Modelling performance of oxidation ditch in wastewater treatment plant by STOAT software

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Abstract. This paper adopted the IAWQ# 1 model based on ASM in STOAT software to model the treating performance of oxidation ditch. STOAT software is a free modeling package for numerical modeling and simulation of wastewater treatment plants (WWTP). The dynamic model evaluates the effects of influent water qualities (TN, TP and COD) and water flow rate on the pollutant removal efficiency. The model was able to predict the changing trend in terms of TN, TP and COD concentrations. The effluent TN and TP concentrations did not greatly affected by the change of influent TN and TP concentrations. The removal efficiency of TN was clearly stronger than that of TP. However, the COD removal performance of oxidation ditch was outstanding. Meanwhile, the water flow rate was of importance for the COD biodegradation efficiency. The increase of water flow rate was likely to decrease COD removal efficiency. The flow rate varied between 1000 and 10000 m$^3$/h, and the effluent COD concentration varied from 118.98 to 501.49 mg/L. Overall, STOAT software is a useful and reliable tool for the prediction and optimization of oxidation ditch process.

1. Introduction
The oxidation ditch process in sewage treatment technology is the deformation and evolution product of activated sludge treatment technology, and the ditch used in oxidation ditch process is the end to end circulating ditch, through aeration to achieve the purpose of oxidation reaction of ditch sewage [1]. The BOD removal efficiency can be up to 97%. The oxidation ditch technology originated in the Netherlands in the 1950s [2]. The first generation of oxidation ditch owned intermittent, aeration, precipitation. The second generation of oxidation ditch had vertical aerator, nitrification and denitrification reaction. The third generation of oxidation ditch had the processing of phosphorus and nitrogen removal. The fourth generation of oxidation ditch is the circulation oxidation ditch that treats wastewater better smoothly and efficiently, reduces plant human labor, improves the efficiency of sewage treatment plant [3].

STOAT is a dynamic sewage treatment works modeling package [4]. A sewage work can be built up defining the treatment processes that they are connected and operated. The performance of the works over a period of time can be predicted. This does not make STOAT a panacea for design work. STOAT takes care of solving differential equations describing process performance. The users are responsible
for selecting processes, deciding how they shall be connected, sized and operated. The interpretation of modeling results is done to decide which to accept. STOAT may be used for a number of applications, including designing new sewage treatment works, designing extensions to existing sewage treatment works, developing new operational practices, testing 'What If' situations. During the simulation of the wastewater treatment process, the simulation is based on the "good modeling practices" developed by Rieger et al. [5]. In order to better simulate wastewater treatment, the process and equipment of the simulated wastewater treatment plant should obtain better historical data and model wastewater treatment process with STOAT software model.

2. Materials and Methods

2.1. Establishment of mathematical model

In the toolbar of STOAT, oxidation ditch and settler model were selected to treat domestic wastewater. Influent water passed a grill into the oxidation ditch, and then settled before the discharge into the environment. One part of sludge was returned back into the oxidation ditch (Figure 1). The system comprises of only one oxidation ditch, whose total volume is 16400 m$^3$. The oxidation ditch operated in alternating anoxic aerobic modes, and a secondary clarifier is connected to the oxidation ditch that has a total surface area of 3600 m$^2$. The return sludge is pumped back to the inlet of the oxidation ditch and mixed with the influent.

In our study, there are 4 stages for the oxidation ditch. The effluent was taken from the last stage. The $K_{La}$ values were modified for each of the compartments to control the dissolved oxygen (DO) concentrations in STOAT. The minimum and maximum DO values for the aerobic compartments were 0.5 and 2.0 mg/l, respectively.

2.2. Model select

IAWQ model was chose to simulate process according to the data form (Table 1), but IAWQ model has two kinds: IAWQ# 1 and IAWQ# 2. IAWQ# 1 model in the simulation run better in the process of sewage treatment, through the model to simulate the COD removal in wastewater. The model assumes that the plant has reached a stable state. The stable state is to obtain the average effluent concentration and solid equilibrium, so as to provide good initial conditions for dynamic simulation [6].

