A Water quality monitoring system: design for Dian Lake sewage treatment plants in towns

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Abstract. Since sewage treatment plant consumes much of electric energy in the city, the optimization and improvement of the equipment and energy consumption monitoring management system is conducive to its development and even driving an energy-consuming society. There are a total of 20 sewage treatment plants of towns that directly affect the water environment of Dianchi Lake. Due to the dispersion of sewage treatment data, the lack of regular testing of water quality, poor accuracy and reliability of data, difficulty in evaluating the effect of sewage treatment and the lack of data management standards and norms, the water quality and quantity will have an impact on the ecosystem of Dianchi Lake if the water from plants is discharged directly or indirectly into the riverways, tributaries or channels of the Lake. Therefore, building a water quality monitoring system for 20 sewage treatment plants of Kunming is an important measure to ensure the water quality and improve the ecosystem of Dianchi Lake. This paper discusses the design of the water quality monitoring system for the sewage treatment plants of towns near Dianchi Lake from the perspective of relevant technologies.

1. Introduction

According to the survey, there are 20 sewage treatment plants of towns of the Dianchi Lake area that directly affect the water environment. The main power-consuming equipment of those plants includes draft fans, water pumps, disinfection equipment, electric valves, agitators, backwashing filter equipment, etc. However, these plants are scattered in space, with a wide range of sites and various types, and the water quality varies greatly. Most of them are barely supervised. Now the thorny problem is how to realize the centralized control and scientific treatment of these sewage treatment plants.

Combined with modern technology, environmental monitoring can detect pollution problems in the environment in time and determine the degree of pollution and future trend. Sewage monitoring is the main application of IoT technology in water quality\cite{1,2}. In order to ensure the water quality, devices such as cameras and analytical sensors are set at the source of water for monitoring. Through the Internet of things, various parameters, including pH, COD, heavy metal content and so on, can be uploaded in real time.
2. Internet of Things in water quality monitoring

Internet of Things in environmental protection is an important part in the development of environmental monitoring. The main application of the Internet of Things in water quality monitoring is to place such sensing devices as electronic sensors or video monitors at the inlet or outlet of detected water in order to monitor the contents of various pollution factors in the water in real time and upload the data it collected to the Internet. When the monitoring data indicates that sewage parameters exceed certain limits, the system will promptly give feedback of the pollution information to the pollutant discharge unit and monitoring center to avoid major pollution incidents. The system will make such response as preventing, controlling or warning through the information it collected. This series of processes constitute the monitoring system, so as to realize the monitoring and comprehensive supervision of water quality and water pollution sources.

The Internet of Things connects various sensors to the Internet and processes data through sensing devices and network transmission. IoT consists of device layer, network layer and application layer. Device layer connects the physical world to the information world by hardware devices, and information from this layer will be transmitted to application layer through network layer. Application layer collects and processes the data before they serve the relevant industries. The Water Quality Monitoring System is designed according to the structure of the Internet of things and gives full play to the advantages of the Internet of things in water quality monitoring. The system is a set of intelligent, real-time, and online water quality monitoring system, which can automatically realize many functions related to the connection of IoT devices such as data collection, data processing and analysis, device control and so on[3]. It can operate reliably for a long time without supervision.

3. Design of the water quality monitoring system

According to the structure of the Internet of things, the system is divided into three layers: Field Ends, Data Transmission Layer and Application Layer.

3.1. Field ends

The field end includes the device layer and two subsystems.

3.1.1. Device layer. The key devices in the Device Layer mainly includes Meters for Testing the Water, Switch, Camera, Digital Video Recorder, Mobile Terminal and Programmable Logic Controller (PLC) System. Programmable Logic Controller (PLC) is the core of industrial control. PLC control system is the core system of the whole device layer.

Programmable Logic Controller (PLC) is an electronic system with digital operation, designed for industrial application [4]. It uses a type of programmable memory for its internal storage program to perform user-oriented instructions such as logical operations, sequence control, timing, counting and arithmetic operations. In addition, various types of mechanical or production processes can be achieved through digital or analog I/O. Sewage treatment plants of towns should be equipped with PLC control cabinets to collect production data and on-site water quality and quantity monitoring data. On-site on-line testing instruments, including water quality and quantity instruments, should also be set at the inlet and outlet. Meanwhile, control instructions issued by upper configuration software will be executed.

3.1.2. Water quality monitoring system. Aimed at serving the needs of on-line analytical instruments and laboratory research, the on-line water quality monitoring system, whose core task is to provide representative, timely and reliable sample information, is a complete system from sampling, pretreatment, analysis to data processing and storage by using automatic control technology, computer technology and special software, so as to realize the on-line detection of the sample. Automatic monitoring system, in general, includes sampling system, pretreatment system, data acquisition and control system, online monitoring and analysis instruments, data processing and transmission system,
and remote data management center, all of which are both systematic and independent for the continuous and reliable operation of the entire system.

