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Study of Dissolved Oxygen Concentration Control by the BSM1 Benchmark Model

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Abstract

This study focuses on the application of the BSM1 benchmark model for the control of dissolved oxygen concentration in wastewater treatment, which is a widely recognized standard model in the field of wastewater treatment and is capable of accurately simulating complex wastewater treatment processes. Through this model, the intrinsic connection between dissolved oxygen concentration and various aspects of wastewater treatment can be deeply analyzed, and then targeted control strategies can be formulated. The results show that the control method of dissolved oxygen concentration based on the BSM1 benchmark model effectively improves the accuracy of dissolved oxygen concentration control, significantly enhances the adaptability of the wastewater treatment system to the fluctuation of water quality and quantity compared with the traditional control method, significantly improves the compliance rate of effluent water quality, and is of great theoretical and practical significance in promoting the intelligent development of the wastewater treatment industry.

Keywords

BSM1; Intelligent Control; Intelligent Control; Model.

1. Introduction

Dissolved oxygen (DO) concentration in the sewage treatment control system is a very important variable, when the DO concentration is high, it will make the system consume too much energy, and at the same time, make the coagulant lose its effect, which will reduce the settling performance of the suspended solids; if the DO concentration is low, it will lead to a large number of filamentous bacteria in the aeration tank, which will result in the expansion of the sludge, leading to the decline in the growth rate of other bacteria, and reduce the quality of the effluent water[1]. Therefore, the optimal control of dissolved oxygen concentration is of great practical significance and theoretical basis for the management of sewage.

In 2018, the European Union's Organization for Science, Technology and Cooperation (OSTC) and the International Water Quality Association (IWQA) cooperated and developed the “Benchmark Simulation Model No. 1” BSM1, which is gradually being applied to the long-term dynamic characterization of wastewater treatment plants in countries around the world[2]. The study will develop a mathematical model based on the BSM1 simulation platform for the general needs of wastewater treatment monitoring, which has become a tool for evaluating control schemes for activated sludge wastewater treatment processes[3].

In this paper, the mathematical modeling of BSM1 is firstly carried out and then the model is built in Simulink. Then the control study is carried out for dissolved oxygen concentration[4].

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2. BSM1 Baseline Simulation Model Overview

The BSM1 model is based on the A^2O process and is used to describe the precipitation and biochemical reactions of the wastewater treatment process[5], and the basic structure is shown in Figure 1. The model has 10 layers of precipitation.

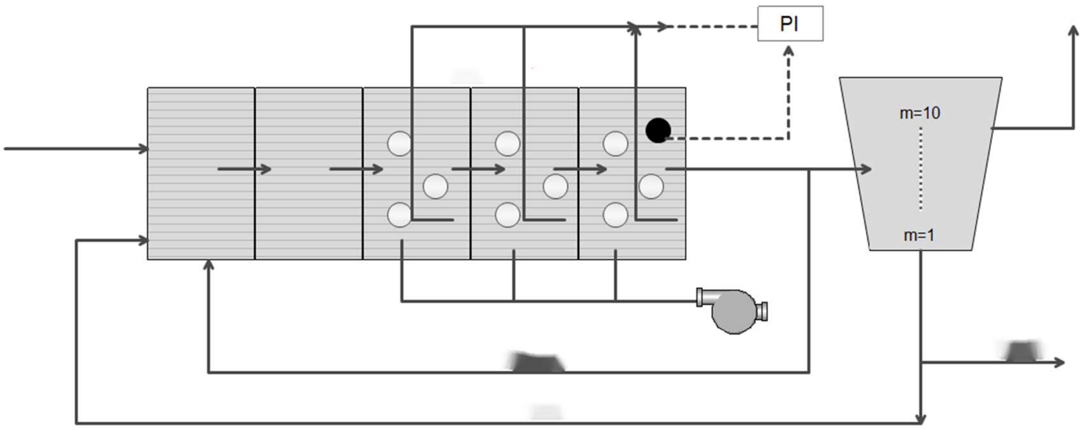

Figure 1. BSM1 structure

BSM1 divided the biochemical reaction process into 13 components and 8 basic reactions in the biological treatment process of wastewater, of which 8 basic reactions mainly involve the process of microbial growth[6], hydrolysis, attenuation, and death. The 13 of these components are shown in Table 1.