STOAT runs on a flow rate of 1000 m$^3$/h. As shown in Table 1, the required parameters are: COD, BOD$$_s$$, ammonia nitrogen (NH$$^3$$-N), total nitrogen (TN), total phosphorus (TP) and total suspended solid (TSS), which varied between 127 and 360 mg/L, 93 and 219 mg/L, 11 and 47 mg/L, 21 and 58 mg/L, 2.64 and 6.24 mg/L, 114 and 227 mg/L, respectively.
Table 1. Parameters of influent into oxidation ditch

| Parameter  | Max  | Min  | Average |
|------------|------|------|---------|
| SRT, d     | 20   | 20   | 20      |
| Flow, m³/h | 1000 | 1000 | 1000    |
| COD, mg/L  | 364  | 127  | 256     |
| BOD₅, mg/L | 219  | 93   | 158     |
| TN, mgN/L  | 58   | 21   | 42      |
| NH₃, mgN/L | 47   | 11   | 31      |
| TP, mg/L   | 6.24 | 2.46 | 3.98    |
| TSS, mg/L  | 227  | 114  | 173     |
| pH         | 7    | 7    | 7       |
| Temperature, °C | 15 | 15 | 15 |

3. Results and Discussions

3.1. Effect of influent water quality

Assuming that the process of simulation has reached a stable state, IAWQ# 1 model was run to simulate the oxidation ditch process sewage under the condition of unchanged sewage water flow rate. The data obtained are shown in Figure 2. Figure 2a illustrates that the effluent TN and TP concentrations did not greatly affect by the change of influent TN and TP concentrations. The removal efficiency of TN was clearly stronger than that of TP. However, the COD removal performance of oxidation ditch was outstanding in Figure 2b.

Table 2. The comparison of water qualities of influent and effluent

| Parameter | COD, mg/L | TN, mg/L | TP, mg/L |
|-----------|-----------|----------|----------|
| Influent  | 362.7     | 57.4     | 6.24     |
| Effluent  | 25.7      | 30.3     | 4.52     |

Table 2 demonstrates the change of concentrations of TN, TP and COD. The influent concentrations of TN varied between 21 and 58 mg/L. Through the treatment of oxidation ditch, the effluent concentration of TN ranged from 29.4 to 30.7 mg/L. The influent concentrations of TP varied between 2.6 and 6.2 mg/L. The effluent concentration of TP ranged from 4.22 to 4.79 mg/L. The influent...
concentrations of COD varied between 127 and 360 mg/L. The effluent concentration of COD ranged from 24.6 to 25.6 mg/L.

3.2. Effects of flow rate

The study of influent water quality variation is not enough. Thus, according to the actual operation situation to simulate, the same model was used to simulate the wastewater treatment process in oxidation ditch under the condition of changed water flow rate. The IAWQ#1 model is simulated under the condition of different water flow rates. The water quality parameters were fixed at the same time. The main changing trend of water flow rate and effluent COD concentration were illustrated in Figure 3. The changing trends of flow rate and effluent COD concentration were identical. This means that flow rate was important for the COD biodegradation efficiency. The increase of water flow rate was likely to decrease COD removal efficiency. The flow rate varied between 1000 and 10000 m$^3$/h, and the effluent COD concentration varied from 118.98 to 501.49 mg/L.

![Figure 3. The effluent COD concentration under the water flow rates varying from 1000 to 10000 m$^3$/h.](image)

3.3. Sensitivity analysis

In order to better use software simulation to evaluate sewage oxidation ditch process, the sensitivity analysis of the data in the simulation process was carried out to make it more consistent with the actual operation status of sewage treatment. In the actual operation of sewage treatment, the settling parameter $k$ affects the operation of secondary clarifier. It can been seen that the increasing $k$ from 3 to 11 had the influence of decreasing the peak effluent suspended solids from approximately 290 mg/l at a $k$ value of 3 to approximately 220 mg/l at a $k$ value of 11 (Figure 4). This shows in detail how sensitive the effluent suspended solids are to the variation in the settling parameter $k$. 
4. Conclusion

The model was able to predict the changing trend in terms of TN, TP and COD concentrations. The effluent TN and TP concentrations did not greatly influence by the change of influent TN and TP concentrations. The removal efficiency of TN was clearly stronger than that of TP. However, the COD removal performance of oxidation ditch was outstanding. Meanwhile, flow rate were important for the COD biodegradation efficiency. The increase of water flow rate was likely to decrease COD removal efficiency. The flow rate varied between 1000 and 10000 m3/h, and the effluent COD concentration varied from 118.98 to 501.49 mg/L. Overall, STOAT software is a useful and reliable tool for the prediction and optimization of oxidation ditch process.

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