of the models of greater acceptance is ASM2 (Henze *et al*., 1995) proposed by the IWA Task Group on Mathematical Modeling for Design and Operation of Biological Wastewater Treatment Processes. It is a mechanistically based model that describes the dynamic and stationary behavior of NDEBPR process involved in biological wastewater treatment.

In practice the following processes, not included in ASM2, have been observed: a) Polyphosphate storage and growth of the phosphorus accumulating organisms (PAOs) under anoxic conditions. Several researchers have studied these processes (Kuba, 1996a; Barker and Dold, 1996). Thus these process were recently added to the model (Henze *et al*., 1999). b) Glycogen storage in PAO metabolism (Maurer *et al*., 1997; Filipe and Daigger, 1998). Also, it has been reported that there are other groups of microorganisms, called glycogen accumulating organisms (GAOs), not taking into account in ASM2, that can grow under enhanced biological phosphorus removal (EBPR) processes (Cech and Hartman, 1993; Satoh *et al*., 1994; Mino *et al*., 1996)

Recently, a modification has been reported to the ASM2 that includes the previous exposed process and permits us to represent the competition between phosphorus accumulating organisms (PAOs) and glycogen accumulating organisms (GAOs) in a nutrient removal activated sludge system (Manga *et al*., 2001).

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This modification to the ASM2 has been implemented in user-friendly software DESASS (*design and simulation of activated sludge systems*), developed by Dpto. Ingeniería Hidráulica y Medio Ambiente, Universidad Politécnica de Valencia (Spain), which includes not only design calculations but also the following facilities: plant arrangement, hydraulics calculations, and machinery assignments from an update database. In this work, DESASS has been used to describe the behavior of the NDEBPR system.



## Materials and methods

### Pilot plant

A pilot plant was operated to study the NDEBPR process. The pilot plant consisted of three reactors in series with a total volume of 384 L. It has a modified UCT (University of Cape Town) configuration (Figure 1). The average hydraulic retention time (HRT) for the pilot plant was maintained at 9.6 hours. The system was maintained at a constant temperature (20°C ± 1°C). Operation of the pilot plant began in October 1997 and continued through March 1999. The operation of the pilot plant was divided into three major phases. The sludge retention time (SRT) for the first, second and third phase was typically maintained at a value of approximately 16, 14 and 12 days, respectively.

#### Wastewater characterization and collecting of data at the pilot plant

The pilot plant was fed with municipal wastewater. Acetic acid was supplemented to the pilot plant influent to improve EBPR (simulating a primary sludge fermentation and elutration process). The average pilot plant influent characteristics are shown in Table 1 (ASM2 influent characterization).

At the steady state conditions an extensive sampling and analysis program was carried out. COD,VSS, TSS and nutrient concentrations were measured at 3 sampling points as shown in Figure 1. The average operating results of the pilot plant during each phase of operation are shown in Table 2.

#### Analytical methods

Most of the analytical techniques were in accordance with APHA (1995) (BOD, polyP digestion, reactive phosphorus, TSS, VSS, $NH_3$-N). COD, $NO_3$-N and Total N were determined with specific Merck kits. Short-chain fatty acids were determined by titration.

#### Computer simulation model

The activated sludge simulator DESASS was used as a simulation platform (Figure 1). It allows simulation of different schemes of plants ranging from single state aerobic systems to complex processes incorporating nitrogen and phosphorus biological removal. The dynamic model used to describe the behavior of the NDEBPR system is a modification to

**Table 1** Influent characteristics

| S.R.T. (d) | 16 | 14 | 12 |
|---|---|---|---|
| $S_F$ (mg COD/l) | 42.3 | 27.0 | 71.0 |
| $S_A$ (mg COD/l) | 82.2 | 80.0 | 80.0 |
| $S_{NH4}$ (mg N/l) | 20.3 | 15.0 | 17.7 |
| $S_{PO4}$ (mg P/l) | 7.0 | 5.0 | 7.7 |
| $S_I$ (mg COD/l) | 38 | 23 | 25 |
| $S_{ALK}$ (mole $HCO^-_3$) | 3 | 5 | 5 |
| $X_I$ (mg COD/l) | 29 | 16 | 25 |
| $X_S$ (mg cod/L) | 57 | 65 | 60 |

