

# Automatic dosing system based on reclaimed water treatment

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**Abstract.** This paper introduces an automatic dosing system used in the reclaimed water reuse equipment for river water treatment. The automatic dosing system can replace the manual regulation mode. In view of the shortcomings of manual dosing in the sewage treatment system, through the study of sewage inlet and outlet flow, online water quality index and other factors. Fully combine feedforward control, feedback control, correction of dosing ratio and other control methods, and use PLC communication and control model to reasonably transform the dosing system, so as to achieve the purpose of intelligent sewage treatment.

## 1 Introduction

Urban wastewater mainly refers to the mixture of domestic sewage, industrial wastewater and atmospheric precipitation produced in the city. Therefore, it is affected by urban scale, industrialization level and climatic conditions. In terms of urban sewage treatment, generally speaking, most cities have similarities. According to relevant investigations and historical experience, the proportion of total phosphorus and total nitrogen in urban sewage treatment is the largest, followed by suspended solids. At present, the manual regulation method adopted in China can not effectively solve the problem of exceeding the standard of total phosphorus and total nitrogen in sewage.

The rainwater and river water treatment system involved in this paper can deal with this kind of over standard problem, which is inseparable from the addition of external chemical agents, and the rational utilization of agents is an important measure to ensure the effluent quality and treatment cost. The automatic dosing system designed in this paper can replace the manual regulation mode to achieve the purpose of intelligent sewage treatment.

## 2 Implementation background

### 2.1 Place of implementation

Chujia river in hangbo street, gongshu district, hangzhou is selected as the research object. The average width of the river, near the monitoring point, is 20 meters. The water depth is

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about 2 meters, and the river velocity is slow, with an average of 0.2 M/S. In recent years, with the rapid development of industry and population in urban areas, the water pollution of urban rivers is becoming more and more serious. Due to various reasons, the urban river water is in a closed slow flow state with static or poor fluidity. It has the characteristics of small watershed area, easy pollution and poor self purification capacity. The water body is easy to show eutrophication, resulting in the black and smelly water body, which seriously affects the natural environment.

## **2.2 Equipment purification method**

The river water and rainwater treatment system is mainly composed of five parts: sand filter box, carbon filter box, disinfection room, equipment room, intermediate water tank and water storage room. The river water and rainwater enter the sand filter box for the first filtration, then the intermediate water tank is used to store water and observe the liquid level of the intermediate water tank, and then transported to the carbon filter box for the second filtration and adsorption treatment. Finally, they enter the water storage room after disinfection in the disinfection room. The equipment room is used to place various electrical components and dosing tanks installed in the device. The dosing port is connected with the dosing tank, which is convenient to add chemicals for purifying water quality to the dosing tank through the dosing port. The focus of this paper is the automatic dosing system.

## **3 Design of automatic dosing control system**

### **3.1 Overview of system design method**

This paper introduces a set of dosing system, which can be used to add sodium hypochlorite, PAC and other agents in wastewater treatment. The dosing equipment provides a complete set of dosing system devices, equipped with accessories, fasteners, electric control cabinet required for safe, effective and reliable operation, as well as power cables and control cables required in the system, including connecting pipes and valves between equipment and equipment. The dosing system is mainly composed of dosing system, dissolution preparation and dilution system, regulation and control system, etc.

The automatic dosing function is mainly provided by the regulation and control system. The regulation and control system is equipped with industrial Ethernet access the automatic dosing system. The transmission equipment of the automatic control system has manual and automatic status, start and stop status, fault and other conventional working condition status signals. The upper computer control interface is added to realize remote monitoring. The automatic control of the whole process of dilution and dosing of the system reagent solution is realized through PLC, and the parameters can be automatically adjusted according to the waste water flow and water quality. The metering pump can realize the automatic adjustment of dosing. When the system is in PLC control mode, the full-automatic control of dilution, valve switching and dosing of metering pump can be realized according to the set parameters to realize unattended operation. At the same time, it also has the function of local control. It should be noted that local control is the priority control mode.

