Simulation of segmented influent AAO Process Wastewater based on ASM2d model

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Abstract. The paper, aiming at the poor denitrification effect of a sewage treatment plant in Shenyang, used STOAT software to build a segmented influent AAO Process Model, corrected the temperature of dynamic parameters, and verified the static and dynamic simulation experiments successively. The simulation results showed that after adjusting the model parameters, the relative error between the static simulation results of COD, NH₄⁺-N and TN and the actual mean value was less than 10%. The relative error between the dynamic simulation results of COD, NH₄⁺-N and TN and the actual mean value was less than 20%. The dynamic simulation results can better simulate the operation of the water plant. The simulation test results have certain guiding significance for the water plant.

1. Introduction

The ASM series models [1] launched by the International Water Association (IWA) have been proved to be suitable for the simulation and optimization of sewage treatment plants [2]. Based on these models, domestic researchers have been widely used in the simulation and optimization of many urban sewage treatment plants. They have carried out simulation and Optimization Research on AO process, inverted AAO Process, Ober oxidation ditch process and improved AAO Process, and achieved good results [3-6]. Aiming at the problem of poor denitrification effect of sewage, this paper uses STOAT software to build a model, and carries out static and dynamic simulation to fit the sewage treatment plant.

2. Construction of model

2.1. Background of simulation

The design scale of a sewage plant in Shenyang is 5.5×10⁴ m³/d, the design dimensions of anaerobic tank, anoxic tank and aerobic tank are 5040 m³, 10080 m³ and 24969 m³ respectively. The design scale of secondary sedimentation tank is 25000 m³/d.

The influent quality of the simulation test is taken from December 2019 to January 2020, and the average influent volume and water quality are taken as the model influent data. The determination of COD components of model influent is complex. Refer to the division of COD components of similar sewage plants in this area by Fu Jinxiang [7] and other areas studied by Wu Zhichao [8]. It is composed of fermentation product (Sₐ), biodegradable substrate (Sᵢ), inert dissolved organic matter (Sᵢ), slow degradable substrate (Xₐ) and inert particulate organic matter (Xᵢ). The average influent concentrations are 8.92 mg/L, 15.90 mg/L, 23.43 mg/L, 144.52 mg/L and 125.95 mg/L respectively, and the average influent concentration of NH₄⁺-N is 28.17 mg/L; The average influent concentration of TN is 32.13 mg/L.
2.2. Construction of ASM2d model
In this study, the STOAT5.0 software of WRC company in Britain was selected, and the ASM2d model [9] was selected for the biochemical reaction tank. The simulation experiment is carried out under the condition of water temperature of 11℃. The stoichiometric parameters and kinetic parameters are taken as the default values of the system. The do of the aerobic tank is set as 2.0mg/L, the average solid concentration of the mixed liquid in the biochemical tank is 3500mg/L, the reflux of digestive solution is 3207m³/h, the sludge reflux is 2060m³/h, the reflux ratio is 90%, and the sludge discharge of the secondary sedimentation tank is set as continuous sludge discharge, and the sludge discharge is 80m³/h. The process model interface is shown in Figure 1.

![Fig.1 Model of Segmented Influent AAO Process](image)

3. Calibration and verification of model
3.1. Static simulation test
The model built in this study lacks accurate reference to stoichiometric coefficients and kinetic parameters at the beginning of the test. According to the recommended value of 20℃ parameters provided by ASM2d model, Arrehenius formula and temperature correction coefficient recommended by IAWQ are used α Direct correction. The Arrehenius formula is as follows:

\[
k(T) = k(20^\circ C) \cdot e^{\alpha(T-20)}
\]

Type: \(k(T)\)——Parameter value of \(T\)℃;
\(k(20^\circ C)\)——Parameter value at 20℃;
\(\alpha\)——Temperature correction factor;
\(T\)——Temperature,℃.

Table 1 shows the recommended values of temperature related parameters at 20℃ and their temperature correction coefficients. See the fourth column for the parameter values (11℃) corrected according to formula(1).

| Kinetic parameters | Recommended value of 20℃ | Coefficient of temperature correction (1/℃) | Correction value of 11℃ (1/d) |
|--------------------|--------------------------|------------------------------------------|-------------------------------|
| \(K_h\)           | 3                        | 0.04                                     | 2.093                         |
| \(\mu_H\)         | 6                        | 0.069                                    | 3.224                         |
| \(b_H\)           | 0.4                      | 0.069                                    | 0.215                         |
| \(b_{PAO}\)       | 0.2                      | 0.069                                    | 0.107                         |
| \(b_{AUT}\)       | 0.15                     | 0.11                                     | 0.056                         |
| \(\mu_{AUT}\)     | 1                        | 0.105                                    | 0.389                         |
3.2. The analysis method of Sensitivity

The analysis method of Sensitivity is to test 45 kinetic parameters and 22 chemometric coefficients of ASM2d model. The parameter with high sensitivity means that it has a great impact on the system state variable, otherwise it has a small impact [10]. The calculation formula of parameter sensitivity s is shown in formula (2):

\[(2)\]

\[
\text{Type: } x_1 \quad \text{—— The value of the original parameter;}
\]

\[
\text{x}_2 \quad \text{—— Value of adjusted parameter;}
\]

\[
y_1 \quad \text{—— The value of the simulated effluent result obtained by the simulation under the condition of the value of the original parameters;}
\]

\[
y_2 \quad \text{—— The value of the simulated effluent result obtained by the simulation after adjusting the parameters.}
\]