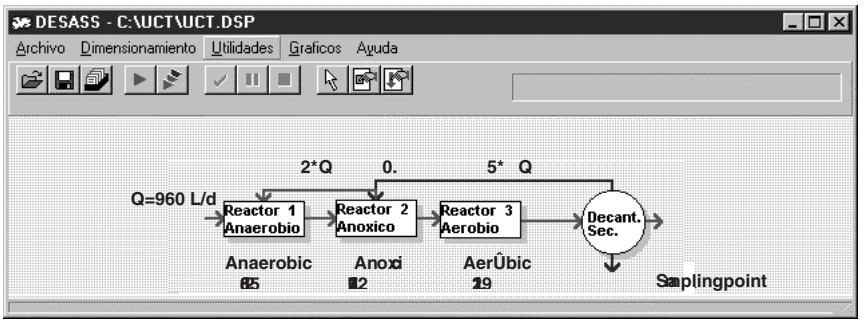


**Figure 1** Pilot plant configuration

the ASM2, which permits representation of the competition between PAOs and GAOs in a nutrient removal activated sludge system (Manga *et al*., 2001).

## Model calibration

The model was calibrated using an off-line methodology, fundamentally based on respirometric techniques and on the individualized analysis of the different processes involved. Data obtained in this individual analysis of every process are used to feed an algorithm, which allows us to calculate the different parameter values of the model.

The methodology used is based on the selective calibration of high influence parameters

**Table 2** Measured and calculated concentrations of the pilot plant

| | Anaerobic tank | | | | | |
|---|---|---|---|---|---|---|
| | S.R.T. 16 (d) | | S.R.T. 14 (d) | | S.R.T. 12 (d) | |
| | Measured | Predicted | Measured | Predicted | Measured | Predicted |
| TSS (mgTSS/l) | 2,286 | 2,243 | 2,047 | 1,862 | 2,054 | 2,016 |
| VSS (mgVSS/l) | 1,709 | 1,663 | 1,410 | 1,252 | 1,499 | 1,445 |
| Suspended COD (mgCOD/l) | 2,743 | 2,568 | 2,271 | 1,935 | 2,526 | 2,233 |
| Soluble P (mgP/l) | 29.0 | 27.8 | 24.9 | 24.5 | 30.1 | 30.6 |
| Ammonia (mgN/l) | 9.8 | 11.3 | 15.5 | 12.1 | 11.5 | 14.8 |
| Nitrate (mgN/l) | <0.2 | 0.0 | 0.7 | 0.0 | 0.8 | 0.0 |

| | Anaerobic tank | | | | | |
|---|---|---|---|---|---|---|
| | S.R.T. 16 (d) | | S.R.T. 14 (d) | | S.R.T. 12 (d) | |
| | Measured | Predicted | Measured | Predicted | Measured | Predicted |
| TSS (mgTSS/l) | 3,154 | 3,362 | 2,732 | 2,783 | 2,929 | 3,019 |
| VSS (mgVSS/l) | 2,308 | 2,443 | 1,850 | 1,832 | 2,112 | 2,116 |
| Suspended COD (mgCOD/l) | 3,744 | 3,767 | 2,710 | 2,827 | 3,226 | 3,265 |
| Soluble P (mgP/l) | 20.9 | 21.7 | 20.5 | 20.9 | 26.0 | 25.6 |
| Ammonia (mgN/l) | 8.8 | 8.4 | 14.8 | 9.9 | 11.1 | 11.8 |
| Nitrate (mgN/l) | <0.2 | 0.2 | 0.8 | 0.2 | 0.9 | 0.2 |

| | Anaerobic tank | | | | | |
|---|---|---|---|---|---|---|
| | S.R.T. 16 (d) | | S.R.T. 14 (d) | | S.R.T. 12 (d) | |
| | Measured | Predicted | Measured | Predicted | Measured | Predicted |
| TSS (mgTSS/l) | 3,236 | 3,400 | 2,766 | 2,817 | 2,992 | 3,066 |
| VSS (mgVSS/l) | 2,298 | 2,418 | 1,822 | 1,802 | 2,081 | 2,086 |
| Suspended COD (mgCOD/l) | 3,730 | 3,723 | 2,733 | 2,776 | 3,203 | 3,213 |
| Soluble P (mgP/l) | 2.5 | 2.1 | 0.4 | 0.3 | 1.9 | 1.0 |
| Ammonia (mgN/l) | <1.5 | 0.1 | <1.5 | 0.1 | 0.0 | 0.1 |
| Nitrate (mgN/l) | 7.6 | 7.2 | 9.6 | 8.6 | 15.0 | 10.2 |
| Soluble COD (mg COD/l) | 40 | 47.2 | 28 | 32.8 | 35 | 33.9 |

involved in the model. The values of low influence parameters were adjusted to improve the fit of the model to pilot plant results. Tables 3, 4 and 5 present parameters values that were derived from the calibration work.