According to the scale, different on-site management systems were designed for these 20 sewage treatment plants in towns.

1) The plants with a scale of less than 1000m$^3$/d will adopt micro automatic water quality monitoring station, which is an outdoor mini-station, integrated with COD UV full-spectrum analyzers, ammonia nitrogen analyzers and two-parameter analyzers. Water samples will be collected to the pool of the micro-station through self-priming water pumps. First, let the water stand and reach the specified level. Then the water quality instruments and two-parameter probes start to sample, collect and analyze data. The data will be transmitted to touch-screen computers for summary and be uploaded to the digital management platform through wired or wireless network to indicate the water quality of these plants in real time.

The whole monitoring system is divided into four units: flow path unit, monitoring unit, testing unit and security unit.

a) the flow path unit
The flow path unit is mainly composed of five-parameter instruments, water quality instruments, self-priming water pumps, magnetic valves, water sample pools, liquid level switches, filter devices and so on.

b) the monitoring unit
The monitoring unit is composed of touch-screen computers, configuration software, PLCs and wired/wireless transmission modules. Instrument control is realized through the configuration software embedded in the touch-screen computer. Sampling control is realized through the configuration software and the PLC program. Signals detected by instruments will be uploaded to the digital water management platform through touch-screen computers using wired network or GPRS wireless network.

c) the testing unit
The testing unit integrates COD instruments, ammonia nitrogen instruments with two-parameter instruments to realize the function of data analysis and transmission.

d) the security unit
The security unit is composed of arresters, code locks and indoor temperature and humidity sensors to prevent loss of devices, destruction and human interference during testing.

2) For plants with a scale of more than 1000m$^3$/d, continuous online monitoring should be conducted. The monitoring data includes parameters such as COD concentration, ammonia nitrogen, TP, TN, pH, suspended solids and flow of the sewage, all of which will be managed effectively.

The whole monitoring system consists of the water quality testing instrument, sampling and pretreatment subsystem, data acquisition and processing subsystem, monitoring station subsystem, discharge building subsystem, etc. All of the results will be transmitted to the on-site PLC control system and SCADA system through standard analog signals so that the data can be stored and analyzed graphically. The system adopts modular design, which can realize fully automatic monitoring: start or stop automatically; store and upload data automatically. Hereby, unattended operations in the workplace can be truly achieved.

3.1.3. Video monitoring system. The video monitoring system is composed of five parts, including camera, transmission, control, display and record. The camera transmits the video to the host through coaxial video cables or network cables. Then the video signal will be distributed to different monitors and recorders by the host. If needed, the voice signal can be recorded into the recorder simultaneously. The operation staff can give instructions through the host to control the movement of the tripod head, adjust the focal length of the lens and switch between different cameras and tripod heads. Using specialized video processing mode, the video can be recorded, replayed and processed, so as to achieve the best video effect.
The video monitoring system of the sewage treatment plant of towns can monitor the important production process in real time by installing cameras in key locations such as biological reaction pool, water inlet and outlet and main process sections, or by using panoramic view. Meanwhile, a digital video recorder will also be installed to collect on-site short video signals, which will be uploaded to the digital water management platform through the data transmission system.

3.2. Data transmission layer
Figure 1 shows the data transmission network. Virtual private network transmits various data to application layer[5]. As an important part of the Internet of things system, the data transmission layer is mainly responsible for data transmission. Data collected through the Device Layer is connected to PLC automatic control system industrial Ethernet network in sewage treatment plant nearby. Through the public network, the network finally summarizes the data to the application layer information platform for display and other applications.

![Figure 1. The data transmission network.](image)

3.3. Application layer
Figure 2 shows the panorama of a sewage treatment plant. We can easily monitor the situation of the plant.

![Figure 2. The panorama of a sewage treatment plant.](image)

Figure 3 shows a partial application of the system. From the figure, we can intuitively see the equipment operation, process parameters and so on. Through various modern information technologies, the system can basically realize water quality monitoring and data transmission concerning equipment operation, pollutant reduction and energy consumption for 20 sewage treatment plants of towns.
Installing cameras at the key process of production ensures the water quality of plants and the scientific and information-based management of sewage treatment in Dianchi Lake area. It also provides comprehensive and accurate basic data and scientific decision support for the prevention and control of water pollution in Dianchi Lake area.

4. Summary
Why do we conduct a Water Quality Monitoring System? As we all know, the Age of Big Data has come, and massive data is even regarded as the core assets of enterprises. Data collection, summary, processing and analysis are particularly important. With the Internet of things, we are able to aggregate scattered data. After the system generates the monitoring data, we display it in a visual way. By combining computer network technology, we process and analyze the key data of sewage treatment so that we can realize intelligent supervision, early warning and decision support. We have even made full preparations for the intelligent and refined management of the enterprise in the near future.
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