Watermatex 2015
9th IWA Symposium on Systems Analysis and Integrated Assessment
14-17 June 2015, Gold Coast, Australia

# Study of the Simulation and Optimization of DNBF Applied for Wastewater Reclamation Plant

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**Keywords:** denitrification; biological filter; simulation, optimization

## Introduction

The water shortage is a serious problem for the development of the northern of China. Recent years millions cubic meter of wastewater has been treated every day and supplied to the surface water system in Beijing. This requires the conventional wastewater treatment plants (WWTP) transfer as wastewater reclamation plants. Denitrification Biological Filter (DNBF) is one of the most effective processes for advanced denitrification [1]. The purpose of present research is to establish the models of DNBF and determine the optimized operation conditions by using BioWin software.

## Methods

### 1. Basic parameters and operation mode of pilot DNBF

A pilot reactor of DNBF was established to get the treatment results of advanced denitrification and to prove the optimized operation conditions based on the simulation. The height of the pilot reactor was 3.5 m, the diameter was 0.30 m and daily treatment capacity was about 14.45$m^3.d^{-1}$. From the bottom up, there are four sections: water1 section, buffer layer, filter bed and water2 section, as summarized in Table 1.

**Table 1.Four sections of pilot DNBF**

| Section | Water1 | Buffer layer | | Filter bed | Water2 |
|---|---|---|---|---|---|
| | | Buffer layer(below) | Buffer layer(above) | | |
| Media | - | cobblestone | cobblestone | ceramics | - |
| Media diameter / mm | - | 16~32 | 8~12 | 5~7 | - |
| Height / m | 0.18 | 0.20 | 0.10 | 2.13 | 0.74 |

The influent of DNBF was the effluent of an A/O process in the WWTP with a daily treatment capacity of 6 x 105$m^3.d^{-1}$. The average concentrations of COD, TN and TP of influent of DNBF are 50.17, 26.41 and 0.49 mg/L respectively. The influent flows from the bottom to the top of the pilot reactor with a velocity of 8 m/h. The C/N of influent was maintained in two conditions by adding methanol as additional carbon source: C/N=4 and C/N=5. Each condition was operated for one month after getting stable.

### 2. General model of DNBF established using BioWin software

DNBF exhibits plug-flow behaviour, which was simulated by using several media bioreactors connected series, each representing a layer of media in the filter bed, while the two bioreactors at the beginning and end of the series represent the two water sections. Methanol was added and mixed with the influent. The configuration of the pilot DNBF is shown in Figure 1.

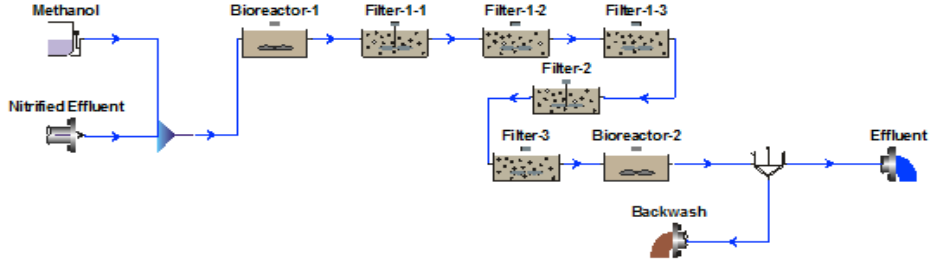


**Figure 1.General model configuration of pilot DNBF**

### 3. Sensitivity analysis and model validation

The data used for sensitivity analysis, model calibration and validation came from the operation data of pilot DNBF under the condition of C/N=5 and C/N=4, data of C/N=5 was used for sensitivity analysis and model calibration, data of C/N=4 was used for model validation, respectively.

Two sensitivity analysis methods, "normalized sensitivity coefficient measure($S_{i,j}$)" [2] and "mean square sensitivity measure ($\delta_j^{msqr}$)" [3], were used to find out the highly sensitive parameters of ASDM model in BioWin. In this research, a 10% increase of every parameter in the ASDM model is applied for the calculation of $S_{i,j}$. The influence of a parameter on the simulation results can be interpreted as follows: (1) $S_{i,j}< 0.25$ means that a parameter has no significant influence on the simulation results; (2) $0.25 \leq S_{i,j}<1$ means that a parameter is influential; (3) $1\leq S_{i,j}<2$ means that a parameter is very influential ; (4) $S_{i,j}\geq 2$ means that a parameter is extremely influential.

## Results and discussion

### 1. Operation results of pilot DNBF

The pilot DNBF was operated under two work conditions, C/N=4, filtration velocity=8 m/h and C/N=5, filtration velocity=8 m/h, each condition lasts for almost one month. The operation results indicated that the concentration of effluent TN decreases with the increase of influent C/N, the concentration was 14.52 ± 6.0042 mg/L when the influent C/N was 4 while the concentration was 7.14 ± 3.5124 mg/L when the influent C/N was 5, which means that adding methanol enhances the removal of TN. The concentration of effluent TN under the condition of C/N=5 has already reached the new discharge standard of municipal WWTP. Therefore, in order to find the optimum C/N of this pilot DNBF under the filtration velocity of 8 m/h, it should be searched between 4 and 5.