## Model simulation

The calibrated modified ASM2 was used to predict the performance of the pilot plant for the three different operation phases. The model predictions were performed with the simulation tool DESASS. A steady state simulation was computed using average pilot plant influent characteristics during each phase of operation as model inputs. The model predictions (using the calibrated parameters shown in Tables 3, 4 and 5) are presented in Table 2. Good correspondence was found between measured and calculated values.



## Discussion

### Comparison of simulated results with measured values

Table 2 shows the comparison of the model results with the pilot plant data. It is seen from Table 2 that the simulation model yielded the reasonable results. It should be noted that DESASS was capable of describing pilot plant data over three different sludge ages and different influent characteristics using a single set of stoichiometric and kinetic parameters for each group of microorganisms involved in the model.

The results of this study verified the predictive capability of the dynamic model. Thus, it demonstrated that dynamic models are a valuable tool for designing NDEBPR systems.

### Biological excess phosphorus removal

Based on the results of this study, a number of considerations can be offered. In the NDEBPR system the biological phosphorus removal was achieved at all sludge ages in spite of the presence of large quantities of glycogen accumulating organisms (GAOs) in the

**Table 3** Stoichiometric parameters

| Symbol | Characterization | Units | Value |
|---|---|---|---|
| ***Heterotrophic biomass*** | | | |
| $Y_H$ | Yield coefficient | gCOD/gCOD | 0.59 |
| ***Nitrifying organisms*** | | | |
| $Y_A$ | Yield of autotrophic biomass | gCOD/gN | 0.24 |
| ***Phosphorus accumulating organisms*** | | | |
| $Y_{SA}$ | SA requirement for PHA storage | gCOD/gCOD | 0.75 |
| $Y_{PO4}$ | PP requirement for PHA storage | gP/gCOD | 0.40 |
| $Y_{PHA}$ | PHA requirement for PP storage | gCOD/gP | 0.32 |
| $Y_{PHA,NO}$ | PHA requirement for anoix storage of PP | gCOD/gP | 0.57 |
| $Y_{PAO}$ | Aerobic yield coefficient | gCOD/gCOD | 0.58 |
| $Y_{PAO,NO}$ | Anoxic yield coefficient | gCOD/gCOD | 0.47 |
| $Y_{GLY}$ | Aerobic glycogen yield coefficient | gCOD/gCOD | 1 |
| $Y_{GLY,NO}$ | Anoxic glycogen yield coefficient | gCOD/gCOD | 1 |
| ***Glycogen accumulating organisms*** | | | |
| $Y_{SA,G}$ | SA requirement for PHA,G storage | gCOD/gCOD | 0.75 |
| $Y_{GAO}$ | Aerobic yield coefficient | gCOD/gCOD | 0.58 |
| $Y_{GAO,NO}$ | Anoxic yield coefficient | gCOD/gCOD | 0.47 |
| $Y_{GLY,G}$ | Aerobic glycogen yield coefficient | gCOD/gCOD | 1 |
| $Y_{GLY,GNO}$ | Anoxic glycocgen yield coefficient | gCOD/gCOD | 1 |