Table 1. Concentrations and units of components in BSM1

Component symbol	Name	Work unit
S_I	Non-degradable soluble organic matter	g COD m-3
S_S	Rapid biodegradation of soluble organic matter	g COD m-3
X_I	Particulate insoluble non-degradable organic matter	g COD m-3
X_S	Insoluble slowly degrading organic matter	g COD m-3
$X_{B,H}$	Active heterotrophic microorganisms	g COD m-3
$X_{B,A}$	Active autotrophic microorganisms	g COD m-3
X_P	Inert microorganisms from biosolids attenuation	g COD m-3
S_O	DO	g COD m-3
S_{NO}	NO3	g N m-3
S_{NH}	NH4	g N m-3
S_{ND}	Biodegradable soluble organic nitrogen	g N m-3
X_{ND}	Particulate degradable insoluble organic nitrogen	g N m-3
S_{ALK}	Alkalinity	mol m-3

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3. Simulink Model Building

3.1 Water Inlet Module

As shown in Figure 2, the water inlet module is mainly constructed using the selector module, which facilitates the use of water inlet data under different operating conditions.

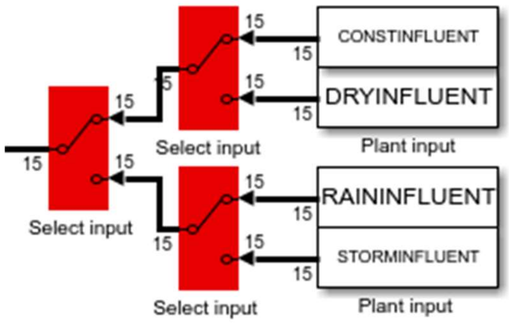

Figure 2. Water inlet module diagram

3.2 Biochemical Reactor Module

The biochemical reactor module needs to build a total of five biochemical cell units, mainly to simulate the BSM1 module in the completion of the state of each unit in the biochemical reaction changes in the situation, the input in each unit model not only contains the 13 components into the reactor, but also contains the flow rate into the reactor, the concentration of solid suspended solids and oxygen transfer coefficients in the reactor, so for each biochemical reactor module, a total of 16 inputs, 15 state variables and 15 outputs[7]. Therefore, for each biochemical reactor module, there are 16 inputs, 15 state variables, and 15 outputs. Figure 3 shows the internal model of a single biochemical reactor.

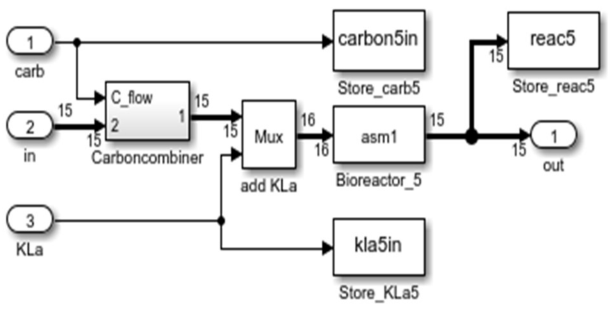

Figure 3. Internal model of a single biochemical reactor

3.3 Sedimentation Module

The main task of the sedimentation model is to describe the distribution of the insoluble and soluble components, and there are 80 differential equations for the change of the content of 8 components, so there are 16 inputs, 42 outputs and 130 state variables in the double-exponential model, which is very similar to the general biochemical reactor model, but there are many variable coupling and nonlinear links in the double-exponential sedimentation model[8]. Figure 4 shows the internal model of the settling module.

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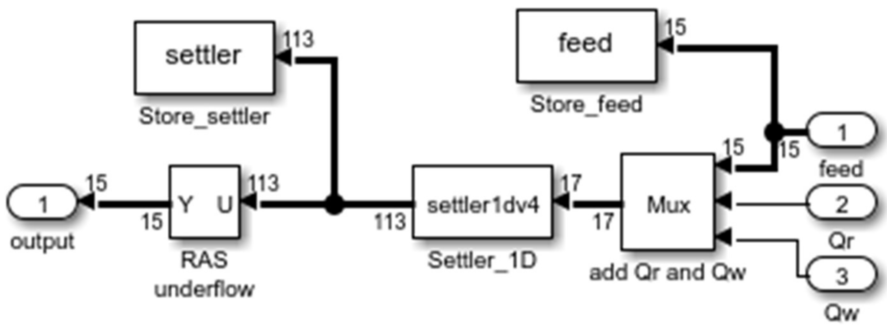

Figure 4. Internal model of the sinking module

3.4 Integration of Modules

Integration of the influent module, biochemical reactor module, and bi-exponential settling module by multiplexer (MUX) and combiner (COMBINER) in Simulink resulted in a benchmark simulation platform for the BSM1 model shown in Figure 5.