### **3.2 Control principle of automatic dosing system**

The upper computer control system calculates the set value of reagent dosing by collecting and controlling the front-end sewage flow, the end of online water quality data, and

automatically or manually setting the correction dosing coefficient, and then feeds back to the dosing diaphragm pump through the PLC system. The diaphragm pump dosing the set reagent by adjusting the frequency of the frequency converter. The detection value of the flowmeter in the dosing pipeline is fed back to the PLC system in real time and uploaded to the upper computer. The central control system compares the actual value of the dosing flowmeter with the dosing set value in real time, and then outputs the signal to the dosing pump frequency converter through the PID control system to adjust the output frequency, so that the actual dosing flow of the dosing diaphragm pump meets the requirements of the set value, That is, the feedback value of the dosing flowmeter tends to be consistent with the set value to realize the automatic control of the dosage. The principle of this system is a complex mechatronics system composed of joint control of multiple systems such as frequency conversion system, communication system and instrument system.

### *3.2.1 Sewage flow feedback control*

Determine the amount of chemicals to be added per KM3 of sewage according to the process requirements and inlet water quality. The inlet flow is controlled by the electromagnetic flowmeter, and the dosage dosing coefficient P1 is set with the inlet pump flow in the process flow or the advanced treatment lift pump flow as the variable of the dosage in different process stages.

### *3.2.2 Effluent quality feedback control*

According to the effluent quality standard, set the stable value of online effluent quality such as TP (total phosphorus) and residual chlorine. This stable value can meet the requirements of reducing reagent waste and avoiding water quality exceeding the standard, that is, the set value of the best effluent quality. Set the water quality feedback coefficient P2 (actual detection value / set value) according to the online actual value and set value of effluent quality.

### *3.2.3 Modified dosing coefficient control*

There are fluctuations and hysteresis in sewage flow feedback and online value feedback of effluent instrument, which is easy to cause low or high effluent index, resulting in reagent waste or insufficient dosing. In addition, during daily operation, the reagent needs to be diluted in a certain proportion according to the process requirements, and a certain adjustment correction coefficient needs to be added. In order to ensure the normal dosing of process agents, the correction coefficient P3 (empirical value / theoretical value) is added.

### *3.2.4 Dosage calculation formula*

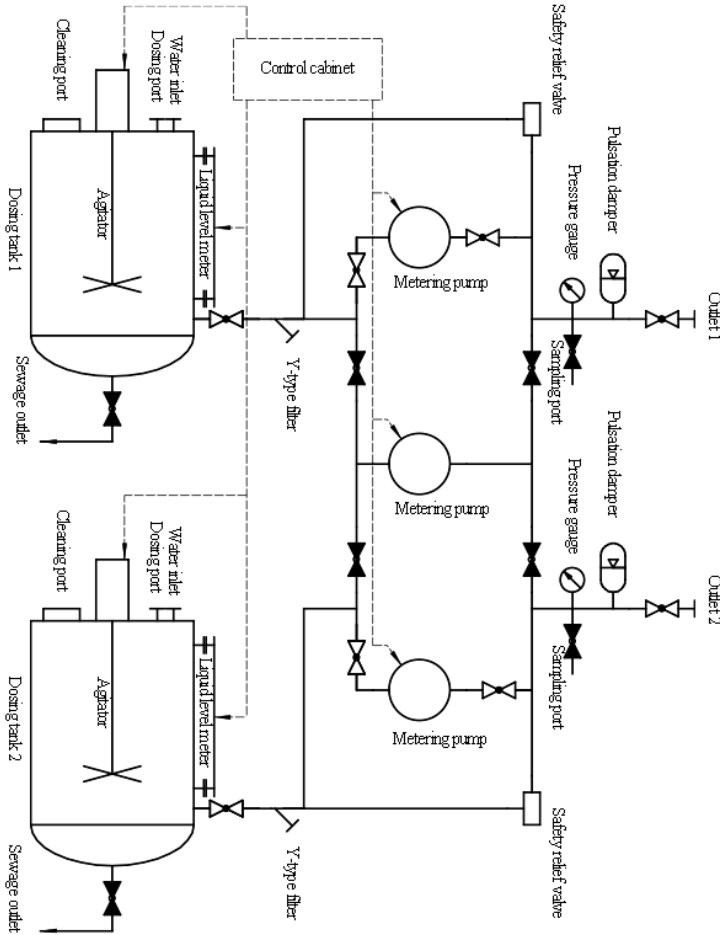
According to the three control modes, three different dosing coefficients P1, P2 and P3 are obtained. The final dosing setting value Q (m3 / h) of the automatic dosing control system is calculated according to the following formula:

$$Q=Q1 \times P1 \times P2 \times P3 \quad (1)$$

Where: Q1 represents inflow flow (KM3 / h), P1 represents dosing amount and dosing coefficient (m3 / KM3), P2 represents water quality feedback coefficient, P3 represents correction coefficient.