3.3. Results of sensitivity analysis

Similarly, influent the average value of the above water quality into the built process model, increase all chemometrics and kinetic parameters in the model by 10% from the original value [11], and screen the parameters with high sensitivity, as shown in Table 2.

| Name    | COD  | NH\textsubscript{4}^-N | TN   |
|---------|------|------------------------|------|
| i\textsubscript{N,BM} | Output value | 28.48 | 0.55 | 9.81 |
|         | Sensitivity | 0.00 | 0.19 | -0.18 |
| i\textsubscript{TSS,B} | Output value | 28.43 | 0.67 | 10.05 |
| m      | Sensitivity | -0.02 | 2.41 | 0.06 |
| Y\textsubscript{H} | Output value | 28.68 | 0.57 | 10.48 |
|         | Sensitivity | 0.07 | 0.56 | 0.49 |
| Y\textsubscript{PAO} | Output value | 28.49 | 0.78 | 10.16 |
|         | Sensitivity | 0.00 | 4.44 | 0.17 |
| b\textsubscript{AUT} | Output value | 28.48 | 0.77 | 10.12 |
|         | Sensitivity | 0.00 | 4.26 | 0.13 |
| K\textsubscript{MAX} | Output value | 28.48 | 0.60 | 10.03 |
|         | Sensitivity | 0.00 | 1.11 | 0.04 |
| K\textsubscript{NH\textsubscript{4}} | Output value | 28.48 | 0.68 | 10.07 |
|         | Sensitivity | 0.00 | 2.59 | 0.08 |
| \mu\textsubscript{AUT} | Output value | 28.51 | 0.25 | 9.82 |
|         | Sensitivity | 0.01 | -5.37 | -0.17 |

The results of sensitivity analysis show that only YH has little effect on COD; There are seven parameters that have a great impact on NH\textsubscript{4}^-N, namely i\textsubscript{TSS,BM}, Y\textsubscript{H}, Y\textsubscript{PAO}, b\textsubscript{AUT}, K\textsubscript{MAX}, K\textsubscript{NH\textsubscript{4}} and \mu\textsubscript{AUT}; Y\textsubscript{H}, Y\textsubscript{PAO} and \mu\textsubscript{AUT} has a relatively large impact on TN. Therefore, the parameter adjustment process is only for NH\textsubscript{4}^-N and TN. After repeated trial and error, ypao is adjusted from 0.625 g(COD)/g(COD) to 0.69 g(COD)/g(COD); K\textsubscript{MAX} is adjusted from 0.34 (X\textsubscript{PP})/g(X\textsubscript{PAO}) to 0.40 (X\textsubscript{PP})/g(X\textsubscript{PAO}); \mu\textsubscript{AUT} is adjusted from 0.0246 h\textsuperscript{-1} to 0.0285 h\textsuperscript{-1}. The relative errors between the simulated values of COD, NH\textsubscript{4}^-N and TN and the actual values are within 10%. It is considered that the fitting degree of the model after
parameter verification is high. The final check water quality results are shown in Table 3.

| Project                  | COD    | NH$_4^+$-N | TN     |
|--------------------------|--------|------------|--------|
| Actual effluent          | 29.19  | 1.20       | 10.03  |
| Initial simulation       | 28.49  | 0.54       | 9.99   |
| Final check              | 28.54  | 1.24       | 10.43  |
| Relative error           | 2.22%  | 3.33%      | 3.99%  |

3.4. Dynamic simulation
The original inflow data is dynamically simulated by the STOAT software to test the accuracy of the model after parameter verification. The dynamic simulation results are shown in Figure 2.

(a) Comparison of COD simulation results with actual effluent results

(b) Comparison of NH$_4^+$-N simulation results with actual effluent results
(c) Comparison of TN simulation results with actual effluent results

Due to the large fluctuation of influent, according to the on-line monitoring of influent carbon nitrogen ratio, adjust the subsection influent ratio when the carbon nitrogen ratio is low, and increase the influent ratio in anoxic section to ensure sufficient carbon source and promote the denitrification reaction process. It can be seen from Figure 2 that the actual effluent results of COD, NH$_4^+$-N and TN are in good agreement with the simulation results, and the relative error between most of the actual effluent results and the simulation results is less than 20%, indicating that the model has good predictability and can be used as a simulation tool for optimizing the biological treatment process of the sewage plant.

A few of the simulated values have large errors with the actual effluent. The analysis reason: the inlet and outlet water quality of the water plant fluctuates greatly, there are changes in water quality and process treatment load, and the simulation software cannot match completely.

4. Conclusion

(1) In this paper, the STOAT software is used as the simulation platform to simulate the multi-stage influent AAO Process of a sewage treatment plant in Shenyang, build the segmented influent AAO Process, and check the stoichiometric coefficient and dynamic parameters. The relative error of the static simulation of the effluent index is within 10%, and most of the dynamic simulation results are within 20%, the model can better reflect the actual operation of the sewage plant.

(2) The recommended values of stoichiometric coefficients and kinetic parameters in ASM2d model are not fully applicable to the simulation of sewage treatment plants in China. It is necessary to reasonably adjust the parameters through sensitivity analysis in combination with the existing data of the sewage treatment plant.

(3) The model is established at low temperature of 11 °C, and its process operation plays a guiding role in the optimization of denitrification of the plant and similar sewage plants at low temperature.

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