### 2. Model validation

Generally, the model can be considered valid when the model predictions can agree with measured values from another independent dataset within the acceptable tolerances. So the operation data of C/N=4 was used for the model validation and the results of model validation is shown in Table 2. In general, the simulation results of C/N=4 operation using the calibrated model also fit with the experiment results well, and the calibrated model can be applied.

**Table 2.Everyday simulation of C/N=4 using calibrated model**

| Parameter | Unit | Effluent | |
|---|---|---|---|
| | | Measurement | Simulation |
| COD | $mgO_2.L^{-1}$ | 45.42 ± 7.4034 | 30.79 ± 5.6590 |
| $NH_3$-N | $mg.L^{-1}$ | 1.48 ± 5.4057 | 1.66 ± 5.57598 |
| TN | $mg.L^{-1}$ | 14.52 ± 6.0042 | 12.97 ± 4.6563 |
| TP | $mg.L^{-1}$ | 0.56 ± 0.9705 | 0.42 ± 0.6088 |
| TSS | $mg.L^{-1}$ | 3.30 ± 4.1900 | 3.68 ± 3.0847 |

*All the data are subjected to standard statistical elaboration with a significance level at 95%

### 4. Optimization of the operation conditions of DNBF

As mentioned above, the optimum operation condition of C/N for denitrification of DNBF should be searched between 4 and 5. According to the "Technical and Engineering Specification of Biological Filter", the filtration velocity of DNBF is 8.0~12.0 m/h and the empty bed HRT is 15.0~25.0 min. In this study, the empty bed HRT was 15.98 min when the filtration velocity was 8.0 m/h, conforming to the requirement of the technical specification. And simulation results reveal that the performance of DNBF gets worse when the filtration velocity gets higher, which also agrees with practical experience. Therefore, the optimized filtration velocity can be set as 8.0 m/h, only leaving the influent C/N to be optimized. The operation conditions used for optimization and the optimization results are shown in Figure 2 and Figure 3, respectively.

In Figure 2, the TN removal rate increases sharply when the C/N increases from 4.0 to 4.4, while the increase begins to slow down when C/N was bigger than 4.4 and finally the curve of TN removal rate tends to be flat when C/N gets even bigger.

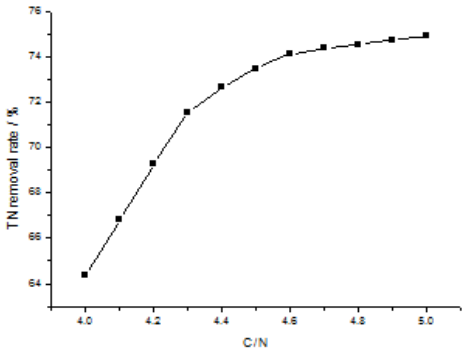


Figure 2.TN removal rate of simulation

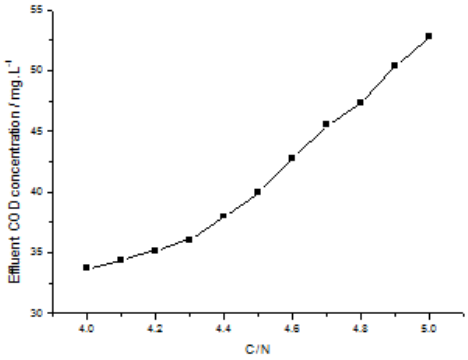


Figure 3. COD conc. of effluent by simulation

As shown in Figure 3, the effluent COD concentration raises abruptly when the C/N was bigger than 4.4, which means that the extra adding methanol no help to improve the removal of TN. Therefore, C/N=4.4 was the point where the adding methanol can be effectively used. In this condition the TN concentration of effluent was 7.99 mg.$L^{-1}$, which can meet the new standard of 10 mg.$L^{-1}$ and leave a 20% allowance to respond the accidental influent shock load. Finally the optimum operation conditions of DNBF was: C/N=4.4, filtration velocity=8 m/h.

## Conclusion

Using BioWin software, a model of DNBF was established for the simulation and optimization of advanced denitrification for wastewater reclamation. The normalized sensitivity coefficient measure (S_(i,j)) and mean square sensitivity measure (δ_j^msqr) were adopted for sensitivity analysis to find out the most sensitive parameters to facilitate the calibration of the model. Five most sensitive parameters were selected as: yield (anoxic), N in biomass, diffusion rate, film surface area to media area ratio-Max, PO4-P(Sol & Me comp.) and suggested to be commonly used for model calibration when simulate other DNBFs by using BioWin software. Based on the experiment results of pilot DNBF and simulation, the optimized operation condition has been presented as: C/N=4.4, filtration velocity=8 m/h, which will be a useful reference for the DNBF applied in reconstruction from a conventional WWTP to a wastewater reclamation plant.

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