## 4 Practical application of automatic dosing control system

The dosing system is mainly composed of dosing system, dissolution preparation and dilution system, regulation and control system, etc.



**Fig. 1.** The dosing principle of the dosing system.

### 4.1. Dosing system

Give a signal that the electric medicine valve is opened in place, open the valve and deliver it to the metering pump through the pipeline, and then the metering pump will deliver it to the dosing point. The water inlet pipe equipped with reagent solution is equipped with electric valve to control the water inlet time. The flushing pipeline of metering pump shall be flushed and cleaned when there is blockage in the pipeline. The dosing amount of the metering pump is controlled according to the proportion of water inflow at the dosing point. The opening time of the electric flushing water valve depends on the actual use and it is generally not used. If the dosing is stopped, it is necessary to start the automatic flushing procedure. The dosing principle of the system is shown in Figure 1.

#### 4.1.1. Dosing system metering pump

The metering pump can realize automatic flow regulation when it is connected with an external frequency converter or an electric stroke length regulating device. By receiving the external control signal, the metering pump can adjust the discharge speed by automatically adjusting the speed of the motor under the condition of fixed suction speed, so as to realize the automatic adjustment of the dosing process and ensure the best and sufficient adjustment effect. The metering pump is equipped with double diaphragm damage pressure alarm. The control end of the metering pump is equipped with movable intelligent operation panel and large-size LCD screen for remote automatic stroke adjustment, with 4 ~ 20mA signal output function.

The accuracy of the filling pump shall be better than 1% of the rated capacity under the conditions of different pressure. After passing through the equalizer and pressure valve, the flow curve needs to change linearly. When the metering pump operates under load, the noise of the pump shall not be higher than 70 dB, and it should be no abnormal vibration, and should be no leakage at each seal.

The metering pump also needs to be used together with safety valve and pulsation damper.

##### -Safety valve

Safety valve is a diaphragm valve, which is an automatic pressure relief device on pressure vessel or pipeline. When the pressure of the protected system exceeds the set pressure, the safety valve opens to discharge to prevent the system pressure from rising. When the system pressure drops to the specified value, the valve will close automatically to ensure the normal operation of the system.

The safety valve works by the spring force. When the system pressure is smaller than the set pressure, the diaphragm closes the pipeline under the action of spring force. When the system pressure is higher than the set pressure, the diaphragm is jacked up, then the pipeline is connected, and the liquid passes through the safety valve.

##### -Pulsation damper

By means of energy balance, reduce the pulse of the liquid medicine output of the precision metering pump, make the liquid medicine output of the precision metering pump uniform, form an approximate linear fluid characteristic, increase the stability of the feed, and eliminate the damage to the metering pump and system caused by the vibration that may be caused by the pulse.

#### 4.1.2. Electromagnetic flowmeter

The electromagnetic flowmeter is based on Faraday's law of electromagnetic induction. The measuring tube of the flowmeter is a short non-magnetic alloy tube lined with insulating material. The two electrodes pass through the pipe wall along the direction of pipe diameter and are fixed on the measuring pipe. The electrode head is basically flush with the inner surface of the lining. When the excitation coil is excited by two wave pulses, a working magnetic field with magnetic flux density  $B$  will be generated in the direction perpendicular to the axis of the measuring tube. At this time, if the fluid with certain conductivity flows through the measuring tube. The electromotive force  $E$  is induced by the cutting magnetic line of force. The electromotive force  $E$  is proportional to the magnetic flux density  $B$ , and the product of the inner diameter  $D$  of the measuring tube and the average flow velocity  $v$ . Electromotive force  $E$  (flow signal) is detected by the electrode and sent to the converter through cable. After amplifying the flow signal, the converter can display the fluid flow, and can output pulse, analog current and other signals for flow control and regulation.