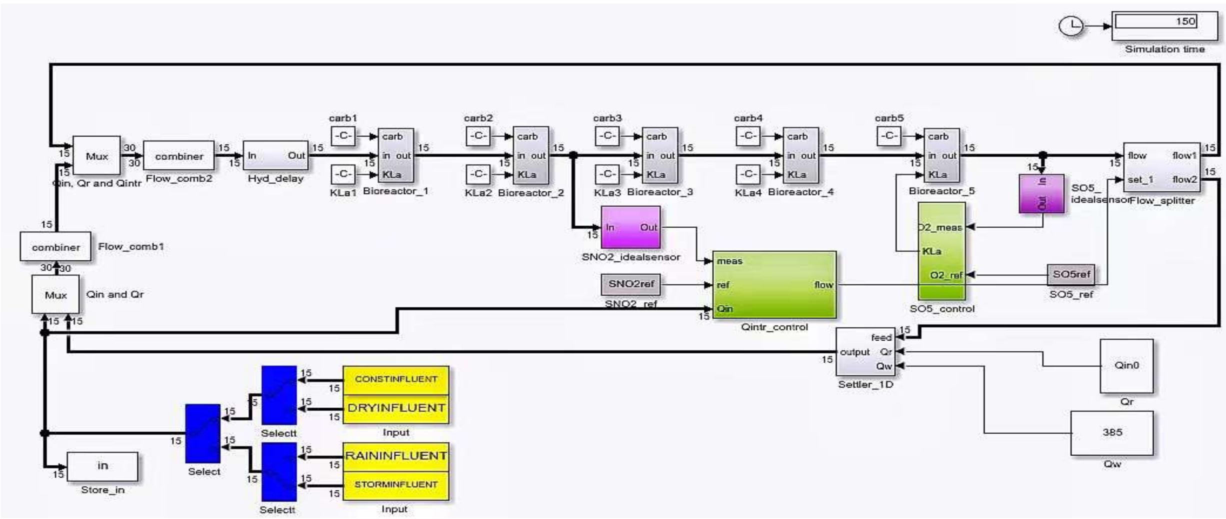

Figure 5. BSM1 model diagram

The study was conducted to validate the correctness of the BSM1-based biochemical tank reaction model by implementing a 14-day simulation experiment on the model. Its steady state input data are the influent data for three working conditions: sunny, rainy and stormy.

4. Dissolved Oxygen Concentration Simulation Validation

In order to ensure the realism of the model simulation, this study collected 14 days of real data in the wastewater treatment plant, specifically including the working condition data under three types of weather: heavy rain, rain, and sunny day.

The biochemical reactor 5 was added to the PI control module, and compared and analyzed with the model relay without the control module. The influent data under the three different working conditions of sunny, rainy and stormy days were input into the BSM1 model, the simulation time was set to [0,14], and the set value of dissolved oxygen concentration was 2 mg/L. The BSM1 model was used as the model for the simulation.

(1) Sunny working conditions

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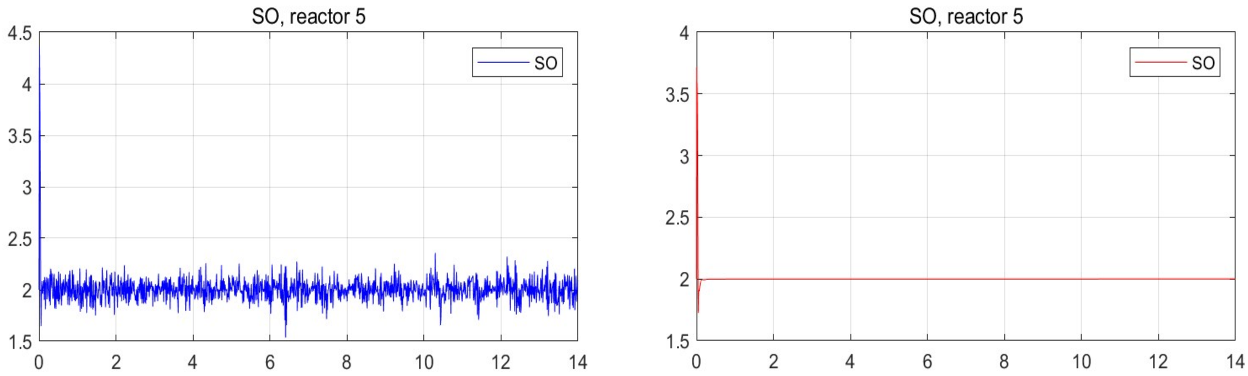