**Table 4** Kinetics parameters

| Symbol | Characterization | Units | Value |
|---|---|---|---|
| ***Heterotrophic organisms*** | | | |
| $\mu_H$ | Maximum growth rate | $d^{-1}$ | 3.00 |
| $q_{fe}$ | Maximum rate for fermentation | gCOD/g$X_H$*d) | 3.00 |
| $(_{NO3}$ | Reduction factor for denitrification | – | 0.58 |
| $b_H$ | Rate constant for lysis of $X_H$ | $d^{-1}$ | 0.32 |
| $K_{O2}$ | Saturation coefficient for $S_{O2}$ | gCOD/$m^3$ | 0.20 |
| $K_F$ | Saturation coefficient for $S_F$ | gCOD/$m^3$ | 15.00 |
| $K_{fe}$ | Saturation coefficient for fermentation of $S_F$ | gCOD/$m^3$ | 4.00 |
| $K_A$ | Saturation coefficient for $S_A$ | gCOD/$m^3$ | 4.00 |
| $K_{NO3}$ | Saturation coefficient for nitrate | gN/$m^3$ | 0.50 |
| $K_{NH4}$ | Saturation coefficient for ammonium | gN/$m^3$ | 0.05 |
| $K_P$ | Saturation coefficient for $S_{PO4}$ | gP/$m^3$ | 0.01 |
| $K_{ALK}$ | Saturation coefficient for alkalinity | mole $HCO^-_3$/$m^3$ | 0.10 |
| ***Nitrifying organisms*** | | | |
| $\mu_{AUT}$ | Maximum growth rate | $d^{-1}$ | 1.30 |
| $b_{AUT}$ | Rate constant for lysis of $X_{AUT}$ | $d^{-1}$ | 0.08 |
| $K_{O2}$ | Saturation coefficient for $S_{O2}$ | gCOD/$m^3$ | 0.50 |
| $K_{NH4}$ | Saturation coefficient for ammonium | gN/$m^3$ | 0.25 |
| $K_P$ | Saturation coefficient for $S_{PO4}$ | gP/$m^3$ | 0.01 |
| $K_{ALK}$ | Saturation coefficient for alkalinity | mole $HCO^-_3$/$m^3$ | 0.50 |



mixed liquor. It was expected that the presence of GAOs in this system was due to an excess of acetic acid in the influent that causes a low P/C feeding ratio. Thus, the uptake of carbon sources by PAOs was slowed down under anaerobic conditions and a part of the acetate remained available as a carbon source for GAOs. GAOs could take up and store the acetate into PHA, utilize the accumulated PHA for growth under aerobic conditions, and becomes a large population in this system. This is consistent with the results found by Liu *et al*. (1997).

On the other hand, it is known that low sludge retention times (SRT) are beneficial to EBPR processes (WEF, ASCE, 1992). The sludge age used in the investigation was high compared with other sludge age used in NDEBPR systems with successful phosphorus removal performance. Table 2 shows that in the second phase of operation (SRT 14 days) low effluent phosphorus concentration was obtained compared with the effluent phosphorus concentration in the third phase (SRT 12 days). Although sludge age decreases effluent phosphorus concentration increases. This could be explained by the difference in average pilot plant influent characteristics used in this study (Table 1).

DESASS was used to show the effect of sludge retention time on biological phosphorus removal in the NDEBPR system (see Figure 2) taking into account the conditions prevailing in the first phase. Simulated results for effluent phosphorus concentration presented in Figure 2 verified that low sludge retention times (SRT) are beneficial to EBPR processes. The increase in phosphorus removal results from the higher PAOs concentration to that of GAOs. Thus, the higher PAOs fraction of the mixed liquor is, the higher is the biological phosphorus removal. Also, DESASS was used to show the effect of hydraulic retention time on EBPR processes taking into account the conditions prevailing in the first phase (see Figure 3). Simulated results for effluent phosphorus concentration presented in Figure 3 showed that low hydraulic retention times (HRT) are beneficial to EBPR processes.

The model results presented in Figure 2 and 3 are consistent with the fact that in this study GAOs growth rate was low compared with PAOs growth rate (see Table 2). Thus, PAOs becomes a large population in this system at low SRT and HRT and have a good phosphorus removal performance. This suggests that an adequate design for controlling