$$E=KBdv \quad (2)$$

Where: E is the signal voltage between electrodes ( V ),B represents magnetic flux density ( T ),D presents inner diameter of measuring pipe ( meter ),V presents average velocity ( meter / sec )

The electromagnetic flowmeter can be configured, and the configured data is saved in EPROM. After power off, the electromagnetic flowmeter can work immediately after restart. The electromagnetic flowmeter can be self-checked continuously. In case of failure, it shall be able to give an alarm through the user's control system, so that the maintenance personnel can query the electromagnetic flowmeter.

#### *4.1.3. Electric ball valve*

Valve use method: close the ball valve, remove the Union and carry out the work in the rear section without stopping the equipment pipeline in the front section. Remote control valve switch. The switch of the valve is automatically switched through contact feedback.

### **4.2. Dissolution preparation dilution system**

The liquid reagent is transported by tank car, and a signal is given to the electric ball valve to open in place. The reagent solution can be discharged into the liquid storage tank (medicine storage tank) directly or through the unloading pump. The liquid storage tank (medicine storage tank) is equipped with an ultrasonic liquid level gauge. The reagent solution is sent to the liquid storage tank (medicine storage tank) according to the requirements through the feedback signal of the ultrasonic liquid level gauge, and then a close in place signal is given to the electric ball valve to close the medicine inlet valve. Open the water inlet valve, the water inlet pipeline will deliver a certain amount of water to the liquid storage tank (medicine storage tank), mix the fixed amount of medicine with water, and the ultrasonic liquid level gauge will feed back the liquid level of the dosing tank (barrel). The system will automatically control the dosage of reagent solution according to the concentration set on the man-machine interface.

The storage tank is equipped with agitator and ultrasonic level gauge. The mixing paddle is made of corrosion-resistant 304 stainless steel plastic coated material, which can effectively prevent the corrosion problem caused by chemicals on the equipment. The dilution proportioning system is fully automatic. User can adjust the proportioning ratio in the system. The ratio has a variety of modes, which can be adjusted according to the volume ratio, density and other operation interfaces, which is convenient for operation and management.

#### *4.2.1. Agitator*

The 10% concentration drug solution is prepared by the agitator, and the blade is used to rotate and stir rapidly to make the drug dissolve and diffuse in the water quickly, and the uniformity is more than 90%. The bidder shall optimize the design of the mixer based on its own high-efficiency flow shaft and ensure the best liquid discharge effect under the long-term operation of the mixer.

#### *4.2.2. Magnetic flap level gauge*

Continuously measure the liquid level of storage tank and provide switching signal control for continuous operation of storage tank. The liquid level gauge is corrosion-resistant, and the supporting pipes are made of corrosion-resistant transparent materials with high,

medium and low liquid level display. Upper computer signal acquisition: high, medium and low liquid level.

### **4.3. Regulation control system**

The regulation control system is automatically controlled by PLC, seamlessly connected with the Ethernet switch on the on-site computer monitoring network, and the flow signal of each outlet main pipe is transmitted to control the dosage of reagent solution. Upload the operation status of reagent dosing system equipment and relevant instrument detection signals. The terminal provides operation and alarm terminal interfaces. The field control cabinet includes touch screen, which can display, set and modify process parameters in real time, and control the dilution and dosing of reagent solution. The metering pump shall be added according to the raw water flow ratio.

The whole set of reagent dosing device is automatically controlled in the whole process through PLC control equipment. When the tank truck is transporting materials, the liquid level of the chemical solution is controlled by the control box of the liquid storage tank / drug storage tank. Then dilute with the designed water volume, and control the start and stop with electric valve. PLC control equipment automatically controls its start and stop through the signal provided by the user.

#### *4.3.1. Control requirements*

The regulation control system can realize the automatic control of the whole process of dilution and dosing of system reagent solution through PLC, and automatically adjust the parameters according to the raw water flow and water quality. It can realize the automatic adjustment of dosing amount, and has the function of manual local control.

