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Simulation and Design Optimization of MBBR Process for the Improvement of Municipal WWTP

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Summary of key findings

In this paper, simulation and design optimization of MBBR process were conducted on BioWIN® platform for a WWTP in north of China. The optimization of operative parameters could only improve the effluent nitrogen in high temperature. After reforming, the plant was able to meet the new emission standard. Some design and operational suggest were given by simulation about temperature, effluent quality, surface area, etc. Performance of the design optimization proved the benefits from modeling and simulation to WWTP reform.

Background and relevance

Description of WWTPs. An existing WWTP in north of China was investigated in this study. This plant was constructed by twelve years ago and applied MBBR process. The capacity of the plant was 200000m^3/d and domestic wastewater is the major source of the influent. Because of the more strict discharge criteria as shown in Table 1, the plant is going to be updated and reformed as the preliminary design written by designing institute.

Field survey and influent characteristics. The survey scopes process configuration, influent properties, and operative parameters. The monitoring program consists of the distribution, dynamics and statistics of pollutant loading, as well as the components of composite water quality indices such as chemical oxygen demand (COD), total nitrogen (TN) and total phosphorous (TP). Except the normal monitoring indices measured by water testing per day, we also care about the wastewater fraction parameters like unbiodegradable solube COD which were determined by our short period measurement (Melcer, 2003).

Process modeling and simulation. We set up the current and reformed plant model and conduct simulation in BioWIN® V3.1 simulator (Environsim, Canada), as shown in Figure 1. Parameter estimation is necessary and important for proper simulation. After sensitivity analysis, we focus on tune of several model parameters. An open test method for calculating Oxygen Uptake Rate (OUR) was used to determine maximum specific growth rate (μ) which has a significant impact on the growth of microorganism, utilizing the DO mass balance of the respiration process (Vanrolleghem et al.,1993). Other sensitive parameters were adjusted according to the comparison between steady state simulation effluent and real effluent. The reformed plant model will follow the parameters used in the current plant model.

Operative and design optimization. Operative optimization analysis for the current process of the plant can tap potentials of the ability of nitrogen and phosphorus removal. Each operative parameters can be adjust to be a best value to verify whether the existing process can reach the new standard. After that, the reformed process will be simulated to evaluate the robustness of designed process, including chilly weather, microbial growth inhibition, fluctuation of influent flow or influent COD, etc. Steady state simulation were conducted to screen the proposals for the purpose of design optimization.

Results

Parameter estimation. The μ_{AOB} and μ_{OHOs} determined by respirometry were 0.54d-1, 2.8d-1. Y_{OHOs} was set as the default value 0.666.

Operative optimization. The return sludge ratio was set too low in current process so that the MLSS in MBBR tank was too low to meet the needs of nitrification. The modification is necessary because optimization of the current process cannot make all of the effluent indices reach the new standard.

Design optimization. In normal state, the reformed process can meet the new emission demands by adding PAC for phosphorous removal. Also some scenario simulation was made for the reformed process to make the system more reliable.

Discussion

Parameter estimation. The μ_{AOB} and μ_{OHOs} determined by respirometry were $0.54d^{-1}$, $2.8d^{-1}$. Y_{OHOs} is an important parameter which affected effluent NH_3-N, TN, TP, MLSS and MLVSS/MLSS of the system. The sensitivity analysis shows that Y_{OHOs} is the only parameter that affected the MLVSS/MLSS. When Y_{OHOs} was set as the default value 0.666, the MLVSS/MLSS in the model was close to the real value. Max vesilind settling velocity and OHOs P in biomass were also adjusted. The Steady state simulated effluent value was in the confidence interval estimated for its measured value (Liwarska-Bizukojc et al.,2013).

Operative optimization. Setting appropriate operative parameters can make a treatment process more effective and economic. The return sludge(RS) ratio is only 11.7% in the current process, little sludge replenishing the MBBR tank make the nitrification in this plant week. The simulation shows that the effluent NH3-N can be obviously improved when the return sludge ratio raised, but the effluent TN cannot be improved because of the lack of anoxic part in the system, as shown in Figure 2(a). To improve the denitrification, we change the 1# tank anoxic as shown in Figure 2(b). When the water temperature was higher than 18℃, the effluent nitrogen indices can reach the new standard, but TP and SS cannot. After the optimization of the current process, we found that modification of design is necessary for this plant.