**Table 5** Kinetics parameters

| Symbol | Characterization | Units | Value |
|---|---|---|---|
| ***Phosphorus accumulating organisms*** | | | |
| $q_{PHA}$ | Rate constant for storage of PHA | gCOD/(gPAO*d) | 3.60 |
| $K_A$ | Saturation coefficient for $S_A$ | gCOD/m$^3$ | 3.63 |
| $K_{PP}$ | Saturation coef. $X_{PP}$ for $X_{PHA}$ storage | gPP/gPAO | 0.01 |
| $K_{GLY}$ | Saturation coef. $X_{GLY}$ for $X_{PHA}$ storage | gCOD/gPAO | 0.001 |
| $q_{PP}$ | Rate constant for storage of PP | gPP/(gPAO*d) | 2.80 |
| $K_{O2}$ | Saturation coefficient for $S_{O2}$ | gCOD/m$^3$ | 0.20 |
| $K_{PS}$ | Saturation coef. $S_{PO4}$ for $X_{PP}$ storage | gP/m$^3$ | 0.20 |
| $K_{ALK}$ | Saturation coefficient for alkalinity | mole $HCO^-_3$/m$^3$ | 0.10 |
| $K_{PHA-P}$ | Saturation coef. $X_{PHA}$ for $X_{PP}$ storage | gPHA/gPAO | 0.07 |
| $K_{MAX}$ | Maximum ratio of $X_{PP}/X_{PAO}$ | gPP/gPAO | 0.28 |
| $K_{IPP}$ | Inhibition coefficient for $X_{PP}$ storage | gPP/gPAO | 0.001 |
| $K_{NO3}$ | Saturation coefficient for nitrate | gN/m$^3$ | 0.50 |
| $K_{PHA}$ | Saturation coef. $X_{PHA}$ for growth | gPHA/gPAO | 0.03 |
| $\mu_{PAO}$ | Maximum growth rate | d$^{-1}$ | 0.84 |
| $K_{NH4}$ | Saturation coefficient for ammonium | gN/m$^3$ | 0.05 |
| $K_P$ | Saturation coef. $S_{PO4}$ for growth | gP/m$^3$ | 0.01 |
| $\eta_{PAO}$ | Anoix reduction coefficient | – | 0.48 |
| $q_{GLY}$ | Rate constant for storage of $X_{GLY}$ | gCOD/(gPAO*d) | 3.8 |
| $K_{PHA-GLY}$ | Saturation coef. $X_{PHA}$ for $X_{GLY}$ storage | gPHA/gPAO | 0.12 |
| $K_{MG}$ | Maximum ratio of $X_{GLY}/X_{PAO}$ | gCOD/gPAO | 0.25 |
| $K_{IG}$ | Inhibition coefficient for $X_{GLY}$ storage | gCOD/gPAO | 0.015 |
| $b_{PAO}$ | Rate constant for lysis of $X_{PAO}$ | d$^{-1}$ | 0.08 |
| $b_{PP}$ | Rate constant for lysis of $X_{PP}$ | d$^{-1}$ | 0.08 |
| $b_{PHA}$ | Rate constant for lysis of $X_{PHA}$ | d$^{-1}$ | 0.08 |
| $b_{GLY}$ | Rate constant for lysis of $X_{GLY}$ | d$^{-1}$ | 0.08 |
| ***Glycogen accumulating organisms*** | | | |
| $q_{PHA,G}$ | Rate constant for storage of $X_{PHA,G}$ | gCOD/(gGAO*d) | 2.60 |
| $K_A$ | Saturation coefficient for $S_A$ | gCOD/m$^3$ | 3.63 |
| $K_{GLY,G}$ | Saturation coef. $X_{GLY,G}$ for $X_{PHA,G}$ storage | gCOD/gGAO | 0.001 |
| $\mu_{GAO}$ | Maximum growth rate | d$^{-1}$ | 0.80 |
| $K_{O2}$ | Saturation coefficient for $S_{O2}$ | gCOD/m$^3$ | 0.20 |
| $K_{ALK}$ | Saturation coefficient for alkalinity | mole $HCO^-_3$/m$^3$ | 0.10 |
| $K_{PHA,G}$ | Saturation coef. $X_{PHA,G}$ for growth | gPHA/gGAO | 0.03 |
| $K_{NO3}$ | Saturation coefficient for nitrate | gN/m$^3$ | 0.50 |
| $K_{NH4}$ | Saturation coefficient for ammonium | gN/m$^3$ | 0.05 |
| $K_P$ | Saturation coef. $S_{PO4}$ for growth | gP/m$^3$ | 0.01 |
| $\eta_{GAO}$ | Anoxic reduction coefficient | – | 0.0 |
| $q_{GLY,G}$ | Rate constant for storage of $X_{GLY,G}$ | gCOD/(gGAO*d) | 1.2 |
| $K_{PHA,G-GLY}$ | Saturation coef. $X_{PHA,G}$ for $X_{GLY,G}$ storage | gPHA/gGAO | 0.008 |
| $K_{MG,G}$ | Maximum ratio of $X_{GLY,G}/X_{GAO}$ | gCOD/gGAO | 0.40 |
| $K_{IG,G}$ | Inhibition coefficient for $X_{GLY,G}$ storage | gCOD/gGAO | 0.015 |
| $b_{GAO}$ | Rate constant for lysis of $X_{GAO}$ | d$^{-1}$ | 0.08 |
| $b_{PHA,G}$ | Rate constant for lysis of $X_{PHA,G}$ | d$^{-1}$ | 0.08 |
| $b_{GLY,G}$ | Rate constant for lysis of $X_{GLY,G}$ | d$^{-1}$ | 0.08 |

GAOs in the NDEBPR system and to improve biological phosphorus removal must take into account low SRT and HRT.