Configure Industrial Ethernet to access the automatic control system and transmit the status signals by manual and automatic status, start and stop status, fault and other normal working conditions of the equipment. Add the upper computer screen to realize remote monitoring.

The main functions of the control system include:

-The system has two modes: local control (field button) and PLC control. Local control is the most priority control mode.

-When the system is in PLC control mode, it can realize full-automatic control of dilution, valve switching and dosing of metering pump according to the set parameters, so as to realize unattended operation.

-The reagent configuration concentration is adjustable, and the ingredients are automatically proportioned according to the set concentration.

-The flow proportional dosing or PID closed-loop control can be selected according to the actual situation.

#### *4.3.2. Frequency converter*

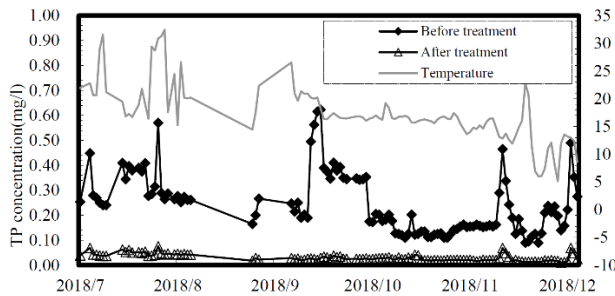
The control mode of the frequency converter adopts sensorless flux vector control. The hardware part of the frequency converter is composed of rectifier part, intermediate circuit part (including DC filter, anti surge circuit and capacitor), inverter part (including IGBT, output reactance, current transformer, etc.) and control part. It also has built-in fast fuse, RFI (EMC) filter and resident software equipped with RS485 communication port and its communication protocol.

The frequency converter is installed in the complete set of electric control cabinet. Each frequency converter has perfect protection functions, which at least include: power failure

protection such as overvoltage, undervoltage, phase loss and input imbalance of main power supply, overload protection and motor coil overheating protection. At the same time, it also includes fault protection functions such as frequency converter overload, frequency converter cooling fan fault, frequency converter temperature rise too high, setting signal too high / low, feedback signal too high / low, frequency converter fault, serial communication timeout and so on. According to the different nature of the fault, the general fault frequency converter shall be treated by reducing the carrier frequency or capacity, so as to maintain the uninterrupted operation of the system and the safety of the equipment as much as possible. The operation panel of the frequency converter can adjust and control the manual key of the machine. At the same time, it can set the speed 0-100% through the touch screen key on the panel of the electric cabinet.

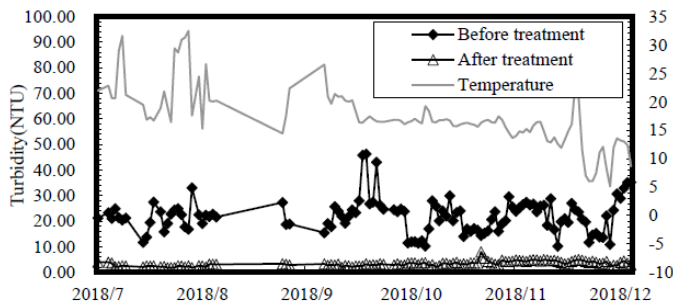
### 5 Data analysis

The automatic dosing system can effectively adjust the total phosphorus (TP) and turbidity NTU indexes of rainwater and river water. As shown in the figure 3, for the change of total phosphorus (TP) before and after treatment, the total phosphorus concentration downstream of the treatment point decreased by 90% on average.



**Fig. 2.** Comparison of total phosphorus concentration before and after treatment.

As shown in the figure 4, in order to change the turbidity NTU before and after treatment, the river water downstream of the treatment point can be controlled below 10NTU or even 5ntu, meeting the requirements of the water quality standard for recreational landscape in the river.



**Fig. 3.** Comparison of NTU before and after treatment.

### 6 Conclusion

The integrated reuse equipment of rainwater and river water realized through the automatic dosing system greatly reduces the cumbersome manual dosing operation process on the



premise of effectively controlling sewage treatment, and the rationality of dosing timing and dosage has been further verified. It is actually effective, the labor cost is reduced, and the dosage is reduced by about 40-50%. Obviously, it has high social and economic benefits.

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