Design optimization. The effect of biological nutrient removal has a close connection with the design. In normal state, the reformed process can meet the new emission demands by adding PAC for phosphorous removal. Some of the scenario simulation is shown in Figure 3. The reformed process has a good performance against the chilly weather when return sludge ratio set at 20%, and it will be more reliable if the plant enhanced the MLSS of aerobic tank when temperature is below 15℃. When the influent COD is below 110mg/L, the effluent TN will exceed because of lack of carbon source, so the unit for putting carbon source is necessary for reformed process. The surface area of biomass carrier is also a key factor, influence the space for microorganism to grow on, so check the real surface area of biomass carrier in the MBBR tank in the reformed process is crucial. The reformed process adds a multi-influent system, but it indicates that a single point of influent has a better effect from the simulation. Other simulation shows that the optimal mixed liquor return ratio for TN removal is 70% in winter, 40% in normal and 30% in summer.

Table 1 emission standard of investigated WWTP

standard	COD	BOD_5	SS	TN	NH_3-N	TP
Old	≤100	≤30	≤30	-	≤25	≤3
New	≤50	≤10	≤10	≤15	≤5	≤0.5

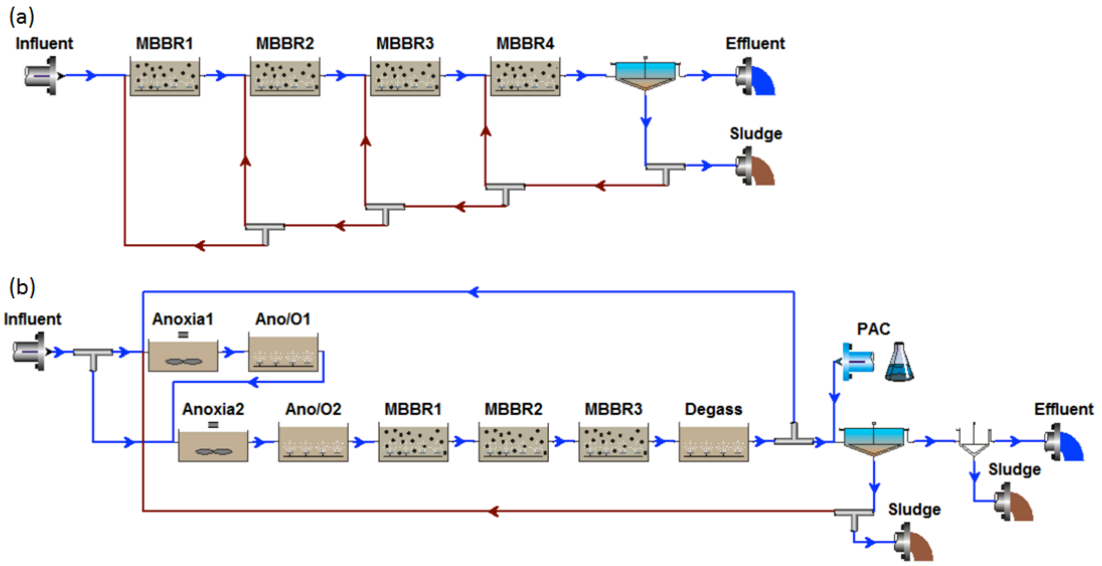

Figure 1 Model of WWTP (a)current process (b) reformed process

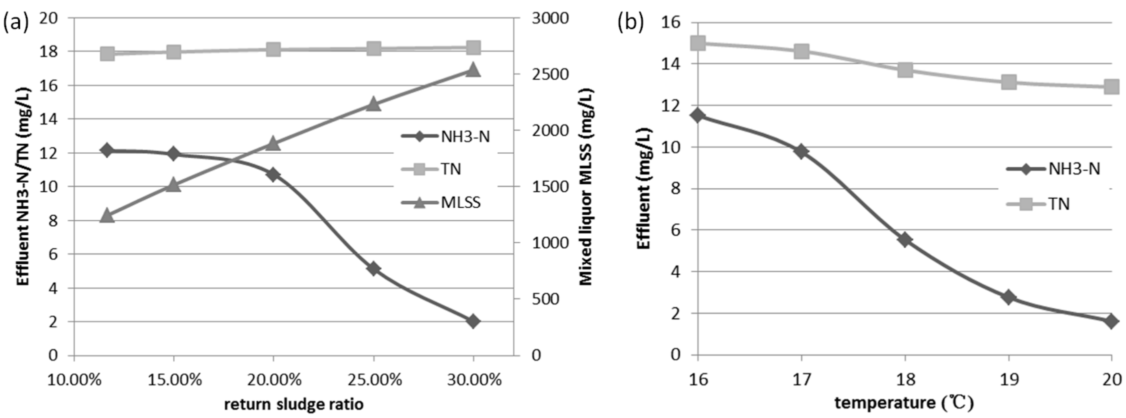

Figure 2 influence on (a)return sludge ratio,(b)temperature when 1# anoxic in current process

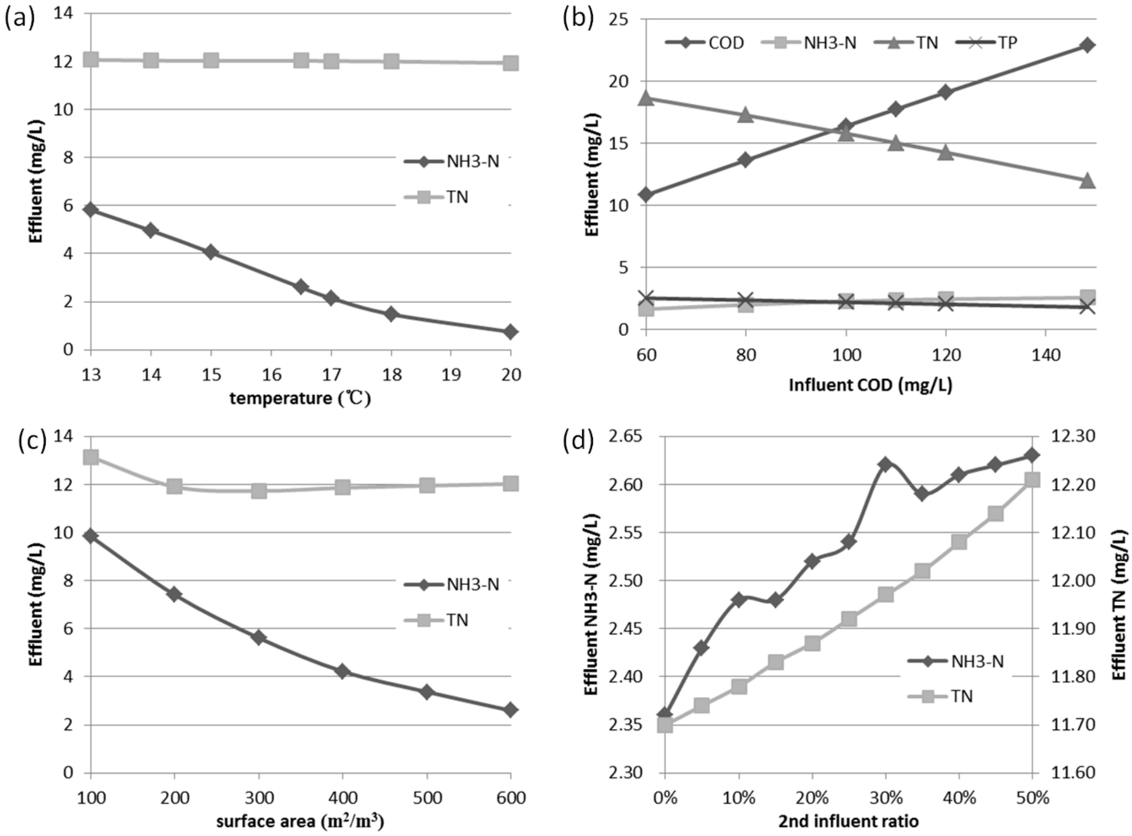

Figure 3 influence on (a)temperature, (b)influence COD, (c) surface area in MBBR, (d)2nd influent ratio in the reformed process

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