#### Biological nitrogen removal

According to Kuba *et al.* (1996b) the optimal phosphorus and nitrogen removal are obtained at about 7.4 gCOD/gN. The COD/N ratio used in this study in the first, second and third phase of operation was about 7.50, 9.05 and 7.30, respectively. Thus this value showed that there was enough organic matter in the influent to remove all nitrogen. However, as can be seen in Table 2, the biological nitrogen removal (BNR) process can not remove effectively nitrogen from the influent wastewater.

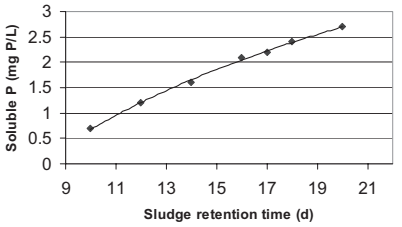


**Figure 2** Effect of sludge retention time on effluent P concentration

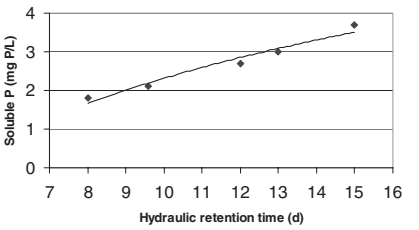


**Figure 3** Effect of hydraulic retention time on effluent P concentration

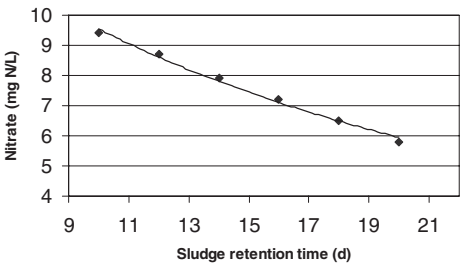


**Figure 4** Effect of sludge retention time on effluent nitrate concentration

Table 2 shows that in the aerobic reactor the nitrifiers oxidize all the ammonium to nitrate. Thus, this process was not limiting nitrogen removal in this system. Furthermore, in an anoxic reactor all nitrate was denitrified. This suggests that an inadequate design of this system has been used for nitrogen removal. The modified UCT configuration does not include a mixed liquor recirculation (MLR) from aerobic reactor to anoxic reactor that could increases nitrogen removal in this system. In order to test this hypothesis DESASS was used to simulate this system taking into account a MLR between the aerobic and anoxic reactors. The model results indicate a good nitrogen removal performance. However, it was observed that high MLR rate (between aerobic and anoxic reactors) has a markedly deleterious influence on the magnitude of phosphorus removal. This is evident because nitrate was not completely denitrified in the anoxic reactor thus recycling nitrate to the anaerobic reactor.

In this study, nitrate is essentially converted to molecular nitrogen by ordinary heterotrophic organisms and PAOs. As can be seen in Table 5, the fraction ($\eta_{PAO}$) of PAOs that can denitrify was approximately 48%. This result closely agreed with the 50% found by Kuba *et al*. (1997), suggesting that denitrification by PAOs significantly contribute to the overall phosphorus removal in this NDEBPR system.

On the other hand, it is known that high sludge retention times (SRT) are beneficial to BNR processes. Table 2 shows that in the first phase of operation (SRT 16 days) low effluent nitrate concentration was obtained compare with the effluent nitrate concentration in the other phases. Furthermore, nitrogen removal decreases as sludge age decreases (see Table 2). This is consistent with the results founded in the literature (WEF, ASCE, 1992).

DESASS was used to show the effect of sludge retention time on biological nitrogen removal in the NDEBPR system (see Figure 4) taking into account the conditions prevailing in the first phase. Model results for effluent nitrate concentration presented in Figure 4 verified that high sludge retention times (SRT) are beneficial to BNR processes.

## Conclusions

The dynamic model was used for the simulation analysis of the pilot plant. The model successfully characterized the nutrient removal performance of the pilot plant. The validity of

the model was confirmed with data from the pilot plant. The model indicates that, in agreement with observations, low sludge retention times are beneficial to EBPR processes and has a markedly deleterious influence on the magnitude of nitrogen removal. The simulation tool DESASS has been found very successful in describing the behaviour of the NDEBPR process. Comparison of experimental data and simulation results shows DESASS is suitable for the design task. The simulation results show that DESASS is effective to study the performance of nutrient removal.



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