Figure 6. Comparison of working conditions on a sunny day

(2) Rainy weather conditions

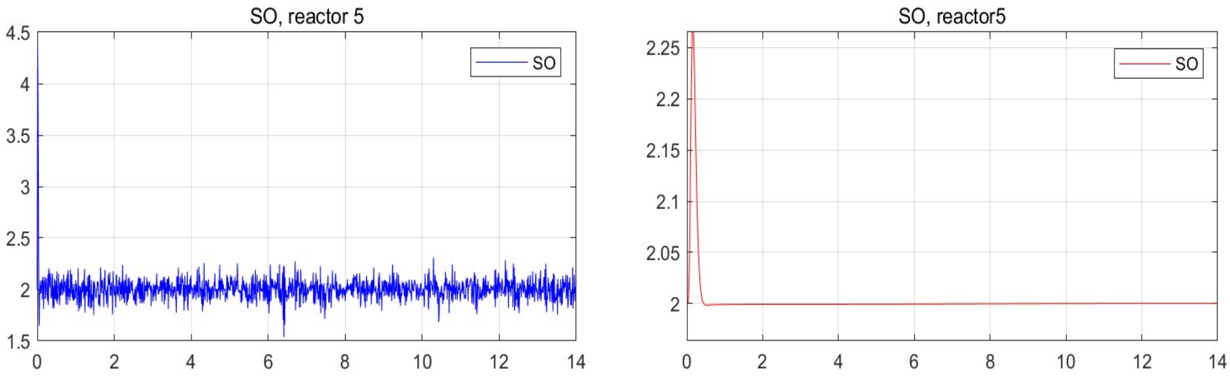

Figure 7. Comparison chart of working conditions in rainy days

(3) Rainstorm conditions

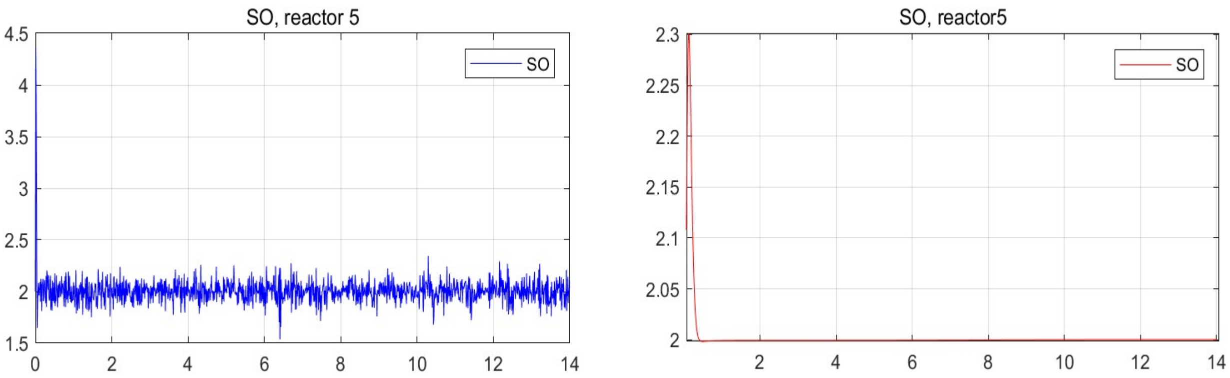

Figure 8. Comparison chart of rainstorm working conditions

Comparing the simulation graphs of the three working conditions, it is found that the effect of adding the PI control module is better than that of not adding it.

5. Conclusion

In this study, the BSM1 benchmark model is used to explore the control of dissolved oxygen concentration in wastewater treatment, which is an effective platform for analyzing the connection between dissolved oxygen concentration and wastewater treatment by virtue of its accurate simulation capability of complex wastewater treatment processes. By comparing three different working conditions, the effect of adding PI control module is better.

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